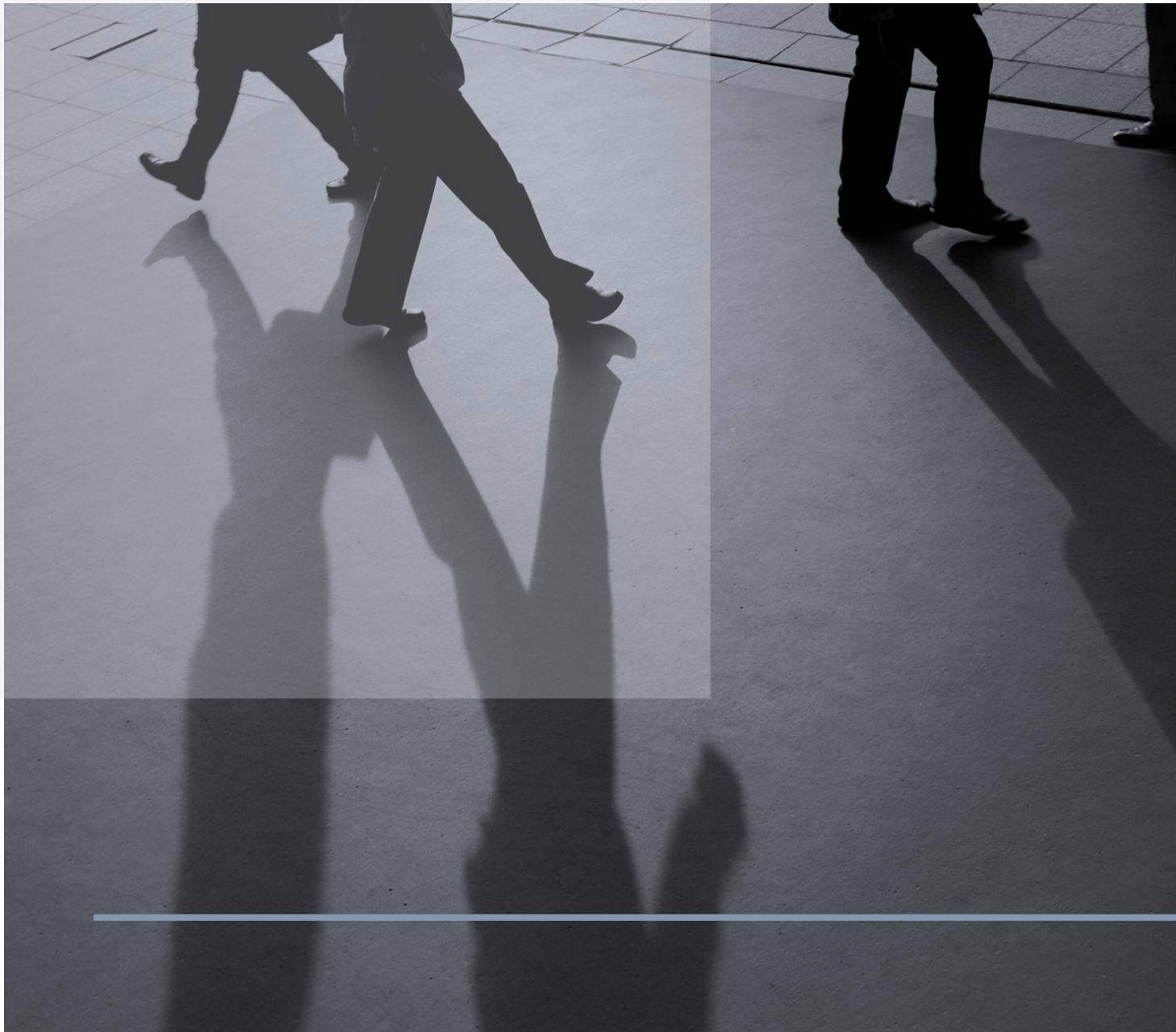


# OCR A LEVEL PHYSICS

A WEEKLY REVISION PLAN

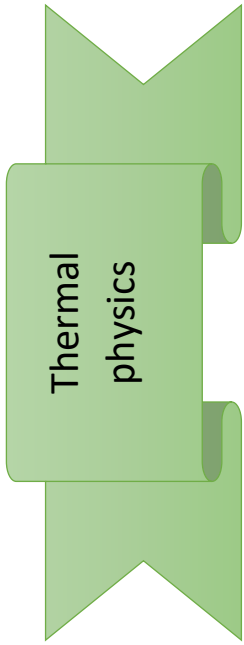


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# Week 1





Thermal  
physics

## Thermal physics

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 5.1.1 a                 | Can you describe thermal equilibrium?  | <input type="checkbox"/> |
| 5.1.1 b                 | Can you explain the absolute scale of temperature?   | <input type="checkbox"/> |
| 5.1.1 c                 | Can you state temperature measurements in degrees Celsius and kelvin?  | <input type="checkbox"/> |
| 5.1.1 d                 | Can you calculate $T(\text{K}) \approx \theta(^{\circ}\text{C}) + 273$ ?                                     | <input type="checkbox"/> |
| 5.1.2 a                 | Can you describe solids, liquids, and gases in terms of spacing, ordering, and motion of atoms or molecules? | <input type="checkbox"/> |
| 5.1.2 b                 | Can you describe the simple kinetic model?   | <input type="checkbox"/> |
| 5.1.2 c                 | Can you explain Brownian motion?   | <input type="checkbox"/> |
| 5.1.2 d                 | Can you explain internal energy as the sum of kinetic and potential energies in a system?                    | <input type="checkbox"/> |
| 5.1.2 e                 | Can you describe absolute zero (0 K)?  | <input type="checkbox"/> |
| 5.1.2 f                 | Can you explain increase in internal energy with temperature?  | <input type="checkbox"/> |
| 5.1.2 g                 | Can you describe changes in internal energy during changes of phase?   | <input type="checkbox"/> |
| 5.1.2 g                 | Can you explain constancy of temperature during changes of phase?  | <input type="checkbox"/> |
| 5.1.3 a                 | Can you calculate the specific heat capacity of a substance –<br>$E = mc\Delta\theta$ ?                      | <input type="checkbox"/> |
| 5.1.3 b i               | Can you describe an electrical experiment to determine the specific heat                                     | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
|                         | capacity of a metal or a liquid?  |                          |
| 5.1.3 c                 | Can you calculate specific latent heat of fusion and specific latent heat of vaporisation; $E = mL$ ?       | <input type="checkbox"/> |
| 5.1.3 d i               | Can you describe an electrical experiment to determine the specific latent heat of fusion and vaporisation? | <input type="checkbox"/> |

## Revision questions

### Solids, liquids and gases

1. Describe the structure of solids, liquids and gases
2. Describe the simple kinetic model for solids, liquid and gases
3. Describe an experiment that demonstrates Brownian motion and discuss the evidence for the movement of molecules provided by such an experiment
4. Define the term *pressure* and use the kinetic model to explain the pressure exerted by gases
5. Define *internal energy*
6. Explain why a rise in temperature of a body leads to an increase in its internal energy
7. Explain why a change of state for a substance leads to changes in its internal energy but not its temperature
8. Describe using a simple kinetic model for matter the terms *melting*, *boiling* and *evaporation*

### Temperature

1. Explain that thermal energy is transferred from a region of higher temperature to a region of lower temperature
2. Explain what is meant by a thermal equilibrium
3. Describe how there is an absolute scale of temperature that does not depend on the property of any particular substance (ie the thermodynamic scale and the concept of absolute zero)
4. Explain how to convert temperatures measured in kelvin to degrees Celsius (or vice versa)
5. What is absolute zero

### Thermal properties of materials

1. Define and apply the concept of specific heat capacity
2. Select and use the equation;  $E = mc\Delta\theta$
3. Describe an electrical experiment to determine the specific heat capacity of a solid or liquid
4. Describe what is meant by the terms *latent heat of fusion* and *latent heat of vaporisation*

### Ideal gases

1. State Boyle's law
2. Select and apply  $p \frac{V}{T} = \text{constant}$
3. State the basic assumptions of the kinetic theory of gases
4. State that one mole of any substance contains  $6.02 \times 10^{23}$  particles and that  $6.02 \times 10^{23} \text{mol}^{-1}$  is the Avogadro constant  $N_A$
5. Select and solve problems using the ideal gas equation expressed as  $pV = NkT$  and  $pV = nRT$
6. Explain that the mean translational kinetic energy of an atom of an ideal gas is directly proportional to the temperature of the gas in kelvin
7. Select and apply the equation  $E = \frac{3}{2}kT$  for the mean translational kinetic energy of the atoms

## Definitions & equations

Here is the list of definitions & equations that you need to know. Fill in the missing information.

Absolute zero

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Pressure

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Internal energy

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Specific heat capacity

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Latent heat of fusion

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Latent heat of vaporisation

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Boyle's law

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A mole

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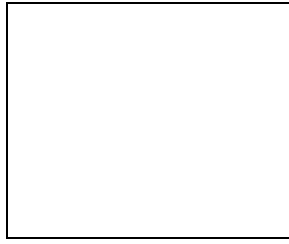
Mean translational kinetic energy

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## Solids, liquids and gases

Draw and describe the three main states of matter:



Spacing:

Ordering:

Motion:

What is the kinetic model and what assumptions do you need to make?

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What happens to the internal energy when the temperature rises?

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What happens to the internal energy and temperature when a substance changes state?

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## Temperature

Heat energy always flows from a *hot/cold* region to a *hot/cold* region.

Regions that have the same temperature are in T\_\_\_\_\_ E\_\_\_\_\_.

What is the difference between the Celsius and Kelvin scale?

\_\_\_\_\_

\_\_\_\_\_

What is 150°C in kelvin? \_\_\_\_\_

What is 174K in °C? \_\_\_\_\_

## Gases

In the ideal gas equations  $pV = NkT$  and  $pV = nRT$  what does each letter mean?

p: \_\_\_\_\_ V: \_\_\_\_\_ N: \_\_\_\_\_

k: \_\_\_\_\_ T: \_\_\_\_\_ n: \_\_\_\_\_

R: \_\_\_\_\_

Boyles law is when \_\_\_\_\_ is proportional to \_\_\_\_\_ when \_\_\_\_\_ is constant.

What is the mass of a mole of Carbon? \_\_\_\_\_ g

What is the mass of a mole of Gold? \_\_\_\_\_ g

How many moles are in 2g of Hydrogen? \_\_\_\_\_ mol

How many moles are in 14g of Helium? \_\_\_\_\_ mol

How many atoms are in 2g of Hydrogen? \_\_\_\_\_

How many atoms are in 7g of Nitrogen? \_\_\_\_\_

$$\frac{3}{2}kT = \frac{1}{2}mv^2$$

This equation tells us the average energy of *1mol/1g/1 individual atom* of a gas. (circle)

When calculating mean translational kinetic energy the temperature should be in units of \_\_\_\_.

When calculating root mean square speed the mass should be in units of \_\_\_\_\_.

## Questions

Q1.

A cylinder contains a mixture of argon gas and neon gas. Argon molecules are twice as massive as neon molecules.

The value of the ratio  $\frac{\text{mean square speed of argon molecules}}{\text{mean square speed of neon molecules}}$  is

A 4

B 2

C  $\frac{1}{2}$

D  $\frac{1}{4}$

**(Total for question = 1 mark)**

Q2.

A carton containing 1.03kg of milk is placed in a refrigerator. The milk cools from 22.5°C to 3.5°C over a period of 115 minutes.

Calculate the average rate at which energy is transferred from the milk as it cools.

specific heat capacity of milk = 3930 J kg<sup>-1</sup> K<sup>-1</sup>

**(3)**

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Average rate of energy transfer = .....

**(Total for question = 3 marks)**

Q3.

The absolute temperature scale is a theoretical scale proposed by Lord Kelvin.

On this scale, zero is the temperature at which

- A** all gases become liquids.
- B** an ideal gas would exert no pressure.
- C** the Celsius temperature is  $-373\text{ }^{\circ}\text{C}$ .
- D** water freezes.

**(Total for Question = 1 mark)**

Q4. The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

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Resistance = .....

(b) Water enters the shower at a temperature of  $7.5\text{ }^{\circ}\text{C}$ .

Calculate the water flow rate required to give an output temperature of  $37.5\text{ }^{\circ}\text{C}$ .

specific heat capacity of water =  $4200\text{ J kg}^{-1}\text{ K}^{-1}$

(3)

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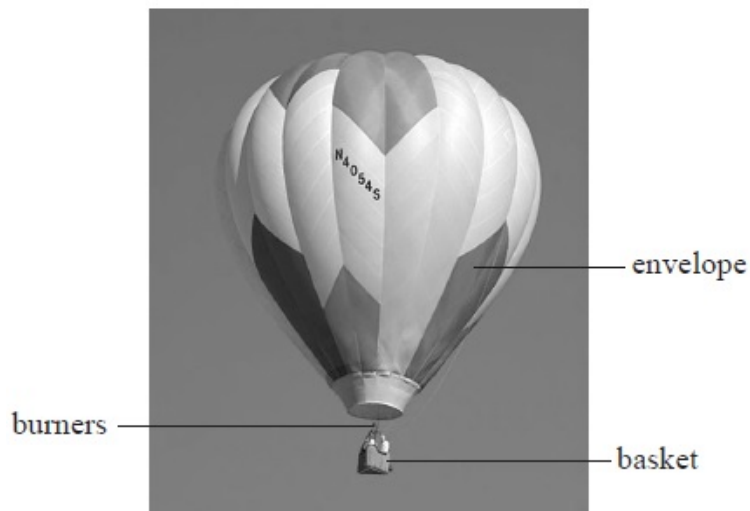
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Flow rate = .....

**(Total for Question = 5 marks)**

Q5.

Hot air ballooning is one way to explore the landscape. Air in a balloon is heated from underneath by a set of burners and the balloon starts to rise.



(a) Explain why heating the air causes the balloon to rise.

(2)

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(b) In 1991, Per Lindstrand and Richard Branson become the first people to cross the Pacific in a hot air balloon.

With a volume of  $7.4 \times 10^4 \text{ m}^3$  the balloon was, at the time, the largest ever built.

Calculate the energy supplied by the burners to heat the air from  $20.0 \text{ }^\circ\text{C}$  to  $35.0 \text{ }^\circ\text{C}$ .

average density of air in the balloon =  $1.20 \text{ kg m}^{-3}$

specific heat capacity of air =  $1010 \text{ J kg}^{-1} \text{ K}^{-1}$

(3)

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Energy = .....

(c) The first balloons used were filled with hydrogen and sealed to keep the volume constant. As the balloon rose there would be changes in the pressure of the hydrogen due to the temperature changes of the atmosphere.

(i) Calculate the new pressure exerted by the hydrogen if the temperature changed from  $20.0 \text{ }^\circ\text{C}$  to  $-5.0 \text{ }^\circ\text{C}$ , as the balloon rose from ground level.

pressure exerted by the hydrogen in the balloon at ground level =  $1.01 \times 10^5 \text{ Pa}$

(2)

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New pressure = .....

(ii) State **two** assumptions that you must make to calculate this change.

(2)

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\*(iii) By considering the motion of molecules in the gas, explain why the pressure exerted by the gas decreases as it cools.

(3)

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**(Total for Question = 12 marks)**

Q6.

A student carries out an experiment to investigate how the volume occupied by a gas depends upon the temperature.

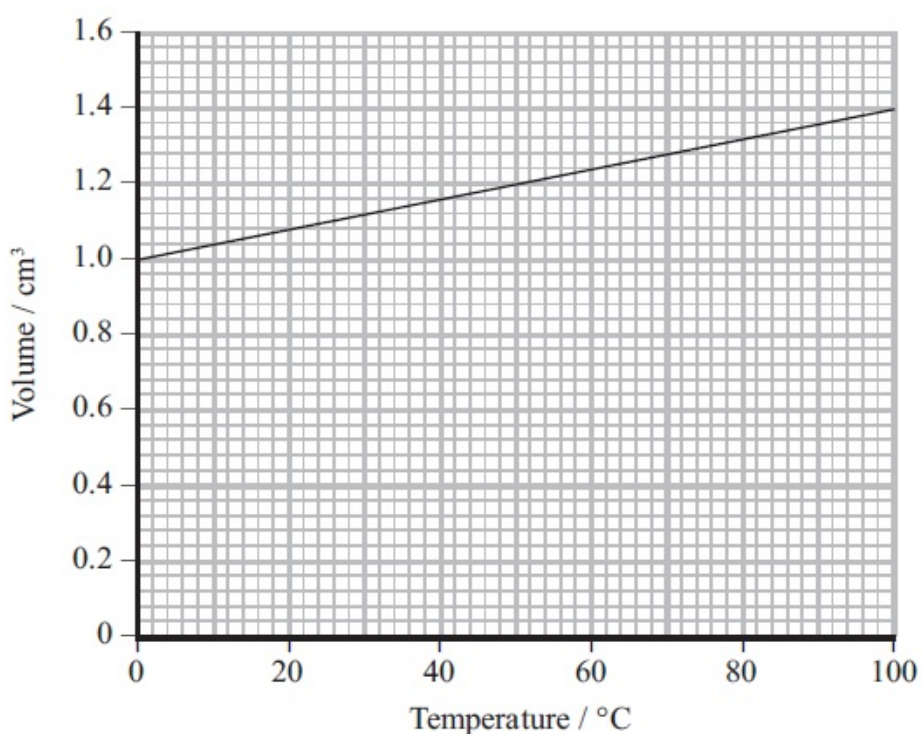
(a) What variables must the student control in this investigation?

(2)

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(b) The following graph is obtained.



Explain how graphs such as this provide evidence for an absolute zero of temperature.

(2)

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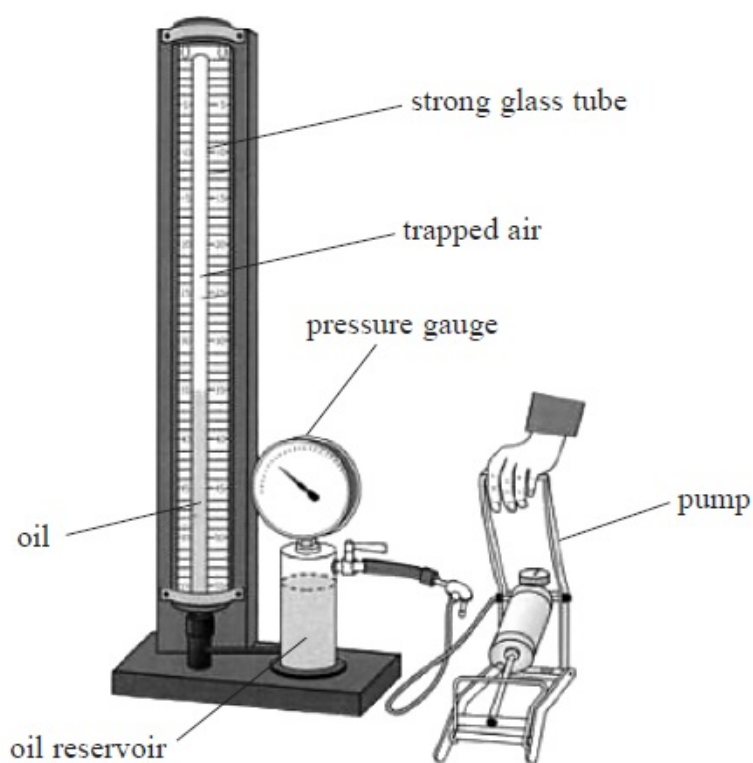
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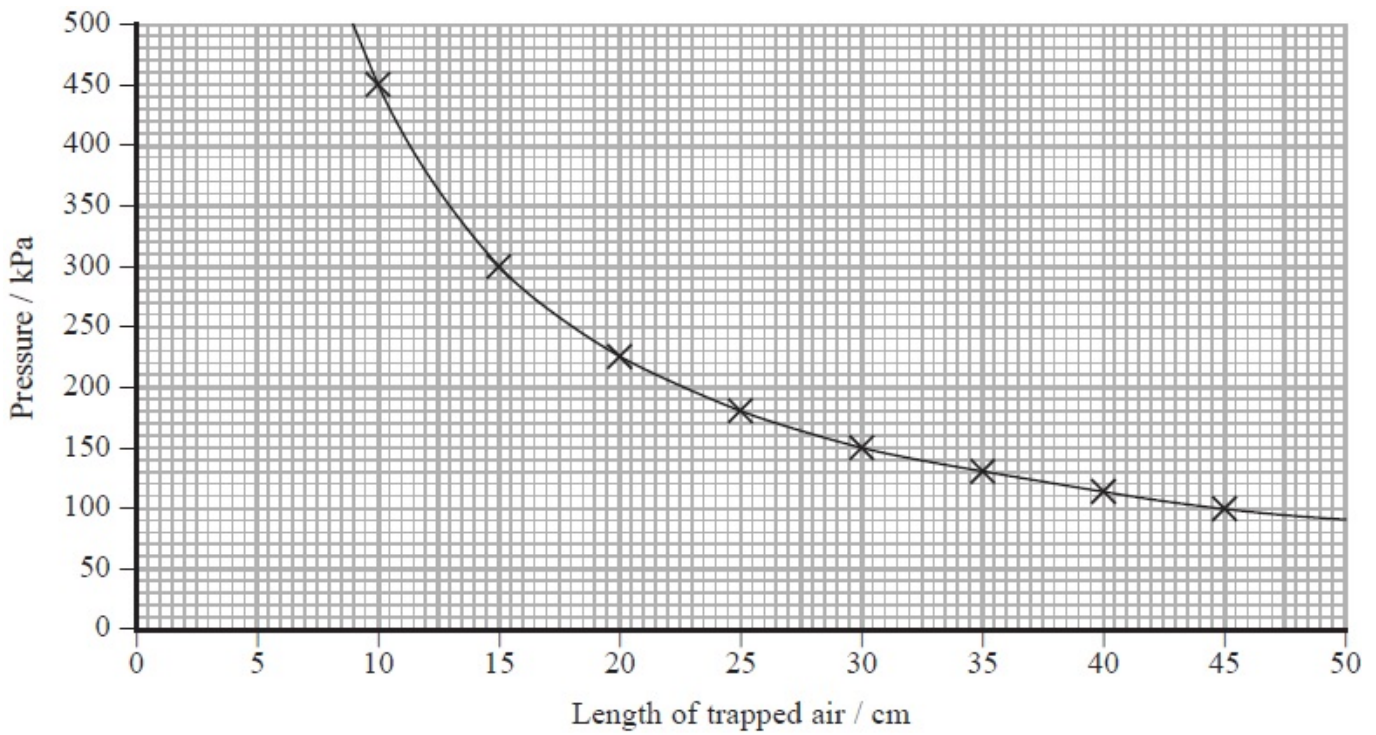
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**(Total for question = 4 marks)**

Q7. A student uses the apparatus shown to investigate the relationship between pressure and volume of a gas.



Air is trapped in a glass tube of uniform cross-sectional area. As the pressure of the trapped air is increased, the length of trapped air decreases. The student collects data and plots the following graph.



(a) State the variables that should be controlled in this investigation.

(2)

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(b) Theory suggests that, for the air trapped in the tube, the pressure  $p$  is inversely proportional to the volume  $V$ .

Use the graph to show that this relationship is correct. State an assumption that you are making.

(4)

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(c) the day that the investigation was carried out, the temperature in the laboratory was 20 °C.

Calculate the number of air molecules trapped in the tube.

cross-sectional area of tube =  $7.5 \times 10^{-5} \text{ m}^2$

(3)

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Number of air molecules = .....

(d) State how the graph would change if

(i) the air molecules in the tube were replaced by the same number of molecules of hydrogen gas.

(1)

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(ii) the temperature of the laboratory was substantially higher.

(2)

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**(Total for Question = 12 marks)**

Q8.

A beach volleyball has a fixed volume of  $5.10 \times 10^{-3} \text{ m}^3$ . The volleyball is filled with air at a pressure of  $1.24 \times 10^5 \text{ Pa}$  at a temperature of  $25.0^\circ\text{C}$ .

The temperature of the air drops to  $0^\circ\text{C}$ . The volume of the volleyball remains constant.

Show that the pressure exerted by the air inside the volleyball is now about  $1.1 \times 10^5$  Pa.

(3)

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**(Total for question = 3 marks)**

Q9.

When an ideal gas reaches the absolute zero of temperature, the gas

- A** becomes a superfluid.
- B** condenses to a liquid.
- C** has maximum molecular potential energy.
- D** exerts no pressure.

**(Total for question = 1 mark)**

Q10. Air is a mixture of mostly nitrogen and oxygen molecules. The mass of an oxygen molecule is slightly greater than the mass of a nitrogen molecule.

On average, in a sample of air at a given temperature

- A** the nitrogen and oxygen molecules have the same speed.

- B** the nitrogen molecules are travelling more slowly than the oxygen molecules.
- C** the oxygen molecules are travelling more slowly than the nitrogen molecules.
- D** the molecules have relative speeds that depend upon the amount of each gas present.

**(Total for Question = 1 mark)**

Q11.

(a) Explain what is meant by internal energy of a liquid.

**(2)**

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(b) A cup of tea contains 175 g of water at a temperature of 85.0 °C. Milk at a temperature of 4.5 °C is added to the tea and the temperature of the mixture becomes 74.0 °C.

(i) Show that the internal energy of the water decreases by about 8 kJ as its temperature decreases.

Specific heat capacity of water = 4200 J kg<sup>-1</sup> K<sup>-1</sup>

**(2)**

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(ii) Calculate the mass of milk that was added to the tea. State an assumption that must be made.

Specific heat capacity of milk = 3900 J kg<sup>-1</sup> K<sup>-1</sup>

**(3)**

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Mass of milk = .....

Assumption

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.....

**(Total for question = 7 marks)**

Q12.

It is suggested that before making tea in a teapot, the teapot should be warmed by pouring hot water into it. This allows more flavour to be extracted from the tea.

(a) Suggest why a pre-warmed teapot may allow more flavour to be extracted.

**(1)**

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(b) (i) 0.26 kg of water at 95 °C is added to a stainless steel teapot. In a very short time the teapot and water both reach a temperature of 81 °C.

Show that the energy transferred from the water is about 15 kJ.

specific heat capacity of water = 4200 J kg<sup>-1</sup> K<sup>-1</sup>

**(2)**

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(ii) Calculate the specific heat capacity of stainless steel, stating any assumption you make.

mass of teapot = 0.43 kg  
initial temperature of teapot = 22 °C

**(3)**

Assumption

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Specific heat capacity = ..... J kg<sup>-1</sup> K<sup>-1</sup>

(iii) The accepted value for the specific heat capacity of stainless steel is about 500 J kg<sup>-1</sup> K<sup>-1</sup>. Compare this with the value you have calculated and explain the difference.

(2)

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**(Total for question = 8 marks)**

Q13.

A car of mass 1200 kg is travelling at a speed of 25 m s<sup>-1</sup>. During braking, 25% of the kinetic energy of the car is transferred to the brake pads.

Calculate the increase in temperature of the brake pads.

total mass of brake pads = 5.3 kg  
specific heat capacity of brake pads = 450 J kg<sup>-1</sup> K<sup>-1</sup>

(4)

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Increase in temperature = .....

**(Total for question = 4 marks)**

Q14.

A gas cylinder of volume  $0.052 \text{ m}^3$  contains oxygen gas at a temperature of  $22^\circ\text{C}$  and a pressure of  $2.0 \times 10^5 \text{ Pa}$ .

Some of the oxygen in the cylinder is used and the gas pressure falls to  $1.6 \times 10^5 \text{ Pa}$ . The temperature remains constant.

Calculate the number of molecules removed from the cylinder

**(3)**

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Number of molecules removed = .....

**(Total for question = 3 marks)**

Q15.

When the absolute temperature of an ideal gas is doubled, the internal energy of the gas changes by a factor of

- A** 1
- B**  $\sqrt{2}$
- C** 2
- D** 4

**(Total for question = 1 mark)**

Q16.

The average kinetic energy of the molecules in an ideal gas is

- A** directly proportional to the square root of the absolute temperature.
- B** directly proportional to the absolute temperature.
- C** independent of the absolute temperature.
- D** inversely proportional to the absolute temperature.

**(Total for question = 1 mark)**

Q17.

A sample of an ideal gas at 27 °C is placed in a sealed container. The gas is heated at constant volume to a temperature of 324 °C.

The ratio of the final pressure to the initial pressure exerted by the gas is approximately

- A** 1
- B** 2
- C** 4
- D** 12

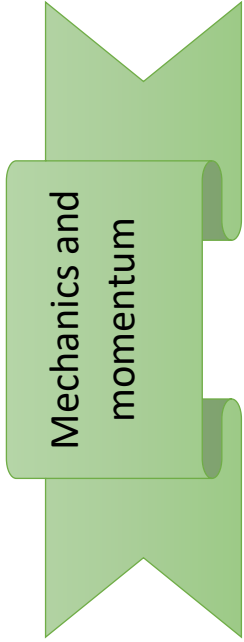
**(Total for question = 1 mark)**

Q18. When energy is supplied to a substance, changes in the average molecular kinetic energy ( $E_k$ ) and the average molecular potential energy ( $E_p$ ) can occur.

When energy is supplied to an ideal gas

# Week 2





Mechanics and  
momentum

**Motion**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 3.1.1 a                 | Can you define displacement, instantaneous speed, average speed, velocity, and acceleration?   | <input type="checkbox"/> |
| 3.1.1 b                 | Can you interpret graphical representations of displacement, speed, velocity, and acceleration?  | <input type="checkbox"/> |
| 3.1.1 c                 | Can you draw displacement–time graphs and calculate velocity from the gradient?  | <input type="checkbox"/> |
| 3.1.1 d                 | Can you interpret velocity–time graphs, where acceleration is the gradient and displacement is the area under the graph?   | <input type="checkbox"/> |
| 3.1.2 a i               | Can you use the equations of motion for constant acceleration in a straight line, including motion of bodies falling in a uniform gravitational field without air resistance?  | <input type="checkbox"/> |
| 3.1.2 a ii              | Can you list and describe techniques and procedures used to investigate the motion and collisions of objects?  | <input type="checkbox"/> |
| 3.1.2 b i               | Can you define acceleration $g$ of free fall?  | <input type="checkbox"/> |
| 3.1.2 b ii              | Can you list and describe techniques and procedures used to determine the acceleration of free fall using a trapdoor and electromagnet arrangement or light gates and a timer? | <input type="checkbox"/> |
| 3.1.2 c                 | Can you define what is meant by reaction time and thinking distance; and calculate braking distance and stopping distance for a vehicle?                                       | <input type="checkbox"/> |
| 3.1.3 a                 | Can you explain the independence of the vertical and horizontal motion of a projectile?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 3.1.3 b                 | Can you describe the two-dimensional motion of a projectile with constant velocity in one direction and constant acceleration in a perpendicular direction? | <input type="checkbox"/> |

## Forces in action

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 3.2.1 a                 | Can you recall and understand the formula net force = mass $\times$ acceleration ( $F = m a$ )?          | <input type="checkbox"/> |
| 3.2.1 b                 | Can you recall the newton as the unit of force?  | <input type="checkbox"/> |
| 3.2.1 c                 | Can you explain why the weight of an object, $W = m g$ ?   | <input type="checkbox"/> |
| 3.2.1 d                 | Can you define and use the terms tension, normal contact force, upthrust, and friction?                  | <input type="checkbox"/> |
| 3.2.1 e                 | Can you draw and interpret free-body diagrams?   | <input type="checkbox"/> |
| 3.2.1 f                 | Can you explain one- and two-dimensional motion under constant force?                                    | <input type="checkbox"/> |
| 3.2.2 a                 | Can you explain drag as the frictional force experienced by an object travelling through a fluid?        | <input type="checkbox"/> |
| 3.2.2 b                 | Can you describe the factors affecting drag for an object travelling through air?                        | <input type="checkbox"/> |
| 3.2.2 c                 | Can you describe the motion of objects falling in a uniform gravitational field in the presence of drag? | <input type="checkbox"/> |
| 3.2.2 d i               | Can you define terminal velocity?  | <input type="checkbox"/> |
| 3.2.2 d ii              | Can you list and describe techniques and procedures used to determine terminal velocity in fluids?       | <input type="checkbox"/> |
| 3.2.3 a                 | Can you define the moment of a force?  | <input type="checkbox"/> |
| 3.2.3 b                 | Can you describe a couple and the torque of a couple?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 3.2.3 c                 | Can you define and use the principle of moments?  | <input type="checkbox"/> |
| 3.2.3 d                 | Can you describe centre of mass/centre of gravity, and describe how to determine the centre of gravity experimentally?            | <input type="checkbox"/> |
| 3.2.3 e                 | Can you describe the conditions for equilibrium of an object under the action of forces and torques?                              | <input type="checkbox"/> |
| 3.2.3 f                 | Can you explain the conditions for equilibrium of three coplanar forces?  | <input type="checkbox"/> |
| 3.2.4 a                 | Can you define density?   | <input type="checkbox"/> |
| 3.2.4 b                 | Can you describe pressure for solids, liquids, and gases?   | <input type="checkbox"/> |
| 3.2.4 c                 | Can you apply Archimedes' principle and use the equation $p = h \rho g$ to calculate the upthrust acting on an object in a fluid? | <input type="checkbox"/> |

**Work, energy, and power**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 3.3.1 a                 | Can you define work done by a force and recall that the unit for work done is the joule?                             | <input type="checkbox"/> |
| 3.3.1 b                 | Can you use $W = F \times \cos \theta$ to calculate the work done by a force?  | <input type="checkbox"/> |
| 3.3.1 c                 | Can you define and apply the principle of conservation of energy?  | <input type="checkbox"/> |
| 3.3.1 d                 | Can you describe and carry out calculations for situations involving the transfer of energy between different forms? | <input type="checkbox"/> |
| 3.3.1 e                 | Can you explain how transfer of energy is equal to work done?  | <input type="checkbox"/> |
| 3.3.2 a                 | Can you define and calculate the kinetic energy of an object?  | <input type="checkbox"/> |
| 3.3.2 b                 | Can you define and calculate the gravitational potential energy of an object in a uniform gravitational field?       | <input type="checkbox"/> |
| 3.3.2 c                 | Can you describe the exchange between gravitational potential energy and kinetic energy?                             | <input type="checkbox"/> |
| 3.3.3 a                 | Can you define and calculate power, and recall that the unit for power is the watt?                                  | <input type="checkbox"/> |
| 3.3.3 b                 | Can you use the equation $P = Fv$ ?  | <input type="checkbox"/> |
| 3.3.3 c                 | Can you calculate the efficiency of a mechanical system?   | <input type="checkbox"/> |

**Laws of motion and momentum**

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 3.1.2 a i               | Can you use the equations of motion for constant acceleration in a straight line, including motion of bodies falling in a uniform gravitational field without air resistance? | <input type="checkbox"/> |
| 3.5.1 a                 | Can you explain Newton's three laws of motion?  | <input type="checkbox"/> |
| 3.5.1 b                 | Can you calculate linear momentum and understand the vector nature of momentum?   | <input type="checkbox"/> |
| 3.5.1 c                 | Can you understand that net force = rate of change of momentum?   | <input type="checkbox"/> |
| 3.5.1 d                 | Can you describe and calculate the impulse of a force?  | <input type="checkbox"/> |
| 3.5.1 e                 | Can you recall that impulse is equal to the area under a force–time graph?  | <input type="checkbox"/> |
| 3.5.2 a                 | Can you define the principle of conservation of momentum?   | <input type="checkbox"/> |
| 3.5.2 b                 | Can you describe and carry out calculations for collisions and interactions of bodies in one dimension and in two dimensions?   | <input type="checkbox"/> |
| 3.5.2 c                 | Can you describe perfectly elastic collisions and inelastic collisions?   | <input type="checkbox"/> |

## Motion

|  |   |
|--|---|
| What is displacement?  | The distance of an object from a point in a specific direction (vector) |
| What is velocity?  | Rate of change of displacement (vector) $\Delta s/\Delta t$ if constant |
| What is speed?   | Change in distance travelled per unit time (scalar)                     |
| What is acceleration?  | Rate of change of velocity (vector) $\Delta v/\Delta t$ if constant     |
| What are the units of acceleration?  | $\text{ms}^{-2}$  |
| What is meant by constant velocity/uniform motion?   | Speed and direction of motion don't change                              |
| What is represented by the gradient of a distance-time graph?                                  | Speed   |
| What is represented by the gradient of a displacement-time graph?                              | Velocity  |
| What is represented by the gradient of a velocity-time graph?                                  | Acceleration  |
| What is represented by the area under a velocity-time graph?                                   | Change in displacement  |
| What is represented by the area under an acceleration-time graph?                              | Change in velocity  |
| When can the suvat equations be used?  | When there is constant acceleration and motion along a straight line.   |
| What is the effect of mass on the acceleration for an object in free-fall?                     | None  |
| What is the relationship between displacement and time for an object falling freely from rest? | Displacement is proportional to time squared ( $\text{sat}^2$ )         |
| What is a projectile   | An object acted upon only by the force of gravity                       |
| What shape is the path of a projectile?  | Parabolic   |
| What is the initial vertical velocity of an object projected horizontally?                     | Zero  |
| What angle of projection that results in maximum range   | $45^\circ$  |
| Ignoring air resistance what is the acceleration of a projectile?                              | Always $g$ downwards  |
| How does horizontal velocity vary in projectile motion?  | It is constant  |
| If a projectile returns to its starting height   | Initial and final velocities have the same magnitude                    |
| What equation used for the horizontal component of projectile motion?                          | Displacement = Velocity x time (since horizontal velocity is constant)  |
| What aspect links the vertical and horizontal motion of a projectile                           | Time taken to fall  |
| Why can SUVAT equations can be used for the vertical component of projectile motion            | Since the motion is in a single direction with a constant acceleration  |
| What is the vertical velocity at the peak of projectile motion?                                | Zero  |

## Forces in action

|   |   |
|---|---|
| What is the centre of mass of an object?  | The point at which the weight can be assumed to act.  |
| What does the weight of an object depend on?  | It's mass and the gravitational field strength ( $W=mg$ )   |
| What is a free-body diagram?  | It is a diagram showing the set of forces acting on a single object.  |
| What is weight?   | The force due to gravity that acts through an objects centre of mass.   |
| What is friction?   | The force that acts between two surfaces in contact to oppose motion.   |
| What is drag?   | The resistive force that acts on an object moving through a fluid   |
| What is tension?  | The force within a stretched object such as a cable or rope.  |
| What is upthrust?   | The upward buoyant force that acts on an object in a fluid.   |
| What is a normal contact force?   | A force that acts perpendicular to a surface when an object rests on it.  |
| How do you calculate the component of weight down a slope?  | $W \sin (\theta)$ where $\theta$ is the angle between the slope and horizontal.   |
| How do you calculate the component of weight acting perpendicular to a slope?                       | $W \cos (\theta)$ where $\theta$ is the angle between the slope and horizontal.   |
| What are the key factors in determining the magnitude of drag force acting on an object in a fluid? | Speed and cross-sectional area  |
| What is terminal velocity?  | The maximum speed reached by a falling object when drag and weight are equal.   |
| What is a moment?   | The turning effect produced by a force.   |
| What units do moments have?   | Nm  |
| How do you calculate a moment about a point?  | Force x perpendicular distance to the line of action of the force   |
| What is meant by a body being in equilibrium?   | The net force and the net moment acting on the body are both zero.  |
| What is the principle of moments?   | For an object in rotational equilibrium the sum of the clockwise moments about any point is equal to the sum of anticlockwise moments about that point. |
| What is a couple?   | A pair of equal and opposite forces acting on an object with different lines of action.   |
| How do you calculate the moment of a couple?  | Force x perpendicular distance between the lines of action of the forces.   |
| What is a triangle of forces?   | A vector diagram of the three forces acting on an object in equilibrium.  |
| What is a resultant/net force?  | The vector sum of forces acting on an object  |
| What is the density of a substance?   | mass per unit volume.   |
| What are the units of density?  | $\text{kgm}^{-3}$   |
| What is pressure?   | Normal force acting per unit area   |

|  |   |
|--|---|
| What is Archimedes principle?                | The upthrust exerted on an object is equal to the weight of fluid displaced |
| What is $p$ in the equation $p = h\rho g$    | Pressure exerted by a fluid   |
| What is $\rho$ in the equation $p = h\rho g$ | Density of the fluid  |
| What is $h$ in the equation $p = h\rho g$    | Depth of the fluid  |

## Work done

|   |  |
|---|--|
| What is work done equivalent to?  | Energy Transferred   |
| What are the SI base units equivalent to the Joule?   | $\text{kgm}^2\text{s}^{-2}$  |
| How is work done calculated?  | $W = F \times \cos\theta$ (distance moved $\times$ component of the force in the direction of motion)                              |
| What is $\theta$ in $W = F \times \cos\theta$ ?   | The angle between the force and motion.  |
| What is energy?   | The capacity of one object or system to do work (or cause a change) on another.  |
| What is represented by the area under a force-distance graph?   | Work done.   |
| What is the principle of conservation of energy?  | The energy of a closed system always remains constant. Energy can never be created or destroyed, only transferred.                 |
| What form of energy is due to the motion of a mass?   | kinetic energy   |
| What form of energy is due to the position of a mass in a gravitational field?                                  | gravitational potential energy   |
| What form of energy is due to the bonds between atoms in a substance?   | chemical energy  |
| What form of energy is due to a reversible change in shape of an object?  | elastic potential energy   |
| What form of energy is due to the position of a charge in an electric field?                                    | electrical potential energy  |
| What form of energy is due to the forces between protons and neutrons in an atom?                               | nuclear energy   |
| What form of energy is due to electromagnetic waves?  | radiant energy   |
| What form of energy is due to the mechanical wave motion of atoms?  | sound energy   |
| What form of energy is due to randomly distributed potential and kinetic energies of the atoms within a system? | thermal energy   |
| What effect does friction have on the energy of a moving object?  | Transfers kinetic energy primarily to thermal energy   |
| Describe the energy transformations for an object sliding downhill at constant speed.                           | Gravitational potential energy decreases at the same rate as work is done by friction.   |
| Describe the energy transformations for a vehicle travelling uphill at constant speed.                          | Work is being done by the driving force and this is equal to the gain in gravitational potential energy plus work done by friction |
| What is power?  | Power is the rate at which work is done $P = W/t$  |
| What is the derived unit of Power?  | Watt (W)   |
| What are the equivalent SI base units of the Watt?  | $\text{kgm}^2\text{s}^{-3}$  |
| What is the equation $P = Fv$ used for?   | The power developed by an object moving at constant speed against a constant resistive force.                                      |
| How is % efficiency calculated?   | $(\text{Useful output energy}/\text{total input energy}) \times 100$   |

## Newton's Laws and Momentum

|   |   |
|---|---|
| What is Newton's 1st Law of motion?   | An object will remain at rest or move at a constant velocity unless acted upon by a resultant force   |
| What is Newton's 3rd Law of motion?   | When two objects interact they exert forces on each other that are equal in magnitude, opposite in direction and of the same type of force. |
| What is Newton's 2nd Law of motion?   | Resultant force acting on an object is proportional to its rate of change of momentum, and is in the same direction.                        |
| What two sets of units can be used for momentum?  | Ns OR kgms <sup>-1</sup>  |
| How is the momentum of an object calculated?  | Mass × velocity ( $p=mv$ )  |
| What is the principle of conservation of momentum?  | The total momentum in a system of interacting objects is constant provided no external force acts.  |
| What is an elastic collision?   | A collision in which kinetic energy is conserved  |
| What is an inelastic collision?   | A collision in which some kinetic energy is transferred to other forms  |
| How is impulse calculated?  | Force × time  |
| What is the relationship between impulse and momentum?  | Impulse is equal to change in momentum.   |
| What is represented by the area under a force time graph  | Impulse   |
| What is represented by the gradient of a momentum-time graph?   | Resultant force   |
| What is the change in momentum when an object of momentum $p$ collides elastically at right angles with a wall? | $-2p$   |
| When can $F=ma$ be used?  | When an object has constant mass.   |



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**(Total for question = 6 marks)**

Q2.

The mass of a rocket including fuel at take-off is 11 000 kg. The engines produce an upwards vertical thrust of 150 000 N.

The acceleration, in  $\text{m s}^{-2}$ , of the rocket at take-off is found using

- A  $\frac{150\,000}{11\,000}$
- B  $\frac{150\,000 - 11\,000}{11\,000}$
- C  $\frac{150\,000 - (11\,000 \times 9.81)}{11\,000}$
- D  $\frac{150\,000 - (11\,000 \times 9.81)}{(11\,000 \times 9.81)}$

**(Total for question = 1 mark)**

Q3.

The Starflyer is a fairground ride which operates 60 m above the ground. As it begins to spin, the chairs in which the riders sit move outwards.



Consider the chair and rider as a single object. By drawing a free-body force diagram and considering the forces acting, explain the following observations.

*The angle to the vertical of the supporting ropes depends on the speed of rotation, but does not depend on the mass of the rider.*

(5)

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**(Total for question = 5 marks)**

Q4.

\* A stationary radium nucleus decays by emitting an alpha particle. The speed of the recoiling nucleus is small compared to the speed of the alpha particle.

Explain why the nucleus recoils and why its speed is small compared to that of the alpha particle.

(4)

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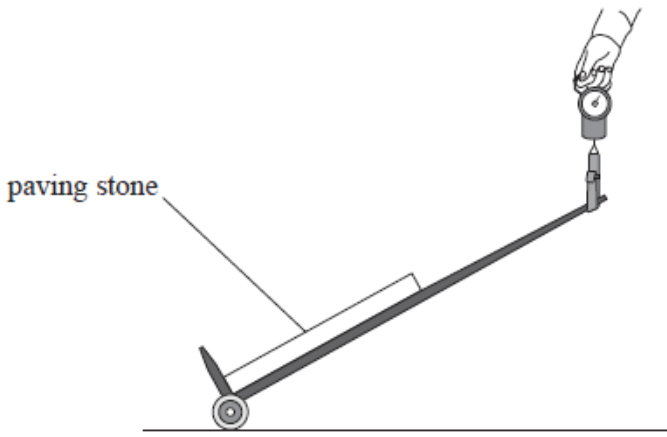
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**(Total for question = 4 marks)**

Q5.

A gardener used a trolley to move a paving stone.



A force meter was attached to the handle of the trolley.

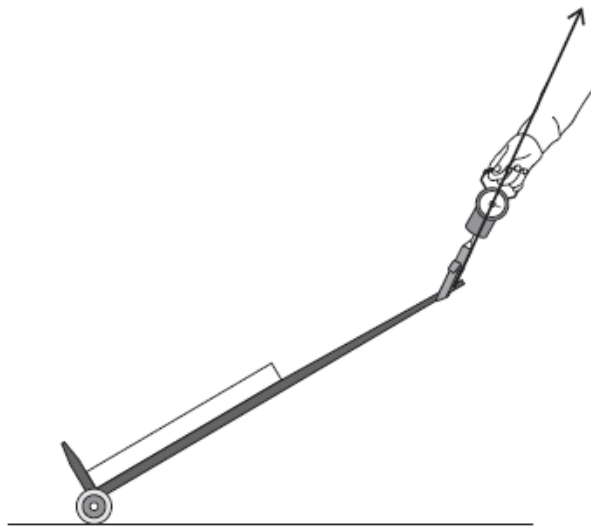
The gardener recorded the following measurements when the trolley was at rest in the position shown in the diagram.

mass of trolley and paving stone = 18.5 kg

length of trolley = 97 cm

force on handle = 50 N

The gardener then pulled the trolley and measured the applied force while the trolley was moving.



The direction of the applied force is  $25^\circ$  to the vertical, as shown by the arrow.

(i) Calculate the magnitude of the applied force.

Assume the magnitude of the vertical component of the force remains at 50 N.

(2)

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Magnitude of applied force = .....

(ii) The gardener continues to walk and pulls the trolley a distance of 15 m in a time of 4.2 s.

Calculate the power developed while pulling the trolley.

(3)

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Power = .....

**(Total for question = 5 marks)**

Q6. (a) State what is meant by centre of gravity.

(1)

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(b) The picture shows a snooker cue. It is made from wood of uniform density and takes the form of a rod with decreasing diameter towards one end.



(i) On the picture, mark the position of the centre of gravity of the snooker cue.

(1)

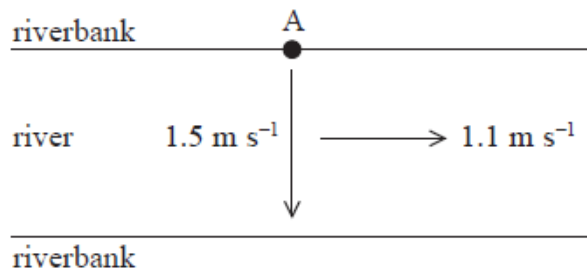
(ii) State a simple method to test if this is the correct position.

(1)

(Total for Question = 3 marks)

Q7.

A student rows across a river heading from point A. Her boat is headed in a direction at right angles to the bank and she rows through the water at a constant speed of  $1.5 \text{ m s}^{-1}$ . The river flows with a current of  $1.1 \text{ m s}^{-1}$ .



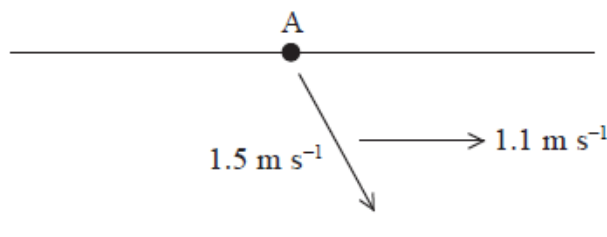
(a) Calculate the velocity of her boat relative to the riverbank.

(4)

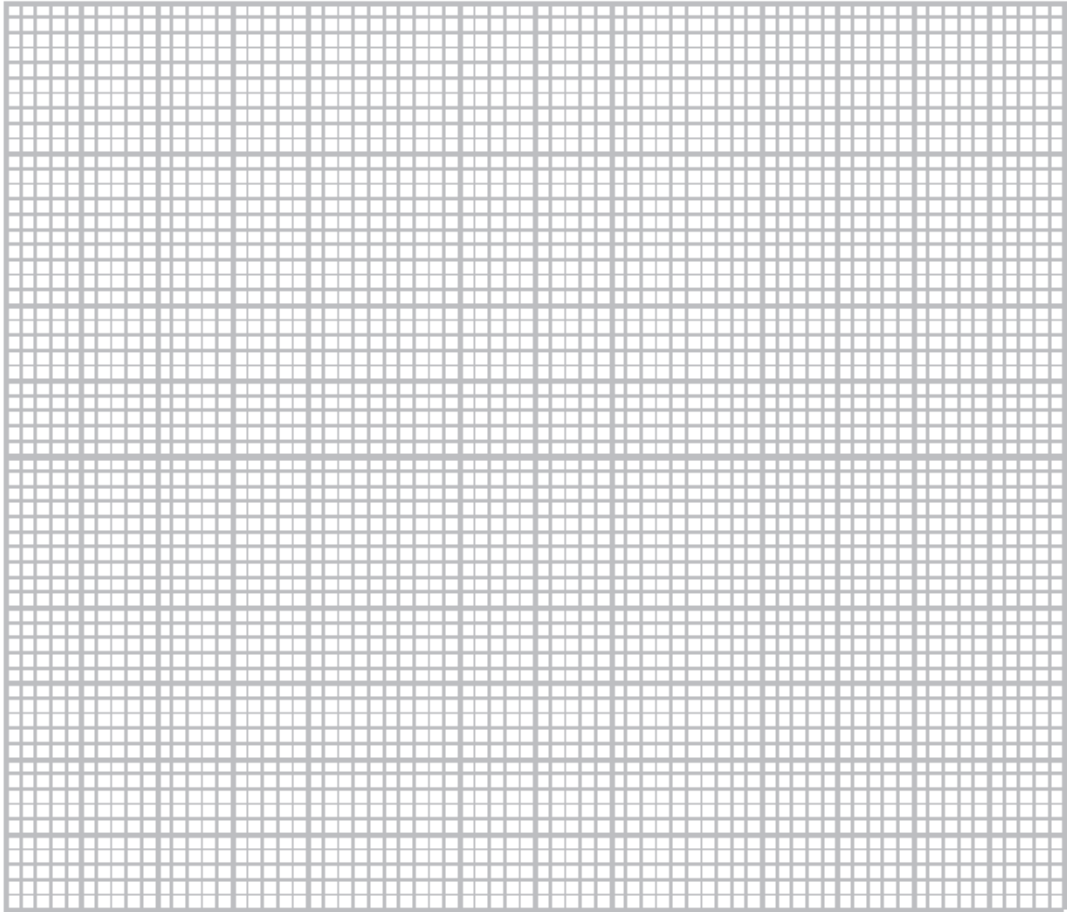
Magnitude of velocity = .....

Angle of velocity to the riverbank = .....

(b) Another student also rows through the water at a constant speed of  $1.5 \text{ m s}^{-1}$  and heads their boat in a direction at  $65^\circ$  to the riverbank.



On the grid below draw a scaled vector diagram to determine the velocity of the boat.



Magnitude of velocity = .....

Angle of velocity to the riverbank = .....

**(Total for question = 7 marks)**

Q8.

An exhibit in a science museum requires the observer to use a pump to create air bubbles in a column of liquid. The bubbles then rise through the liquid.



(i) Complete the free-body force diagram for a bubble as it rises through the liquid.

(3)



\*(ii) It is observed that larger bubbles reach the top of the column of liquid in less time than smaller bubbles.

By considering the forces acting on a bubble as it rises, explain this observation.

(3)

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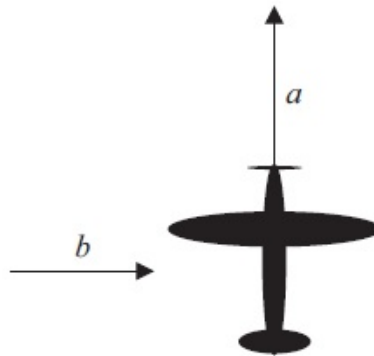
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Q9.

An aeroplane is flying horizontally and heading north through the air. Its speed through the air is  $\alpha$  and the wind is blowing east with a speed  $b$ .



The speed over the ground is given by

- A**  $\alpha + b$
- B**  $\alpha^2 + b^2$
- C**  $\sqrt{\alpha + b}$
- D**  $\sqrt{\alpha^2 + b^2}$

**(Total for question = 1 marks)**

Q10.

\* Particle accelerators accelerate particles to very high speeds before collisions occur. New particles are created during the collisions.

Two particles of the same type can undergo two kinds of collision.

**Fixed target:** a high speed particle hits a stationary particle.

**Colliding beams:** two particles travelling at high speeds, in opposite directions, collide head-on.

By considering the conservation of energy and momentum, explain which type of collision is able to create a new particle with the largest mass.

**(6)**

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**(Total for question = 6 marks)**

Q11.

Which of the following statements is always true for an inelastic collision?

- A** Both momentum and kinetic energy are conserved.
- B** Neither momentum nor kinetic energy is conserved.
- C** Kinetic energy is not conserved.
- D** Momentum is not conserved.

**(Total for question = 1 mark)**

Q12.

A body, initially at rest, explodes into two masses  $M_1$  and  $M_2$ . These masses move apart with speeds  $v_1$  and  $v_2$  respectively.

The ratio  $v_1/v_2$  is equal to

$\frac{\sqrt{M_1}}{\sqrt{M_2}}$    **A**    $\frac{M_1}{M_2}$



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**(Total for Question = 5 marks)**

Q14.

A motorist received a speeding penalty notice, from the police, for a short journey along 120 m of road.

(a) The car's specification states that the minimum time for the car to accelerate from 0 to 60 miles per hour is 9.5 seconds.

Show that the maximum value for the average acceleration of the car over 9.5 s is about  $3 \text{ m s}^{-2}$ .

1 mile = 1600 m

**(2)**

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(b) The police recorded a maximum speed for the car of  $20 \text{ m s}^{-1}$ .

The motorist knows that the speed at the start and at the end of the 120 m journey was zero.

Assume that the car had:

- constant positive acceleration, equal to the value in part (a), for the first 60 m of the journey
- constant negative acceleration of the same magnitude for the final 60 m of the journey.

Determine whether the motorist should challenge the penalty notice.

**(3)**

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(c) Explain why the assumptions about the acceleration in (b) may not be correct in practice.

(2)

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**(Total for question = 7 marks)**

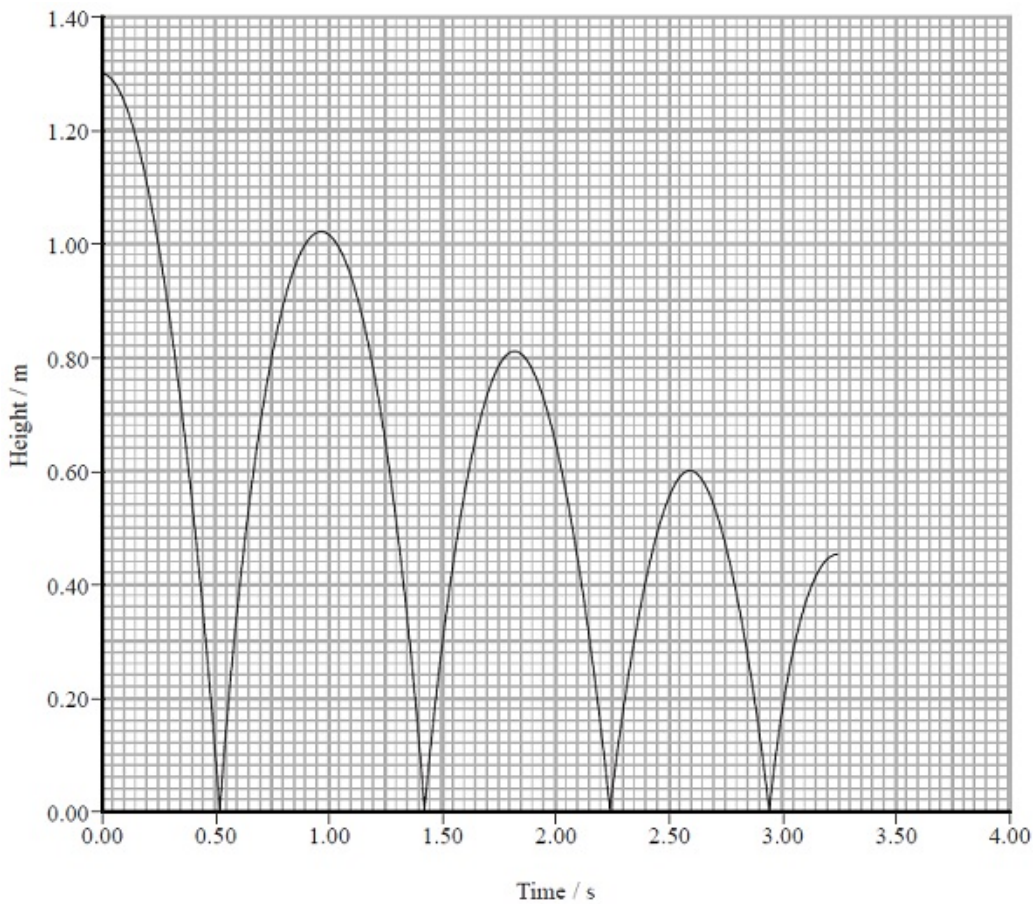
Q15.

The correct definition of the term centre of gravity is the point at which

- A** all of the force acts on a body.
- B** gravity acts on a body.
- C** the weight of a body may be considered to act.
- D** the weight is concentrated.

**(Total for question = 1 mark)**

Q16. A ball is dropped from a height of 1.3 m. The graph shows how the height above the ground varies with time for several bounces.



How can the velocity of the ball at time  $t = 2.5$  s be determined from the graph?

- A** Calculate the area between the graph and the time axis up to  $t = 2.5$  s.
- B** Divide the displacement at  $t = 2.5$  s by 2.5 s.
- C** Divide the height at  $t = 2.5$  s by 2.5 s.
- D** Draw a tangent to the graph at  $t = 2.5$  s and calculate its gradient.

**(Total for Question = 1 mark)**

Q17.

A ball is kicked, giving it an initial velocity  $v$  at an angle of  $35^\circ$  to the vertical. The ball remains in the air for a time  $t$ .

Which of the following gives the distance travelled over the ground?

**(1)**

- A  $vt \cos 35^\circ$
- B  $\frac{v \cos 35^\circ}{t}$
- C  $vt \sin 35^\circ$
- D  $\frac{v \sin 35^\circ}{t}$

**(Total for question = 1 mark)**

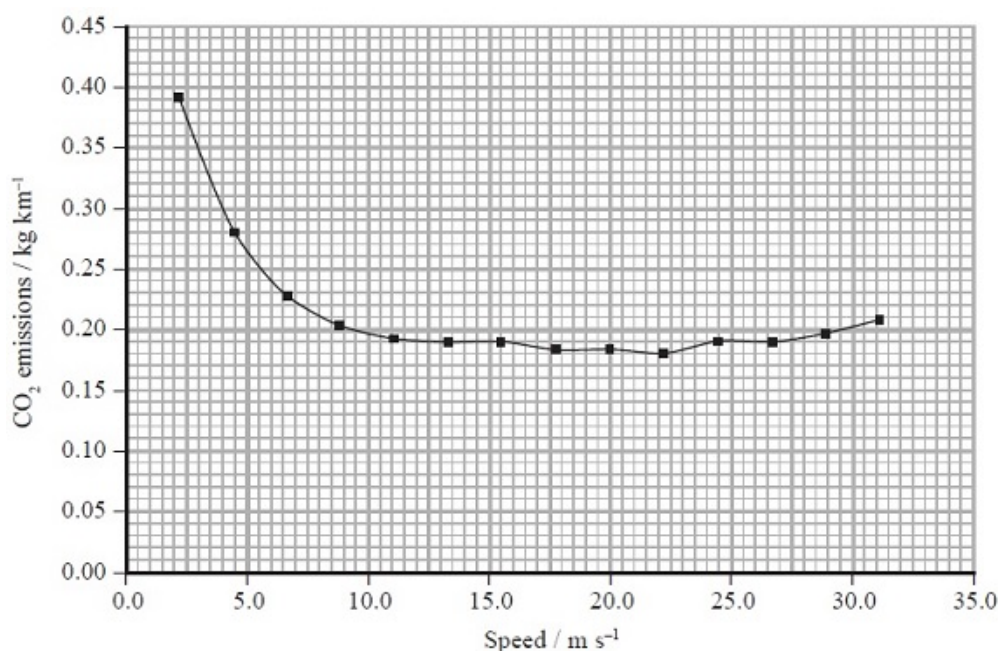
Q18. Queues of cars often form behind cyclists on narrow, rural roads.

Sometimes cars that would normally travel at  $65 \text{ km hour}^{-1}$  may be limited to about  $20 \text{ km hour}^{-1}$  by a cyclist.

(a) Show that  $65 \text{ km hour}^{-1}$  is about  $18 \text{ m s}^{-1}$ .

**(1)**

(b) The graph shows the amount of carbon dioxide emitted per kilometre by a typical car at different speeds.



During a 10 minute journey a cyclist, travelling at  $5 \text{ m s}^{-1}$ , has an average of three cars queuing behind him. The cars would otherwise be travelling at  $18 \text{ m s}^{-1}$ . The cars emit more carbon

dioxide because they are travelling slowly.

(i) Calculate the extra carbon dioxide emitted by the 3 cars due to travelling at this reduced speed for 10 minutes.

(4)

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Extra carbon dioxide emitted = .....

(ii) If the cyclist had made the same journey in his car at  $18 \text{ m s}^{-1}$ , his car would have emitted 0.54 kg of carbon dioxide. Comment on the significance of this.

(1)

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**(Total for Question = 6 marks)**

Q19. The 'Stealth' roller coaster at the Thorpe Park theme park is advertised as reaching  $135 \text{ km hour}^{-1}$  from rest in 2.3 seconds.

Most roller coasters are driven slowly up to the top of a slope at the start of the ride. However the carriages on 'Stealth' are initially accelerated horizontally from rest at ground level by a hydraulic launch system, before rising to the top of the first slope.

(a) (i) Calculate the average acceleration of the carriages.

$$135 \text{ km hour}^{-1} = 37.5 \text{ m s}^{-1}$$

(2)

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Average acceleration = .....

(ii) Calculate the minimum average power which must be developed by the launch system.

mass of carriages and passengers = 10 000 kg

(3)

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Minimum average power = .....

(iii) Suggest why the power in (ii) is a minimum value.

(1)

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\*(b) The force required to launch 'Stealth' is not always the same. The ride is monitored and the data from preceding launches is used to calculate the required force.

If the mass of the passengers for a particular ride is significantly more than for preceding launches, this can lead to 'rollback'. This is when the carriages do not quite reach the top of the first slope and return backwards to the start.

Explain why 'rollback' would occur in this situation.

(3)

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(c) Suggest why roller coasters may have a greater acceleration when the lubricating oil between the moving parts has had time to warm up.

(2)

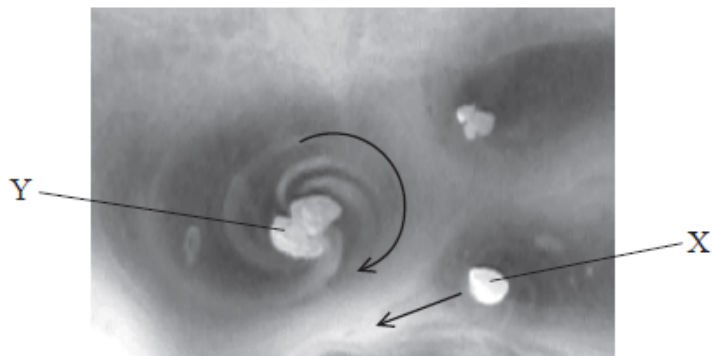
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**(Total for Question = 11 marks)**

Q20.

Solid carbon dioxide changes state directly from solid to gas. This process is called sublimation. Solid carbon dioxide, when placed on water, will move rapidly across the surface due to jets of ejected gas.

The diagram below shows the direction of movement for two large pieces of solid carbon dioxide placed on water.



\*(a) When placed at rest on water, piece X begins to move rapidly in the direction shown.

With reference to Newton's laws of motion explain the motion of piece X.

(5)

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(b) When placed at rest on water, piece Y remained in one position whilst spinning around.  
Suggest why piece Y remains in one position.

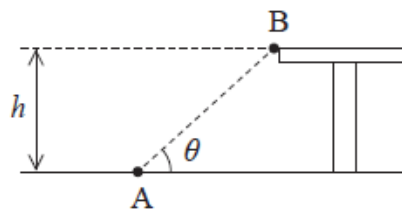
(2)

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**(Total for question = 7 marks)**

Q21.

An object of mass  $m$  is moved from point A on the ground, to point B on a bench of height  $h$  as shown in the diagram.



Which of the following is a correct expression for the work done on the object?

(1)

- A  $\frac{mgh}{\sin \theta}$
- B  $\frac{mgh}{\cos \theta}$
- C  $mgh$
- D  $mgh \sin \theta$

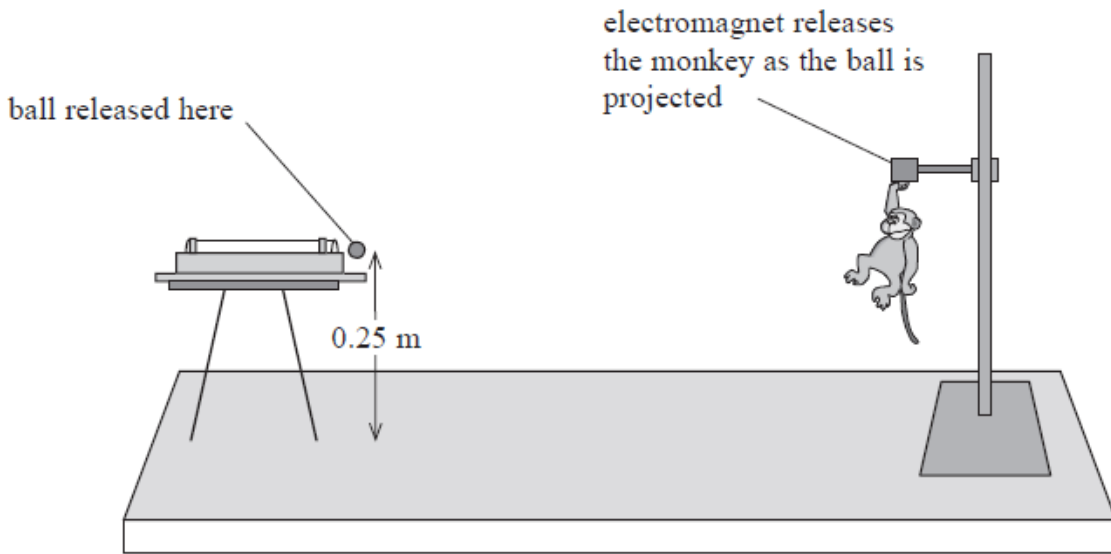
**(Total for question = 1 mark)**

Q22.

The monkey and hunter is a thought experiment to illustrate the independence of the horizontal and vertical motion of a projectile.

A student models the experiment by projecting a table tennis ball horizontally at a toy monkey. The ball and monkey are initially at the same height, 0.25 m, above the bench.

The monkey drops at the instant the ball is projected. The monkey and the ball will always meet irrespective of their horizontal separation.



(a) (i) Show that the time taken for the ball to fall to the bench is about 0.2 s.

(2)

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(ii) The ball is projected with a horizontal velocity of  $2.6 \text{ m s}^{-1}$

Calculate the horizontal distance that the ball should travel if the ball is to hit the monkey as it reaches the bench.

(2)

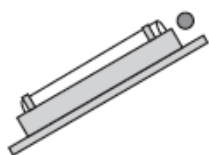
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Horizontal distance = .....

(b) A variation of this experiment is where the monkey is initially higher so that the ball has to be projected upwards towards the monkey. The two objects will still always meet.



(i) Complete the diagram above to show the paths of the ball and the monkey.

(2)

(ii) The ball is projected with a velocity of  $3.0 \text{ m s}^{-1}$  at an angle of  $20^\circ$  to the horizontal. If the monkey is at a horizontal distance of  $0.50 \text{ m}$ , how far will it have fallen when it meets the ball?

(3)

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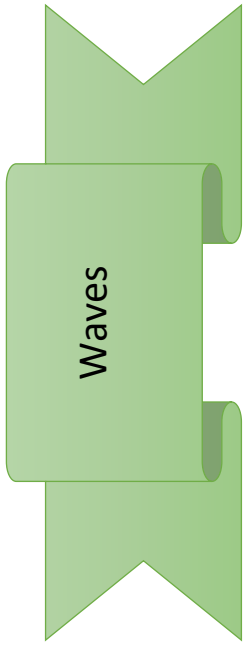
Distance fallen = .....

**(Total for question = 9 marks)**

**Mark Scheme**

# Week 3





## Waves 1

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.4.1 a                 | Can you describe progressive waves, both longitudinal and transverse?   | <input type="checkbox"/> |
| 4.4.1 b i               | Can you define displacement, amplitude, wavelength, period, phase difference, frequency, and speed of a wave?                                 | <input type="checkbox"/> |
| 4.4.1 b ii              | Can you list and describe techniques and procedures used to use an oscilloscope to determine frequency?                                       | <input type="checkbox"/> |
| 4.4.1 c                 | Can you use the equation $f = \frac{1}{T}$ ?  | <input type="checkbox"/> |
| 4.4.1 d                 | Can you use the wave equation $v = f\lambda$ ?  | <input type="checkbox"/> |
| 4.4.1 e                 | Can you produce graphical representations of transverse and longitudinal waves?   | <input type="checkbox"/> |
| 4.4.1 f i               | Can you describe reflection, refraction, polarisation, and diffraction of all waves?  | <input type="checkbox"/> |
| 4.4.1 f ii              | Can you list and describe techniques and procedures used to demonstrate wave effects using a ripple tank?                                     | <input type="checkbox"/> |
| 4.4.1 f iii             | Can you list and describe techniques and procedures used to observe polarising effects using microwaves and light?                            | <input type="checkbox"/> |
| 4.4.1 g                 | Can you describe and determine the intensity of a progressive wave using $I = \frac{P}{A}$ and intensity $\propto$ (amplitude) <sup>2</sup> ? | <input type="checkbox"/> |
| 4.4.2 a                 | Can you describe the electromagnetic spectrum and the properties of electromagnetic waves?  | <input type="checkbox"/> |

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 4.4.2 b                 | Can you describe the orders of magnitude of wavelengths of the principal radiations from radio waves to gamma rays?  | <input type="checkbox"/> |
| 4.4.2 c                 | Can you describe plane polarised waves and polarisation of electromagnetic waves?  | <input type="checkbox"/> |
| 4.4.2 d i               | Can you describe refraction of light with reference to the refractive index?   | <input type="checkbox"/> |
| 4.4.2 d i               | Can you carry out calculations using the refraction law $n \sin \theta = k$ ?  | <input type="checkbox"/> |
| 4.4.2 d ii              | Can you list and describe techniques and procedures used to investigate refraction and total internal reflection of light using ray boxes, and transparent rectangular and semi-circular blocks? | <input type="checkbox"/> |
| 4.4.2 e                 | Can you define and calculate the critical angle using $\sin C = \frac{1}{n}$ ?   | <input type="checkbox"/> |
| 4.4.2 e                 | Can you describe the conditions needed for total internal reflection to occur?   | <input type="checkbox"/> |

| Question   | Answers |
|--|---------|
| What is a progressive Wave                                     |         |
| Define displacement of a wave and state its unit               |         |
| Define the amplitude of a wave and state its unit              |         |
| Define the period of a wave and state its units                |         |
| Define the frequency of a waves and state its units            |         |
| State the relationship between frequency and period of a wave  |         |
| State the relationship between speed, frequency and wavelength |         |
| What is the phase of a particle on a wave                      |         |
| What is the phase difference between two particles on a wave   |         |
| What are the units that Phase Difference can be expressed in?  |         |
| State the equation for work out phase difference in radians    |         |

|   |  |
|---|--|
| What is a wave front?   |  |
| What are mechanical waves?  |  |
| Why are EM Waves not mechanical?                                      |  |
| Describe a longitudinal wave  |  |
| Describe a transverse wave  |  |
| Define Polarisation   |  |
| Describe a node on a stationary wave                                  |  |
| Describe an anti-node on a stationary wave                            |  |
| What is superposition?  |  |
| How is a stationary wave formed?                                      |  |
| What is the stationary wave called that forms at the lowest frequency |  |

## Questions

Q1.

Two students are carrying out an investigation to determine a value for the speed of sound in air.

They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval  $t$  between the two pieces of wood being hit and the echo being heard. The procedure is repeated. The students also measure the air temperature.

(a) Explain how a sound wave travels through air.

(2)

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(b) The students repeat the investigation on a different day. The results are shown in the table.

|       | temperature / °C | $t_1$ / s | $t_2$ / s | $t_3$ / s | mean $t$ / s |
|-------|------------------|-----------|-----------|-----------|--------------|
| Day 1 | 12               | 0.51      | 0.43      | –         | 0.47         |
| Day 2 | 18               | 0.44      | 0.69      | 0.48      | 0.46         |

(i) Deduce why the students thought it necessary to make a third measurement on day 2.

(1)

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(ii) Calculate the percentage uncertainty in the mean value of time on day 1.

(2)

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Percentage uncertainty = .....

(iii) Calculate the difference in the value for the speed of sound between day 1 and day 2 obtained from these results.

(2)

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Difference in speed = .....

(iv) The students state that the difference in the speed of sound between day 1 and day 2 is due to the change in air temperature.

Explain whether the results obtained are sufficient for this statement to be made.

(2)

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**(Total for question = 9 marks)**

Q2. Analysing the light from a star allows elements present in its outer atmosphere to be identified because each element produces a distinctive set of spectral lines.

\*(a) Describe how a spectral line is produced by a hot gas, explaining why a particular element can only give rise to particular frequencies.

(6)



(c) Suggest what the phenomena in parts (a) and (b) imply about the nature of light.

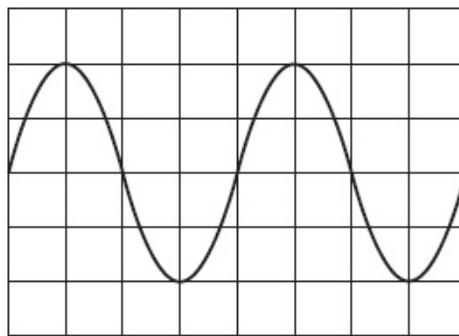
(1)

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**(Total for Question = 10 marks)**

Q3.

A particular sound is investigated by connecting a microphone to an oscilloscope. The diagram shows the trace of a sound wave on the oscilloscope. The screen of the oscilloscope has a grid on it. On the x-axis 1 division represents 5 ms.



The frequency of the sound wave is

- A** 0.05 Hz
- B** 0.1 Hz
- C** 50 Hz
- D** 100 Hz

**(Total for question = 1 marks)**

Q4.

The length of the string is 4 m.  
What is the wavelength of the stationary wave?

- A** 1 m
- B** 2 m
- C** 4 m
- D** 8 m

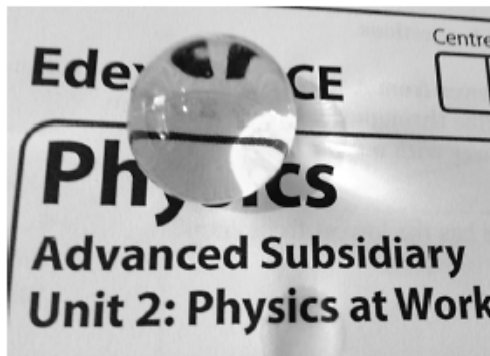
(Total for question = 1 mark)

Q5.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

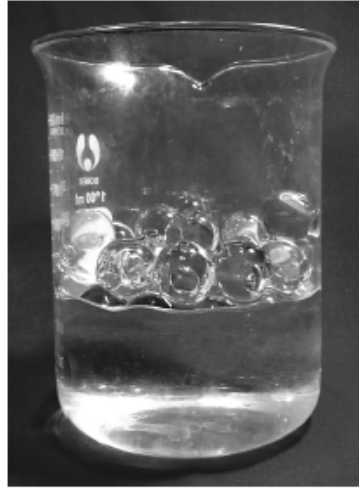
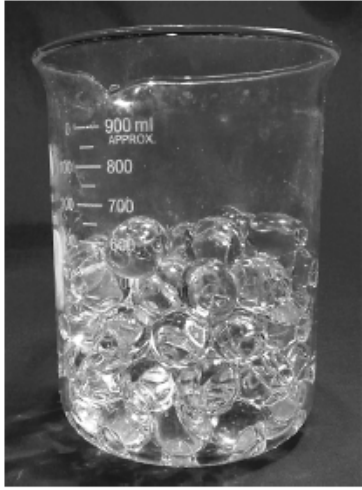
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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.



Explain how this shows that the gel has the same refractive index as water.

(2)

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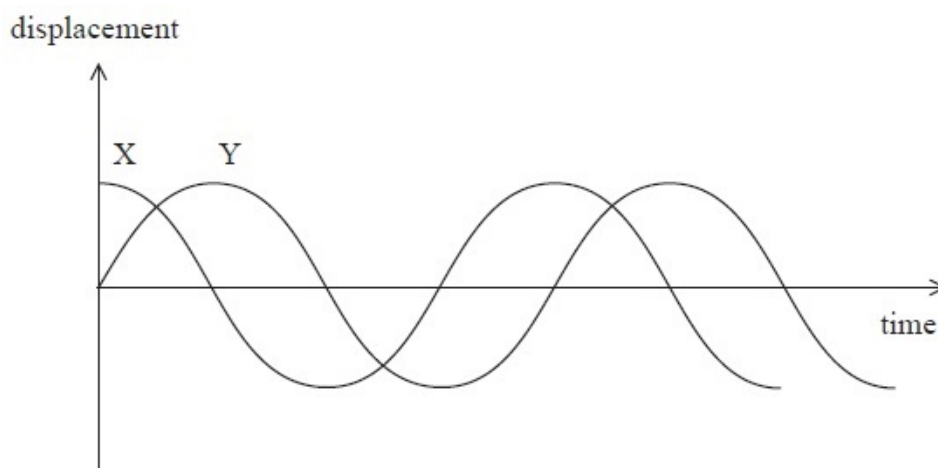
Q6.

Which of the following does **not** apply to longitudinal waves?

- A** coherence
- B** polarisation
- C** superposition
- D** transmission

**(Total for question = 1 mark)**

Q7. The diagram shows displacement-time graphs for two oscillations, X and Y.

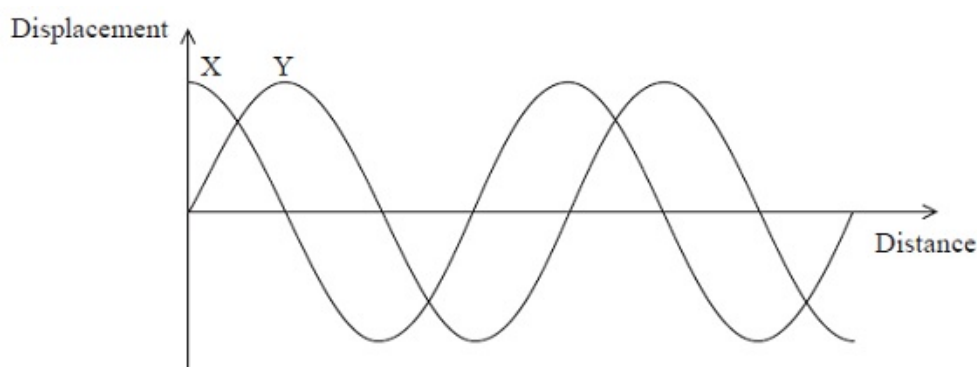


Which of the following statements correctly describes their phase relationship?

- A** X and Y are in antiphase
- B** X and Y are in phase
- C** X is  $\pi/2$  radians ahead of Y
- D** Y is  $\pi/2$  radians ahead of X

**(Total for Question = 1 mark)**

Q8. The diagram shows a displacement-distance graph at an instant for two waves, X and Y, travelling to the right.



Which of the following statements correctly describes the phase relationship between the two waves?

- A** X and Y are in antiphase
- B** X and Y are in phase
- C** X is  $\pi/2$  radians ahead of Y
- D** Y is  $\pi/2$  radians ahead of X

Q9.

An ultrasonic distance estimator can be used to measure the length of a room.



The estimator is held against one wall. It emits pulses of ultrasound and detects them when they return after reflection by the opposite wall.

(a) Explain why the ultrasound must be emitted in pulses.

(1)

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(b) The shortest distance the estimator can measure is 40 cm. Calculate the longest pulse duration that would allow this distance to be measured.

speed of ultrasound in air =  $330 \text{ m s}^{-1}$

(3)

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Pulse duration = .....

(c) When the estimator is pointed at a sloping wall, as shown in the photograph, it is unable to measure this distance.



Suggest why the estimator is unable to measure the distance to the sloping wall.

(1)

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**(Total for question = 5 marks)**

Q10. When light rays enter the Earth's atmosphere from space they undergo refraction. This can lead to a star appearing to be in a different position from its actual position.

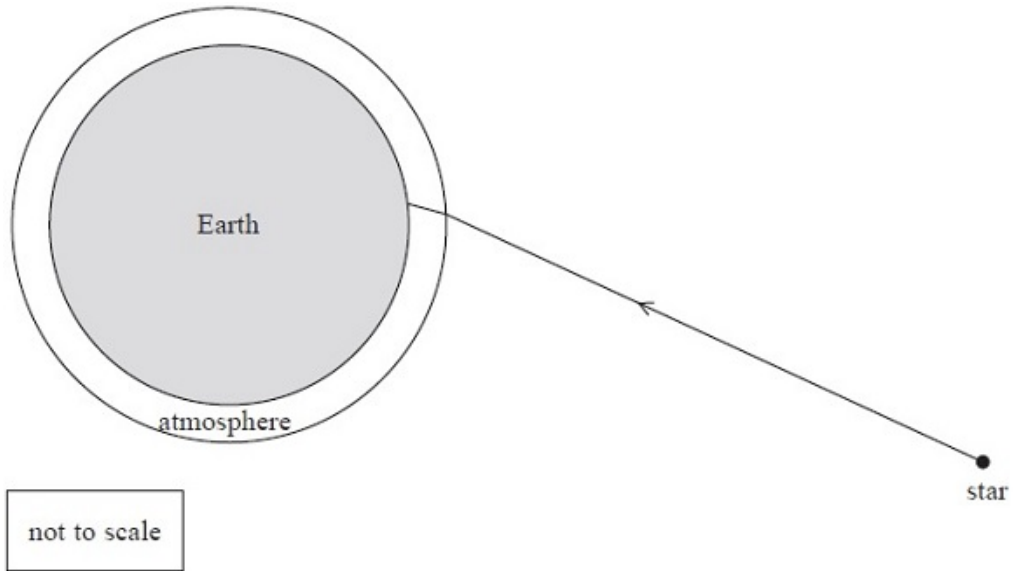
(a) Explain what is meant by refraction and why it occurs for light entering the Earth's atmosphere.

(3)

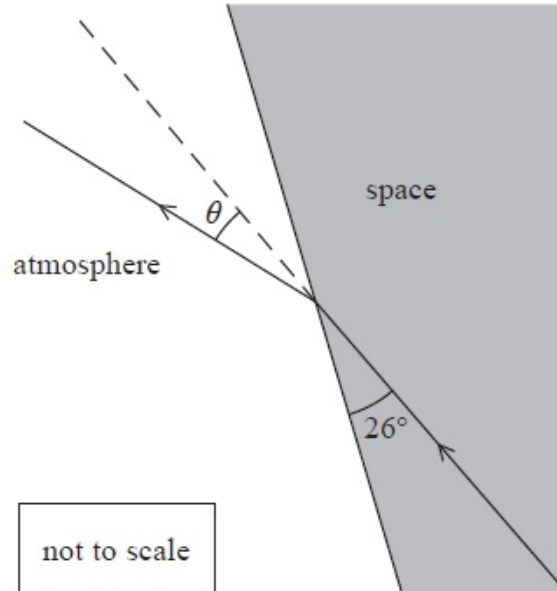
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(b) The diagram shows a ray of light from a star reaching the Earth's surface.



The diagram shows in more detail the ray of light as it enters the atmosphere.



Calculate the change in direction  $\theta$  of the ray.

refractive index of atmosphere = 1.001

(4)

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 $\theta = \dots\dots\dots$

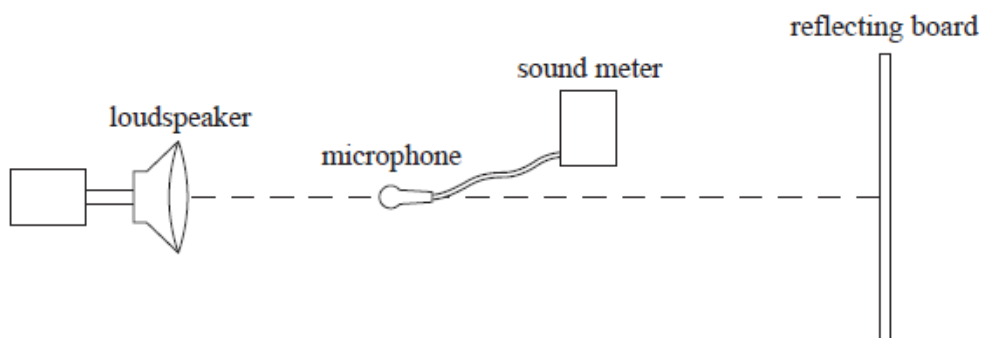
**(Total for Question = 7 marks)**

Q11.

Two students are carrying out an investigation to determine a value for the speed of sound in air.

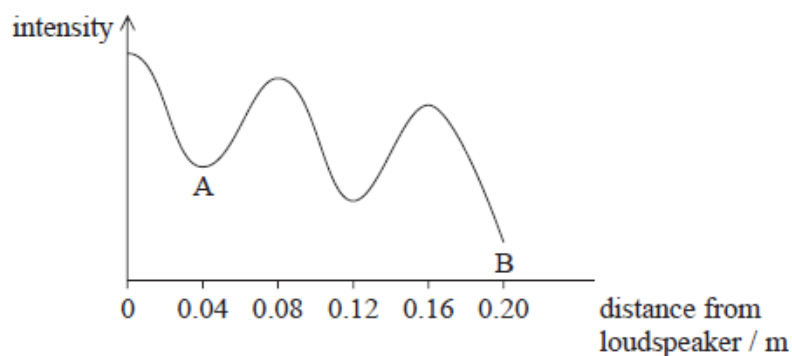
They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval  $t$  between the two pieces of wood being hit and the echo being heard. The procedure is repeated. The students also measure the air temperature.

A method to determine a value for the speed of sound is shown in the diagram.



A loudspeaker is placed at a distance from a vertical reflecting board. Sound waves reflect off the board and set up a standing wave between the loudspeaker and the board. A microphone connected to a sound meter is moved in a straight line from the loudspeaker to the board. As the microphone is moved, the sound meter records the varying intensity of the standing wave.

The sketch graph shows how the intensity varies with distance from the loudspeaker.



(i) Explain why the intensity at point B is less than the intensity at point A.

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(ii) Use the graph to determine a value for the speed of sound.

frequency of sound wave = 2.0 kHz

(3)

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Speed of sound = .....

**(Total for question = 6 marks)**

Q12.

A glass tube, closed at one end, has a loudspeaker placed at the other end. This is used to

create a vibrating column of air, producing sound.

The wave in the tube is best described as

- A** longitudinal and progressive.
- B** longitudinal and standing.
- C** transverse and progressive.
- D** transverse and standing.

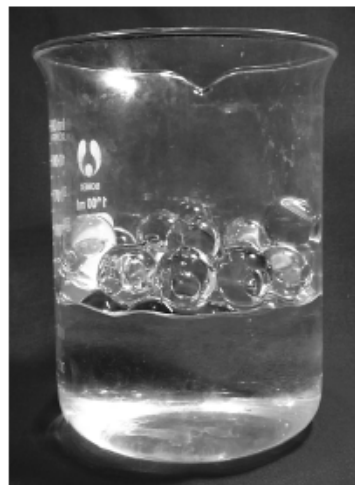
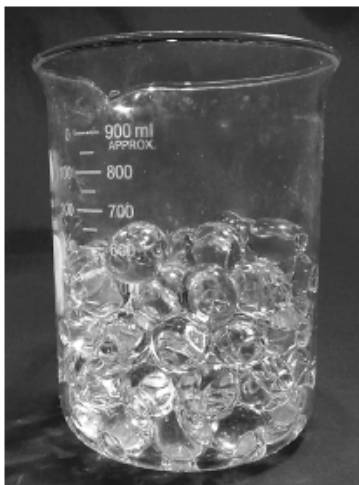
**(Total for question = 1 mark)**

Q13.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.



(a) A student decides to use a gel ball to model the formation of a rainbow by raindrops. He wants to see if total internal reflection occurs.

Explain what is meant by total internal reflection.

(2)

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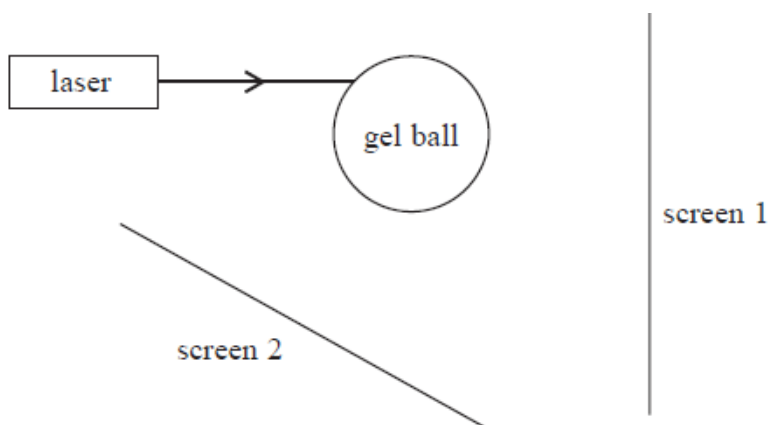
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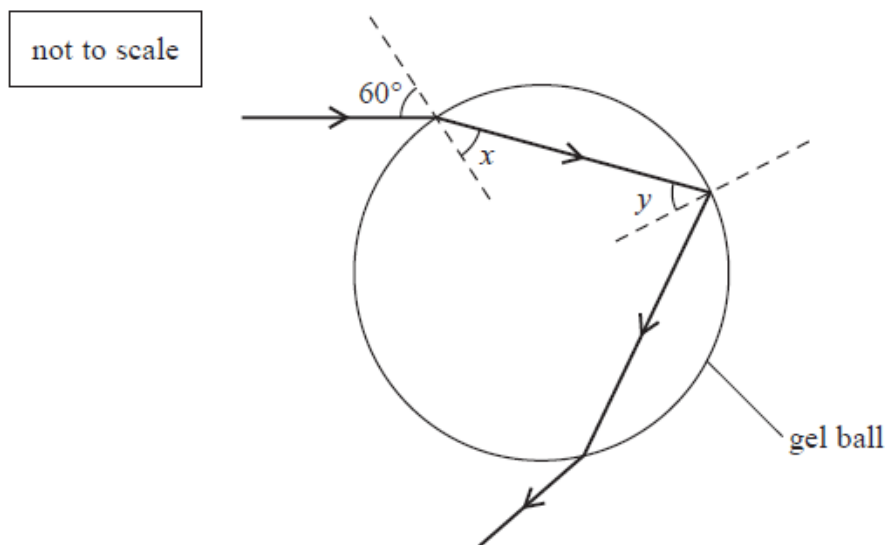
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(b) The student shines a narrow laser beam at a gel ball using the arrangement shown.



When the angle of incidence of the laser beam with the gel ball is  $60^\circ$ , light from the laser illuminates screen 2 following the path shown.



(i) Show that the angle  $x$  is about  $40^\circ$ .

refractive index of gel = 1.33

(2)

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(ii) Show that the critical angle for light striking the boundary of gel with air is about  $50^\circ$ .

(2)

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(iii) Angle  $x$  has the same value as angle  $y$ .  
Explain whether light from the laser will be observed on screen 1.

(2)

Q14.

Which of the following wave properties is **not** exhibited by sound waves?

(1)

- A** diffraction
- B** interference
- C** polarisation
- D** refraction

(Total for question = 1 mark)

Q15.

The diagram represents a stationary wave on a string.



Which diagram correctly shows the position of nodes N and/or antinodes A?



(Total for question = 1 mark)

Q16.

In February 2013 the largest known meteor for a century exploded over the Ural region of Russia.

The explosion was detected by stations monitoring infrasound, a type of sound with a frequency

too low for humans to hear.

Describe how infrasound travels through the air.

(3)

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**(Total for question = 3 marks)**

Q17. Ultrasonic testing can be used for detecting corrosion inside metal pipes.

(a) Describe how the ultrasound travels through a metal.

(3)

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(b) A steel pipe was manufactured with a wall thickness of 4.0 cm.

After several years of use this pipe is tested for corrosion. A pulse of ultrasound is sent into the steel from the outer surface and the reflection from the inner surface is detected after a time of  $5.1 \times 10^{-6}$  s.

Determine whether the steel is corroded at this point.

speed of sound in steel =  $5900 \text{ m s}^{-1}$

(4)

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(c) In this technique the ultrasound is emitted as pulses.

Explain why pulses are used rather than a continuous wave and how the duration of the pulse affects the thickness of the pipe wall that can be accurately measured.

(3)

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**(Total for Question = 10 marks)**

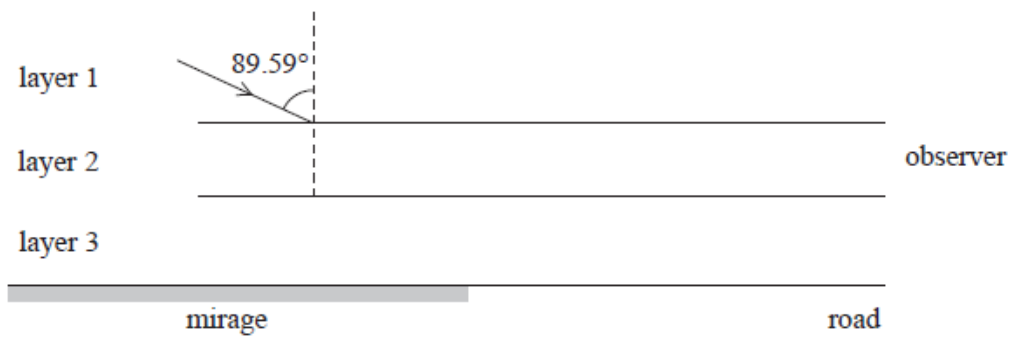
Q18.

On sunny days a mirage can sometimes be observed when a virtual image of the sky is seen on the surface of a road.



The Sun's rays heat up the surface of the road. The heated road then heats the surrounding air so that the layer of air just above the road is at a higher temperature than the air above it. Warm air has a lower refractive index than cool air.

The diagram represents a simple model which is sometimes used to explain how a mirage is formed. The three layers, each with a different refractive index, represent air at three different temperatures. Layer 3 represents the air at the highest temperature closest to the road. A light ray is shown incident at the interface between layer 1 and layer 2.



|         | refractive index |
|---------|------------------|
| layer 1 | 1.00032          |
| layer 2 | 1.00030          |
| layer 3 | 1.00028          |

critical angle for light travelling from layer 1 to layer 2 =  $89.64^\circ$   
 critical angle for light travelling from layer 2 to layer 3 =  $89.64^\circ$

Use the information to discuss whether the observer sees a mirage on the road in the position shown.

(6)

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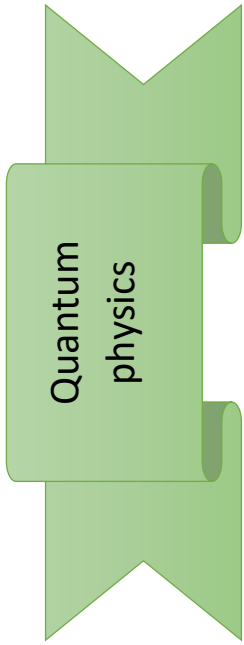
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# Week 4





## Quantum physics

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 4.5.1 a                 | Can you explain the particulate nature (photon model) of electromagnetic radiation?                            | <input type="checkbox"/> |
| 4.5.1 b                 | Can you define a photon as a quantum of energy of electromagnetic radiation?                                   | <input type="checkbox"/> |
| 4.5.1 c                 | Can you describe and calculate the energy of a photon using $E = hf$ and $E = \frac{hc}{\lambda}$ ?            | <input type="checkbox"/> |
| 4.5.1 d                 | Can you define the electronvolt (eV) as a unit of energy?  | <input type="checkbox"/> |
| 4.5.1 e i               | Can you use LEDs and the equation $eV = \frac{hc}{\lambda}$ to estimate the value of the Planck constant $h$ ? | <input type="checkbox"/> |
| 4.5.1 e ii              | Can you determine the Planck constant using different coloured LEDs?   | <input type="checkbox"/> |
| 4.5.2 a i               | Can you explain the photoelectric effect, including a simple experiment to demonstrate this effect?            | <input type="checkbox"/> |
| 4.5.2 a ii              | Can you demonstrate the photoelectric effect using, for example, a gold-leaf electroscope and zinc plate?      | <input type="checkbox"/> |
| 4.5.2 b                 | Can you describe the one-to-one interaction between a photon and a surface electron?                           | <input type="checkbox"/> |
| 4.5.2 c                 | Can you explain Einstein's photoelectric equation $hf = \phi + KE_{\max}$ ?                                    | <input type="checkbox"/> |
| 4.5.2 d                 | Can you define work function and threshold frequency?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.5.2 e                 | Can you explain the idea that the maximum kinetic energy of the photoelectrons is independent of the intensity of the incident radiation?                             | <input type="checkbox"/> |
| 4.5.2 f                 | Can you explain the idea that a rate of emission of photoelectrons above the threshold frequency is directly proportional to the intensity of the incident radiation? | <input type="checkbox"/> |
| 4.5.3 a                 | Can you explain electron diffraction, including experimental evidence of this effect?   | <input type="checkbox"/> |
| 4.5.3 b                 | Can you describe diffraction of electrons travelling through a thin slice of polycrystalline graphite?  | <input type="checkbox"/> |
| 4.5.3 c                 | Can you use the de Broglie equation $\lambda = \frac{h}{p}$ ?   | <input type="checkbox"/> |

## Cosmology (the Big Bang)

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 5.5.3 a                 | Can you calculate distances measured in astronomical units, light-years, and parsecs?   | <input type="checkbox"/> |
| 5.5.3 b                 | Can you define stellar parallax?  | <input type="checkbox"/> |
| 5.5.3 c                 | Can you understand the equation relating the parallax $p$ in seconds of arc and the distance $d$ in parsec?   | <input type="checkbox"/> |
| 5.5.3 e                 | Can you explain the Doppler effect?   | <input type="checkbox"/> |
| 5.5.3 e                 | Can you describe the Doppler shift of electromagnetic radiation?  | <input type="checkbox"/> |
| 5.5.3 f                 | Can you demonstrate the Doppler equation for a source of electromagnetic radiation moving relative to an observer, $\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$ ? | <input type="checkbox"/> |
| 5.5.3 g                 | Can you demonstrate Hubble's law, $v \approx H_0 d$ , for receding galaxies?  | <input type="checkbox"/> |
| 5.5.3 h                 | Can you explain galactic red shift and the model of an expanding Universe?  | <input type="checkbox"/> |
| 5.5.3 i                 | Can you explain Hubble constant $H_0$ in $\text{km s}^{-1} \text{Mpc}^{-1}$ and $\text{s}^{-1}$ ?   | <input type="checkbox"/> |
| 5.5.3 j                 | Can you explain the Big Bang theory?  | <input type="checkbox"/> |
| 5.5.3 k                 | Can you describe the experimental evidence for the Big Bang theory from microwave background radiation?   | <input type="checkbox"/> |
| 5.5.3 l                 | Can you explain the idea that the Big Bang gave rise to the expansion of space-time?  | <input type="checkbox"/> |
| 5.5.3 m                 | Can you explain the estimation of the age of the Universe?  | <input type="checkbox"/> |

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 5.5.3 m                 | Can you demonstrate that $t \approx H_0^{-1}$ ?  | <input type="checkbox"/> |
| 5.5.3 n                 | Can you describe the evolution of the Universe after the Big Bang to the present?  | <input type="checkbox"/> |
| 5.5.3 o                 | Can you explain current ideas about the composition of the Universe in terms of dark energy, dark matter, and a small percentage of ordinary matter? | <input type="checkbox"/> |

**OCR Physics A**

**Stars**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 5.5.1 a                 | Can you explain the terms planets, planetary satellites, comets, solar systems, galaxies, and the Universe?  | <input type="checkbox"/> |
| 5.5.1 b                 | Can you describe the formation of a star from interstellar dust and gas in terms of gravitational collapse, fusion of hydrogen into helium, radiation, and gas pressure? | <input type="checkbox"/> |
| 5.5.1 c                 | Can you describe the evolution of a low-mass star like our Sun into a red giant and white dwarf?   | <input type="checkbox"/> |
| 5.5.1 c                 | Can you define a planetary nebula?   | <input type="checkbox"/> |
| 5.5.1 d                 | Can you describe the characteristics of a white dwarf; electron degeneracy pressure; and the Chandrasekhar limit?  | <input type="checkbox"/> |
| 5.5.1 e                 | Can you explain the evolution of a massive star into a red supergiant and then either a neutron star or black hole; and a supernova?                                     | <input type="checkbox"/> |
| 5.5.1 f                 | Can you describe the characteristics of neutron stars and black holes?   | <input type="checkbox"/> |
| 5.5.1 g                 | Can you understand the Hertzsprung–Russell (HR) diagram as luminosity–temperature plot?  | <input type="checkbox"/> |
| 5.5.1 g                 | Can you explain the main sequence, red giants, red supergiants, and white dwarfs?  | <input type="checkbox"/> |
| 5.5.2 a                 | Can you calculate the energy levels of electrons in isolated gas atoms?  | <input type="checkbox"/> |
| 5.5.2 b                 | Can you explain the idea that energy levels have negative values?  | <input type="checkbox"/> |
| 5.5.2 c                 | Can you describe emission spectral lines from hot gases in terms of transition of electrons between discrete energy levels and emission of photons?                      | <input type="checkbox"/> |

**OCR Physics A**

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 5.5.2 d                 | Can you demonstrate the equations $hf = \Delta E$ and $\frac{hc}{\lambda} = \Delta E$ ?   | <input type="checkbox"/> |
| 5.5.2 e                 | Can you explain that different atoms have different spectral lines, which can be used to identify elements within stars?                        | <input type="checkbox"/> |
| 5.5.2 f                 | Can you describe continuous spectra, emission line spectra, and absorption line spectra?  | <input type="checkbox"/> |
| 5.5.2 g                 | Can you demonstrate the use of a transmission diffraction grating to determine the wavelength of light?   | <input type="checkbox"/> |
| 5.5.2 h                 | Can you understand the condition for maxima $d \sin \theta = n\lambda$ , where $d$ is the grating spacing?                                      | <input type="checkbox"/> |
| 5.5.2 i                 | Can you demonstrate the use of Wien's displacement law $\lambda_{\max} \propto \frac{1}{T}$ to estimate the peak surface temperature of a star? | <input type="checkbox"/> |
| 5.5.2 j                 | Can you calculate the luminosity $L$ of a star using Stefan's law $L = 4\pi r^2 \sigma T^4$ , where $\sigma$ is the Stefan constant?            | <input type="checkbox"/> |
| 5.5.2 k                 | Can you demonstrate the use of Wien's displacement law and Stefan's law to estimate the radius of a star?                                       | <input type="checkbox"/> |

## Photons and Wave-particle Duality

|   |   |
|---|---|
| What determines the energy of a photon?                             | The frequency/wavelength  |
| What is a photon?   | A quantum of energy of electromagnetic radiation  |
| How do you calculate the energy of a photon?                        | $E = hf$ OR $E = hc/\lambda$  |
| What is an electron volt?   | The energy gained or lost by an electron passing through a potential difference of 1V                             |
| How do convert from eV to J?  | multiply by $1.6 \times 10^{-19}$   |
| How do convert from J to eV?  | divide by $1.6 \times 10^{-19}$   |
| What is the threshold p.d. of an LED?                               | The minimum potential difference required for the LED to produce light.   |
| How can the threshold p.d. of an LED be used to find photon energy? | The energy transferred by the electrons ( $e \times V$ ) is equal to the energy of the photons produced ( $hf$ ). |
| What is meant by wave particle duality?                             | It describes how all matter can display both wave and particle properties.  |
| What is the key piece of evidence for wave particle duality?        | When an electron beam passes through polycrystalline graphite it produces a diffraction and interference pattern. |
| What does the De Broglie wave equation apply to?                    | Everything  |
| What is the relationship between momentum and wavelength?           | Inverse proportionality   |

## The Photoelectric Effect

|  |   |
|--|---|
| What is the photoelectric effect?  | The emission of electrons from a metal surface when illuminated with light.   |
| What is the atomic structure of a metal?   | A lattice of positive ions surrounded by a sea of free electrons.   |
| What is a photoelectron?   | An electron that has been removed from a metal by absorbing a photon  |
| What is the work function?   | The minimum energy required to remove an electron from the surface of a metal   |
| What is the threshold frequency?   | The minimum frequency of light required to produce photoelectrons from a metal  |
| What is monochromatic light  | Light of a single frequency/wavelength  |
| What is the relationship between work function and threshold frequency?                                    | $\phi = hf_0$   |
| What is required for a photon to be able to produce photoelectrons?  | Its frequency is greater than the threshold frequency   |
| Why can't light sources below the threshold frequency produce photoelectrons?                              | The photon energy is less than the work function  |
| How do photons and electrons interact?   | A single photon can be absorbed/emitted by a single electron which gains/loses the energy of the photon.                                |
| What is the effect on an electron of absorbing a photon?   | The electron gains the energy of the photon   |
| What effect does increasing the frequency of a monochromatic light source have on photoelectrons produced? | Photoelectrons will have a greater maximum kinetic energy   |
| What is the effect of increasing the intensity of a monochromatic light source on photoelectrons produced? | More photoelectrons will be produced but they will have the same maximum kinetic energy   |
| Why does the kinetic energy of photoelectrons from monochromatic light vary in the photoelectric effect?   | The work function is a minimum energy. Some electrons are liberated from deeper into the metal and require more energy to be liberated. |

|  |   |
|--|---|
| What two factors that determine the maximum kinetic energy of photoelectrons?                                | The frequency of the light and the work function of the metal |
| What determines the rate at which energy is delivered by a wave?   | Intensity/amplitude of the wave                               |
| What is $hf$ in Einstein's photoelectric effect equation ( $hf = \phi + KE(\max)$ )                          | The energy of the incident photon.                            |
| What is $\phi$ in Einstein's photoelectric effect equation ( $hf = \phi + KE(\max)$ )                        | The work function of the metal.                               |
| What is $KE(\max)$ in Einstein's photoelectric effect equation ( $hf = \phi + KE(\max)$ )                    | The maximum kinetic energy of the photoelectrons              |
| According to the wave model how is energy transferred from light to electrons in a metal?                    | It is delivered continuously and builds up over time          |
| If light is above the threshold frequency, how long will it take for photoelectrons to start being produced? | It is instantaneous   |
| What happens if very intense light that is below the threshold frequency is used?                            | No photoelectrons are produced, regardless of intensity.      |

**Big ideas you need to know about – make sure you can summarise your understanding of these below using correct terminology:**

A – What does it mean when we say something is quantised? What does quantum theory mean in terms of our understanding of the nature of light and how light interacts with matter?

B - Huygen's argued that light is a wave but actually...

C - It used to be believed that Electrons are particles. In reality...

D –What is wave particle duality? Describe a key demonstration that provides evidence of it and explain why we don't we notice it in our day to day lives?

E – State the main observations from the Photoelectric effect.

F - Describe how the photon model of light explains these observations.

G- Describe how these observations contradict a wave model of light.

## Questions

Q1.

Helium was first discovered because of dark lines observed in the continuous spectrum of light from the Sun. The lines were caused by a few specific frequencies of light in the spectrum being present at very much lower intensity than the rest.

Scientists deduced that this was due to an unknown element in the Sun's atmosphere.

(a) Explain how helium in the Sun's atmosphere caused this set of dark lines.

(5)

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(b) The diagram shows some of the energy levels for an atom of another element.

$n = 5$  —————  $-0.38 \text{ eV}$

$n = 4$  —————  $-0.55 \text{ eV}$

$n = 3$  —————  $-0.85 \text{ eV}$

$n = 2$  —————  $-1.51 \text{ eV}$

$n = 1$  —————  $-3.41 \text{ eV}$

(i) Determine which energy levels are associated with photons of frequency  $4.6 \times 10^{14} \text{ Hz}$ .

(4)

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(ii) Suggest why the energy levels all have a negative value.

(2)

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(c) Lines such as those described in (a) can be used to determine the motion of stars relative to

the Earth.

Suggest how these lines may be used to determine the motion of stars.

(3)

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**(Total for question = 14 marks)**

Q2.

In the 1920s Louis de Broglie proposed that an electron could behave as a wave.

Calculate the wavelength of an electron that is travelling at a speed of  $2.2 \times 10^7 \text{ms}^{-1}$ .

(3)

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Wavelength = .....

**(Total for question = 3 marks)**



**(Total for question = 6 marks)**

Q4.

Which variables are linked in the de Broglie equation?

- A** frequency and wavelength of a photon
- B** wavelength and momentum of a moving electron
- C** energy and frequency of a photon
- D** work function and threshold frequency of a metal

**(Total for question = 1 mark)**

Q5. The de Broglie wavelength for neutrons used to study crystal structure is 1.2 nm. mass of a neutron =  $1.67 \times 10^{-27}$  kg

The speed of these neutrons would be

- A**  $3.0 \times 10^6 \text{ m s}^{-1}$
- B**  $3.3 \times 10^2 \text{ m s}^{-1}$
- C**  $3.0 \times 10^{-3} \text{ m s}^{-1}$
- D**  $3.3 \times 10^{-7} \text{ m s}^{-1}$

**(Total for Question = 1 mark)**

Q6. The de Broglie wavelength associated with electrons moving at  $2.5 \times 10^6 \text{ m s}^{-1}$  is

- A**  $2.9 \times 10^{-4} \text{ m}$
- B**  $2.4 \times 10^{-8} \text{ m}$
- C**  $2.9 \times 10^{-10} \text{ m}$

D  $2.4 \times 10^{-39}$  m

**(Total for Question = 1 mark)**

Q7.

The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of  $10^{-10}$  m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is  $1.00 \times 10^{-10}$  m.

**(3)**

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Speed = .....

(ii) Calculate the kinetic energy of this electron in electronvolts.

**(3)**

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Kinetic energy = ..... eV

(b) When  $\beta$  radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

**(2)**

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**(Total for question = 8 marks)**

Q8.

(a) State what is meant by the de Broglie wavelength.

(2)

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(b) An electron is accelerated from rest, in a vacuum, through a potential difference of 500 V.

(i) Show that the final momentum of the electron is about  $1 \times 10^{-23}$  N s.

(3)

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(ii) Calculate the de Broglie wavelength for this electron.

(2)

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de Broglie wavelength = .....

**(Total for question = 7 marks)**

Q9.

In the 19th century experiments with magnetic and electric field deflections were used to determine the charge to mass ratio of electrons.  
Later experiments showed the diffraction of electrons as they passed through thin metal foils.  
Deduce what these experiments tell us about electrons.

(3)

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**(Total for question = 3 marks)**

Q10.

When electromagnetic radiation is incident on a metal plate, electrons may be emitted.

(a) State what is meant by threshold frequency.

(1)

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(b) Calculate the threshold frequency for a metal with a work function of 2.28 eV.

(3)

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Threshold frequency = .....

**(Total for question = 4 marks)**

Q11.

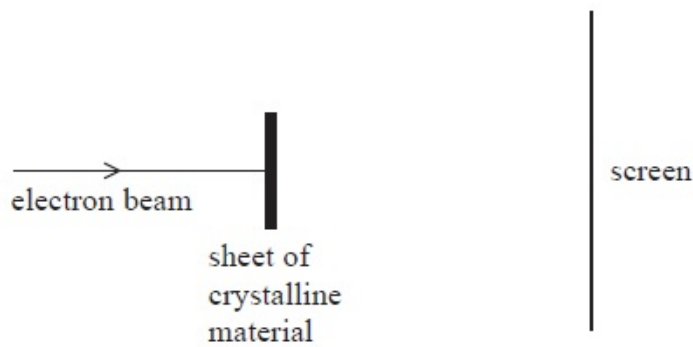
A beam of electrons spreads out into several distinct beams after passing through a crystalline material.

This demonstrates that

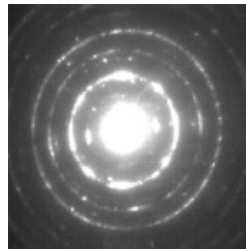
- A** electrons behave as particles.
- B** electrons behave as waves.
- C** electrons exist in energy levels.
- D** electrons have negative charge.

**(Total for question = 1 mark)**

Q12. A beam of electrons is directed towards a section of crystalline material.



The following pattern is produced by the electrons on the screen.

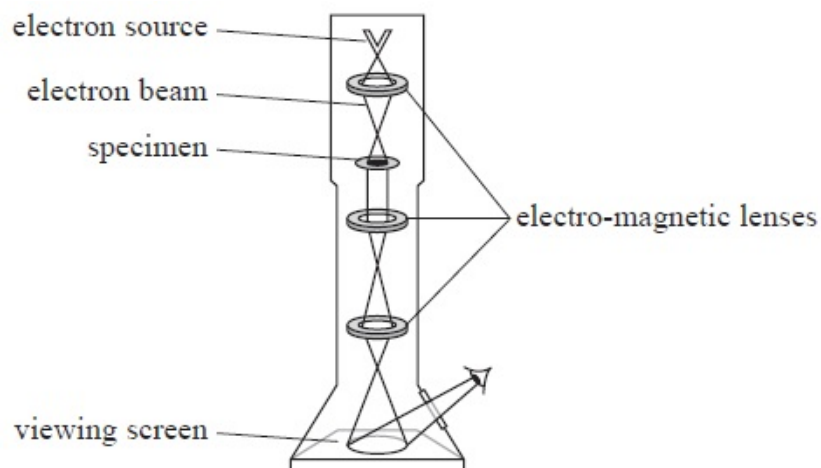


This pattern demonstrates

- A** diffraction.
- B** polarisation.
- C** reflection.
- D** refraction.

**(Total for Question = 1 mark)**

Q13. A transmission electron microscope passes a beam of electrons through a tiny specimen to form an image on a viewing screen.

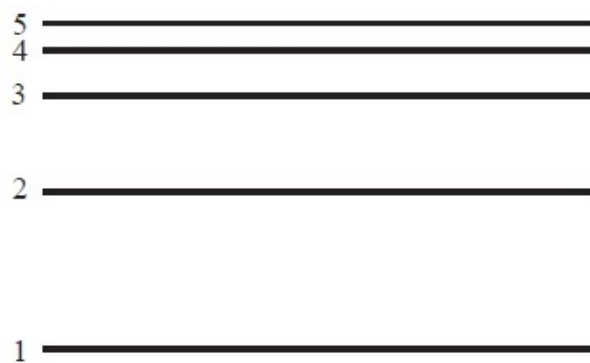


Due to the wave nature of electrons, diffraction occurs which can blur the image. To reduce this effect when viewing a smaller object the beam must contain

- A** more electrons per second.
- B** fewer electrons per second.
- C** faster moving electrons.
- D** slower moving electrons.

**(Total for Question = 1 mark)**

Q14. The diagram shows five energy levels in an atom.



Electromagnetic radiation is incident on the atom.

Which transition would be caused by the absorption of the lowest frequency of radiation?

- A** 1 to 5
- B** 1 to 2
- C** 4 to 5
- D** 5 to 4

**(Total for Question = 1 mark)**

Q15.

A helium-neon gas laser is often used in the laboratory as a source of high intensity, coherent, monochromatic light.

The diagram shows some of the energy levels above the ground level  $E_3$  for helium atoms and for neon atoms. The highest shown levels for helium atoms and neon atoms are almost identical.

$E_2$  ————— 20.61 eV

$E_3$  ————— 20.66 eV

$E_2$  ————— 18.70 eV

$E_1$  ————— 0 eV

helium

$E_1$  ————— 0 eV

neon

Helium atoms in the gas are excited to level  $E_2$  by the current passing through the laser. They collide at high speed with neon atoms. Because the energies are so similar, the energy is transferred from the helium atoms to the neon atoms. The neon atoms become excited in turn to level  $E_3$ . As the neon atoms subsequently drop to level  $E_2$  they emit photons.

(a) Explain what is meant by a photon.

(2)

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(b) Calculate the frequency of the photons produced as the neon atoms drop from level  $E_3$  to level  $E_2$ .

(3)

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Frequency = .....

(c) An electron in level  $E_3$  of neon has 0.05 eV more energy than an electron in level  $E_2$  of helium.

Suggest the source of the energy to make up this difference.

(1)

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(d) The photograph shows a device for making a vertical slit with variable width.



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When the slit is fully open a laser beam is shone through it and a single point of light is seen on a screen.

As the slit is reduced in width the point of light becomes a horizontal line that gets longer as the slit gets narrower.

Explain this observation

(3)

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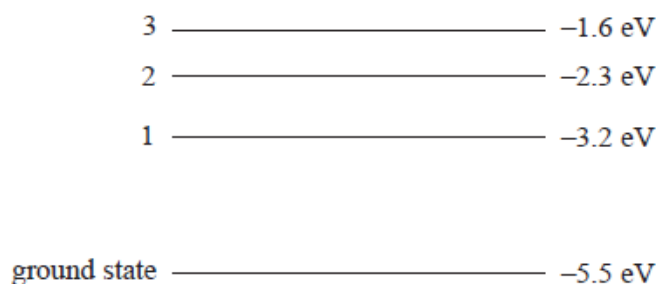
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**(Total for question = 9 marks)**

Q16.

The diagram shows the lowest energy levels for a certain atom.





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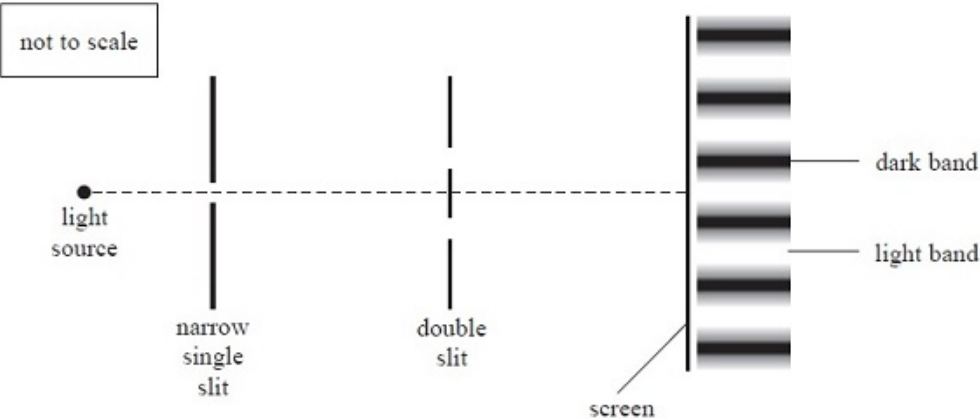
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**(Total for question = 6 marks)**

Q18. In the 17th century, Isaac Newton suggested that light was made up of very small particles which he called corpuscles.

Newton's theory was favoured in England throughout the 18th century because of his great reputation although scientists elsewhere applied the wave theory.

In 1801 Thomas Young demonstrated his double slit experiment. Monochromatic light from a narrow single slit was passed through a double slit and a pattern of light and dark bands was seen on a screen, as shown in the diagram.



\*(a) Explain how the light and dark bands are formed in the double slit experiment.

(4)

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(b) The observation of light and dark bands with the double slit experiment depends on the light from the slits being coherent.

Explain why coherence is necessary to observe the light and dark bands.

(2)

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(c) State why Young's experiment disproved Newton's corpuscular theory.

(1)

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**(Total for Question = 7 marks)**

Q19.

Barnard's star is a red dwarf star in the vicinity of the Sun. The wavelength of a line in the spectrum of light emitted from Barnard's star is measured to be 656.0 nm. The same light produced by a source in a laboratory has a wavelength of 656.2 nm.

Visible light from the star originates from the photosphere. In the photosphere of Barnard's star, hydrogen and helium atoms are at a temperature of 3100 K.

(i) Calculate the mean kinetic energy of an atom in the photosphere at a temperature of 3100 K.

(2)

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Mean kinetic energy = .....

(ii) Describe how these atoms emit visible light.

(2)

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**(Total for question = 4 marks)**

**Mark Scheme**

Q1.

## Questions

Q1.

Barnard's star is a red dwarf star in the vicinity of the Sun. The wavelength of a line in the spectrum of light emitted from Barnard's star is measured to be 656.0 nm. The same light produced by a source in a laboratory has a wavelength of 656.2 nm.

Calculate the velocity of Barnard's star relative to the Earth.

(3)

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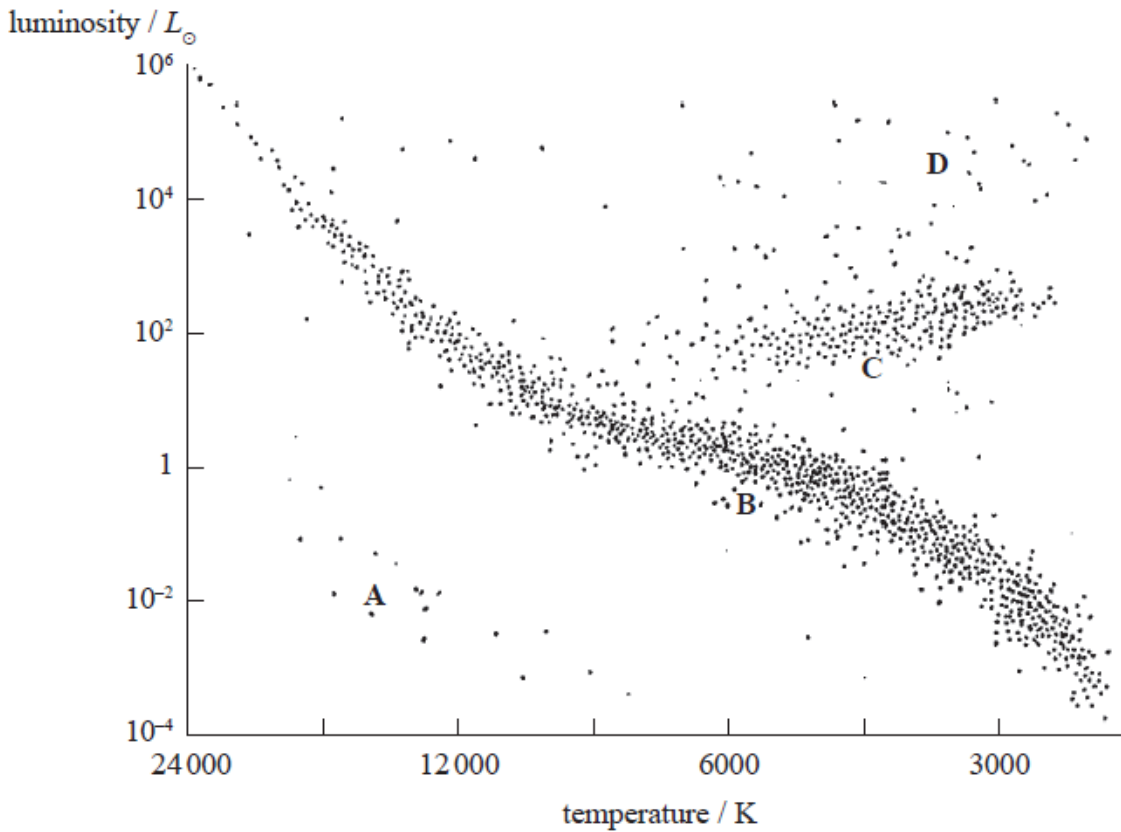
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Velocity = .....

**(Total for question = 3 marks)**

Q2.

Four regions **A**, **B**, **C** and **D** are labelled on the Hertzsprung-Russell diagram.



Which region includes the position of the Sun?

(1)

- A
- B
- C
- D

(Total for question = 1 mark)

Q3.

A line in the hydrogen spectrum of a star in the Milky Way galaxy is observed to have a wavelength of 656.3 nm. In a laboratory on Earth this line has a wavelength of 654.9 nm.

Which of the following expressions gives the magnitude of the velocity of the star relative to Earth?

(1)

A  $\frac{656.3}{654.9} \times 3 \times 10^8 \text{ms}^{-1}$

B  $\frac{654.9}{(656.3 - 654.9)} \times 3 \times 10^8 \text{ms}^{-1}$

C  $\frac{654.9}{656.3} \times 3 \times 10^8 \text{ms}^{-1}$

D  $\frac{(656.3 - 654.9)}{654.9} \times 3 \times 10^8 \text{ms}^{-1}$

**(Total for question = 1 mark)**

Q4.

The distance to astronomical objects relatively close to the Sun is determined using trigonometric parallax. For objects beyond a certain distance standard candles are used.

(a) State what is meant by a standard candle.

**(1)**

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(b) Explain why trigonometric parallax is not used beyond a certain distance.

**(2)**

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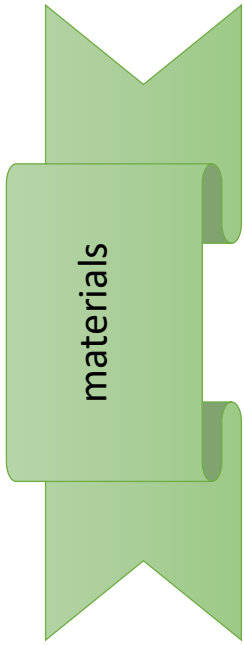
(c) Describe how distances too large for the use of standard candles can be determined.

**(3)**

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# Week 5





## Materials

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 3.4.1 a                 | Can you define and describe tensile and compressive deformation, and extension and compression?  | <input type="checkbox"/> |
| 3.4.1 b                 | Can you state Hooke's law?   | <input type="checkbox"/> |
| 3.4.1 c                 | Can you determine the force constant $k$ of a spring or wire using $F = kx$ ?  | <input type="checkbox"/> |
| 3.4.1 d i               | Can you sketch and interpret force–extension (or compression) graphs for springs and wires?  | <input type="checkbox"/> |
| 3.4.1 d ii              | Can you describe techniques and procedures used to investigate force–extension characteristics for arrangements which may include springs, rubber bands, and polythene strips? | <input type="checkbox"/> |
| 3.4.2 a                 | Can you use a force–extension (or compression) graph to determine the work done in extending (or compressing) the material?  | <input type="checkbox"/> |
| 3.4.2 b                 | Can you calculate elastic potential energy using $E = \frac{1}{2}Fx$ and $E = \frac{1}{2}kx^2$ ?   | <input type="checkbox"/> |
| 3.4.2 c                 | Can you define stress, strain, and ultimate tensile strength?  | <input type="checkbox"/> |
| 3.4.2 d i               | Can you calculate the Young modulus of a material using tensile stress and tensile strain?   | <input type="checkbox"/> |
| 3.4.2 d ii              | Can you describe techniques and procedures used to determine the Young modulus for a metal?  | <input type="checkbox"/> |
| 3.4.2 e                 | Can you interpret and sketch stress–strain graphs for typical ductile, brittle, and polymeric materials?   | <input type="checkbox"/> |
| 3.4.2 f                 | Can you describe elastic and plastic deformations of materials?  | <input type="checkbox"/> |



## Materials

|  |   |
|--|---|
| What is a tensile force?                                       | A force produces an extension of the object.  |
| What is a compressive force?                                   | A force that reduces the length of an object.   |
| What is Hooke's Law?   | Force is proportional to extension so long as the elastic limit is not exceeded.                      |
| What is elastic deformation?                                   | When an object will return to its original shape when the load is removed.                            |
| What is plastic deformation?                                   | A permanent change in shape that remains once the load is removed.                                    |
| What is k in $F = kx$  | The force constant.   |
| What are the units of force constant (k)                       | $\text{Nm}^{-1}$  |
| What is represented by the area under a force-extension graph? | The work done stretching the object.  |
| What is meant by an elastic material?                          | A material which can be significantly deformed and will return to its original shape.                 |
| What is tensile stress?  | The force applied per unit cross sectional area.  |
| What is tensile strain?  | The fractional change in length of an object.   |
| What is a ductile material?                                    | A material which can be drawn into a wire or hammered into thin sheets.                               |
| What is the limit of proportionality of a material?            | The point at which a material stops obeying Hooke's Law   |
| What is the elastic limit of a material?                       | The point at which a material starts to plastically deform.   |
| What is the yield point of a material?                         | The point at which the material starts to extend rapidly as stress increases.                         |
| What is the ultimate tensile strength of a material?           | The maximum stress a material can withstand before breaking.  |
| What is the breaking strength of a material?                   | The stress at the point of fracture.  |
| What is a strong material?                                     | One with a high ultimate tensile strength.  |
| What are the units of Young Modulus?                           | $\text{Pa}$ OR $\text{Nm}^{-2}$   |
| When does the Young Modulus apply to a material?               | When stress is proportional to strain OR when it is obeying Hooke's law                               |
| How do you find the Young Modulus from a stress-strain graph?  | The gradient of the initial straight line region.   |
| What material property does Young Modulus measure?             | The stiffness.  |
| What is a brittle material?                                    | A material that shows only elastic behaviour up to its breaking point, without plastically deforming. |
| What is a polymeric material?                                  | A material made from long chain molecules.  |

### Big ideas you need to know about – ensure you can summarise your understanding of these below using correct terminology:

A – Sketch a force-extension graph for a material that obeys Hooke's Law and state what is represented by the gradient and area under the graph.

B – Rubber exhibits a hysteresis loop, explain with the aid of a force extension graph what this means. What occurs in terms of energy when rubber is loaded and unloaded?

C – Why is it useful to consider stress and strain rather than just force and extension for a material?

## Questions

Q1.

A student is investigating a 'Cartesian diver'.

The diver is made from a plastic pipette. When placed in a plastic bottle full of water the diver rises to the top and touches the lid.



(a) Show that the downward force of the lid on the diver is about 0.02 N.

$$\text{volume of diver} = 8.0 \times 10^{-6} \text{ m}^3$$

$$\text{mass of diver} = 0.0059 \text{ kg}$$

$$\text{density of water} = 1.0 \times 10^3 \text{ kg m}^{-3}$$

(3)

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(b) When the pressure is increased by squeezing the bottle, water is forced into the diver increasing its weight. The diver sinks, then remains at rest in the position shown.



The volume of air in the empty pipette in part (a) was  $8.0 \times 10^{-6} \text{ m}^3$ .

Show that the volume now occupied by the air is about  $6 \times 10^{-6} \text{ m}^3$ .

(3)

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(c) The pressure of the air in the empty pipette in part (a) was  $1.01 \times 10^5 \text{ Pa}$ .

Calculate the pressure of the air in part (b).

(2)

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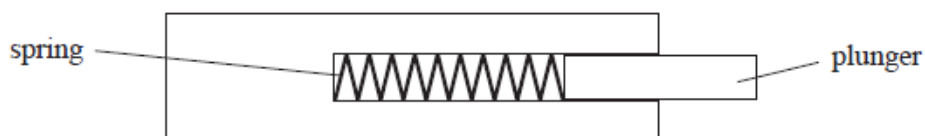
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Pressure = .....

**(Total for question = 8 marks)**

Q2.

A school dynamics trolley has a plunger attached to a spring. When the plunger is pushed in, the spring is compressed. When the plunger is released, it is pushed back out by the spring.



(a) A student investigated the spring to determine whether it obeys Hooke's law in compression.

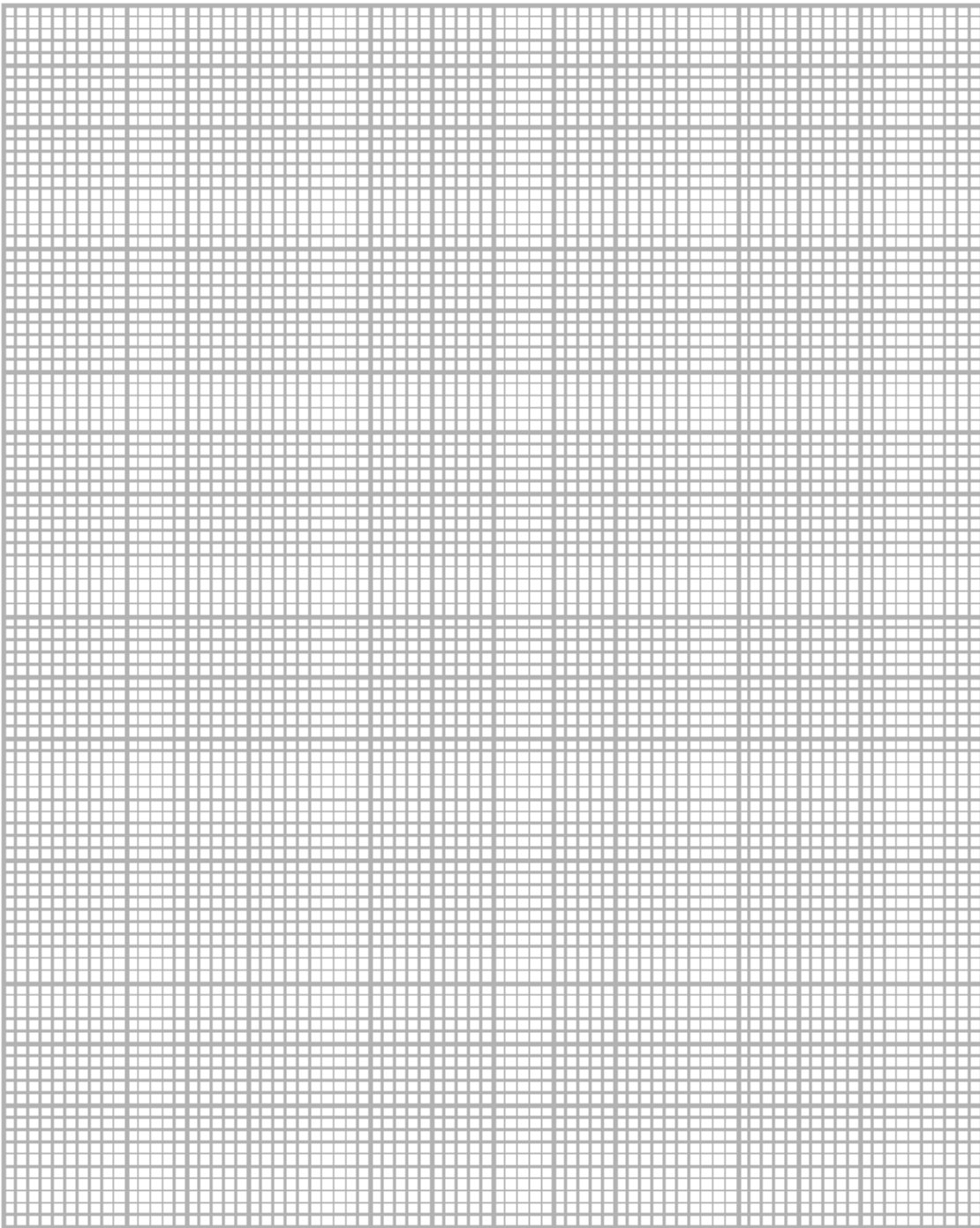
The trolley was placed vertically in front of a scale and weights were added in turn to the top of the plunger, as shown. The position of the end of the plunger was recorded each time.



The recorded results are shown in the table.

| Weight / N | Position of plunger / cm |  |
|------------|--------------------------|--|
| 0.00       | 37.3                     |  |
| 2.00       | 37.0                     |  |
| 4.00       | 36.6                     |  |
| 6.00       | 36.2                     |  |
| 8.00       | 35.9                     |  |
| 10.00      | 35.5                     |  |

(i) Use the results to plot a graph of weight against compression. You may use the additional column for your processed data.



(ii) The student concluded that the spring obeys Hooke's law with a spring constant of about  $600 \text{ N m}^{-1}$ .

Determine whether the student's conclusion is justified.

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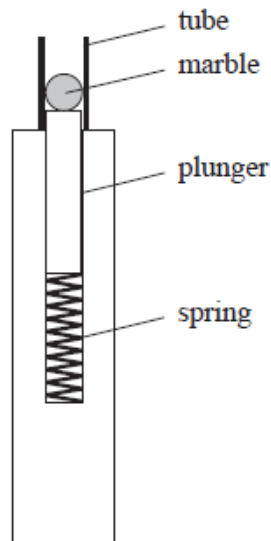
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(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



Determine the maximum possible launch velocity of the marble when the spring is compressed by 5.4 cm.

spring constant =  $610 \text{ N m}^{-1}$

mass of marble = 4.1 g

mass of plunger = 35.4 g

(4)

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Maximum launch velocity = .....

(c) The launch velocity was measured using a light gate and data logger. This produced a smaller value for the launch velocity than that calculated in (b).

Give a reason why this method produced a smaller value for the launch velocity.

(1)



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Viscosity of glycerol = .....

(ii) There are two cylinders available for the student to use. One cylinder has a diameter of 1.5 cm and the other has a diameter of 5.0 cm.

State and justify which cylinder the student should use in order to gain a more accurate value for the viscosity of glycerol.

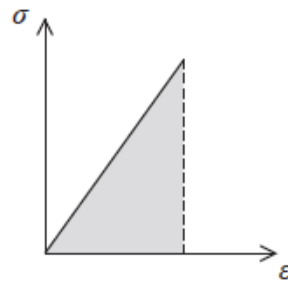
(2)

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**(Total for question = 6 marks)**

Q4.

A force was applied across the ends of an iron bar. The following stress-strain graph was obtained.



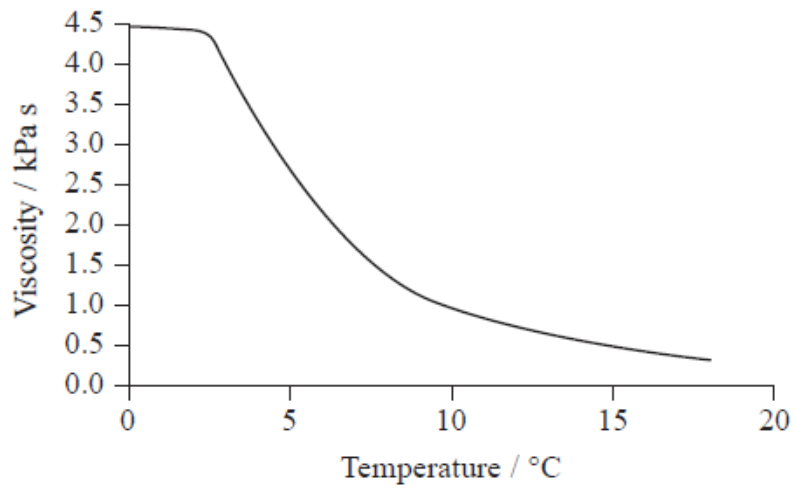
The shaded area represents

- A  $\frac{\text{work done}}{2 \times \text{volume}}$
- B  $\frac{\text{work done}}{\text{volume}}$
- C  $\frac{2 \times \text{work done}}{\text{volume}}$
- D work done

**(Total for question = 1 mark)**

Q5.

The graph shows the effect of temperature on viscosity for butter.



A student wants to spread butter on some bread.

Explain why it is easier to use butter at room temperature than straight from the fridge.

(2)

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**(Total for question = 2 marks)**

Q6.

Read the following article and then answer the questions that follow.

"The fastest, tallest and longest dive coaster, on which amusement park thrill seekers can experience free fall, is set to open next summer at Cedar Point in Sandusky, Ohio. Valravn is designed to take riders up to a 66 m peak from which they plummet vertically with an acceleration  $g$  and feel weightless.

The advent of steel-frame roller coasters in 1959 made taller structures possible.

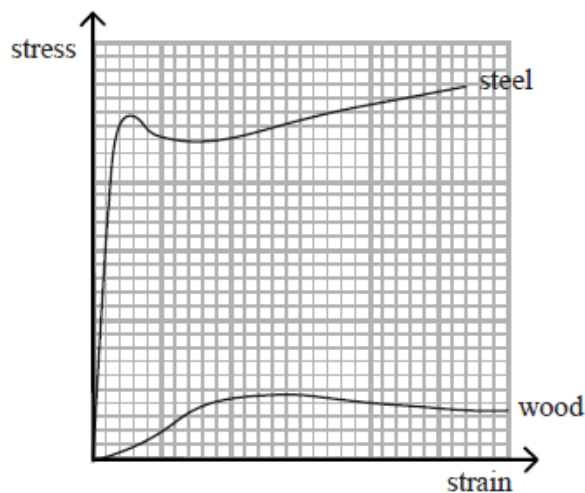
Whereas height remains one of the best ways to attain intense speeds, a coaster car can also be shot from its starting point via electromagnetic propulsion or a catapult. Cars on these launched coasters have the potential to go from zero to  $130 \text{ km h}^{-1}$  in two seconds.

Although coasters can definitely go faster, they're limited by the acceleration those higher speeds would require. Roller coasters reach their peak speeds in a matter of seconds. The achieved acceleration is what causes  $g$ -forces, which allows riders to feel an increased or decreased sense of their mass. These  $g$ -forces can be dangerous but they are also well understood by physicists, so roller coasters are built according to strict standards that keep them well within safe levels.

Coasters are only permitted to accelerate up to  $6g$ ."

(Source: *Shriek Science: Simple Physics Powers Extreme Roller Coasters* Hackett Jennifer, Oct 14, 2015)

The graph shows typical stress-strain curves for wood and steel.



Discuss how the use of steel, rather than wood, has made the construction of faster and taller roller coasters possible.

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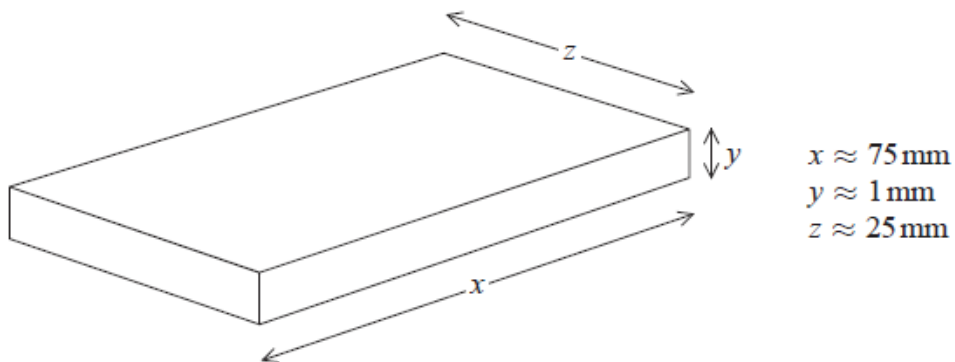
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**(Total for question = 5 marks)**

Q7.

A student carries out measurements to determine the density of glass. The student has 20 glass microscope slides available.

The approximate dimensions of one slide are shown.



(a) The density is calculated using the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Describe how the student can determine an accurate value for the density of the glass. Your answer should include the measuring instruments required.

**(4)**

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(b) State one precaution that the student should take to ensure the measurements are accurate.

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**(Total for question = 5 marks)**

Q8.

A spring obeys Hooke's law. A force of 2.0 N extends the spring by 0.30 m.

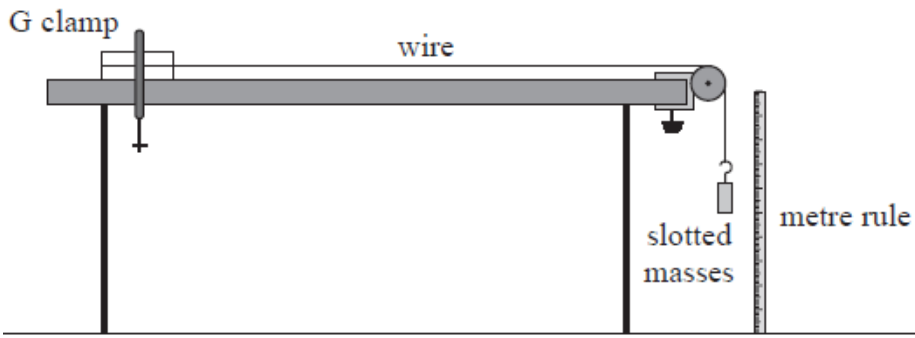
The energy stored in the spring when a force of 2.0 N is applied is

- A** 0.09 J
- B** 0.30 J
- C** 0.60 J
- D** 0.90 J

**(Total for question = 1 mark)**

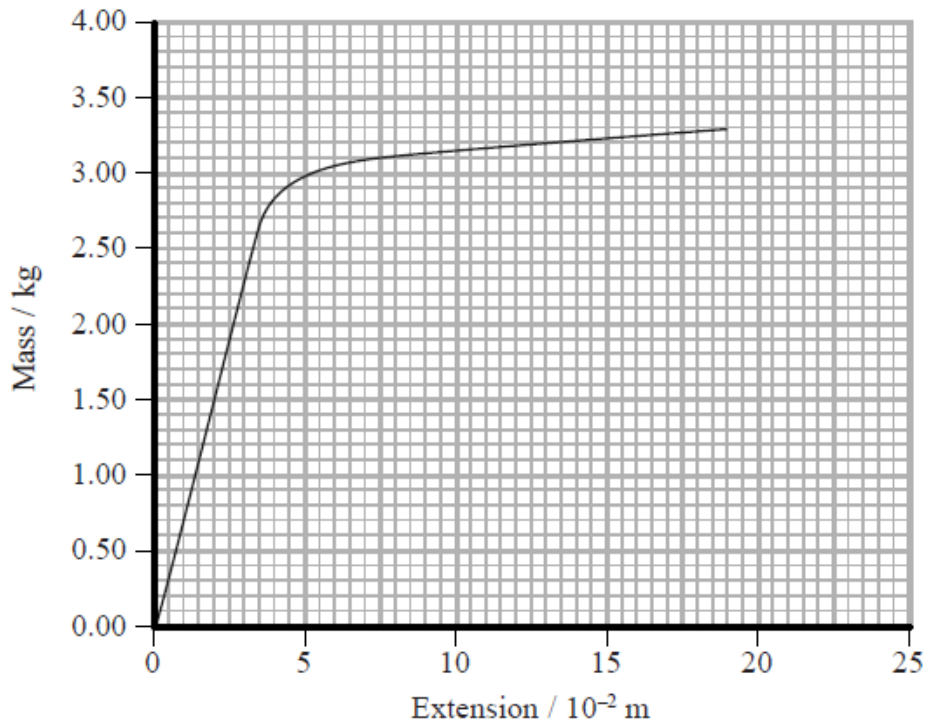
Q9.

The diagram shows the equipment a student used to investigate the behaviour of a material in the form of a wire under an increasing tension.



Masses were added up to a maximum of 3.30 kg. Each time a mass was added the extension of the wire was calculated.

(a) The following mass-extension graph was obtained.



(i) Initially the extension increased linearly.

State what is meant by 'increased linearly' in relation to this graph and what can be concluded about the wire from this observation.

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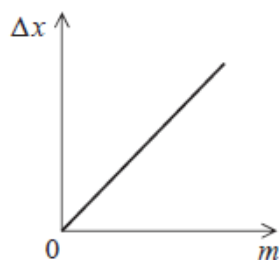
(ii) Use the graph to calculate the maximum energy that the wire could store while behaving linearly.

(3)



Q10.

A spring is hung vertically and masses are added to the lower end.  
The graph shows how the extension  $\Delta x$  of the spring varies with the mass  $m$  added.



The work done in extending the spring can be expressed as

(1)

- A  $mg\Delta x$
- B  $\frac{mg}{\Delta x}$
- C  $\frac{1}{2}mg\Delta x$
- D  $\frac{mg}{2\Delta x}$

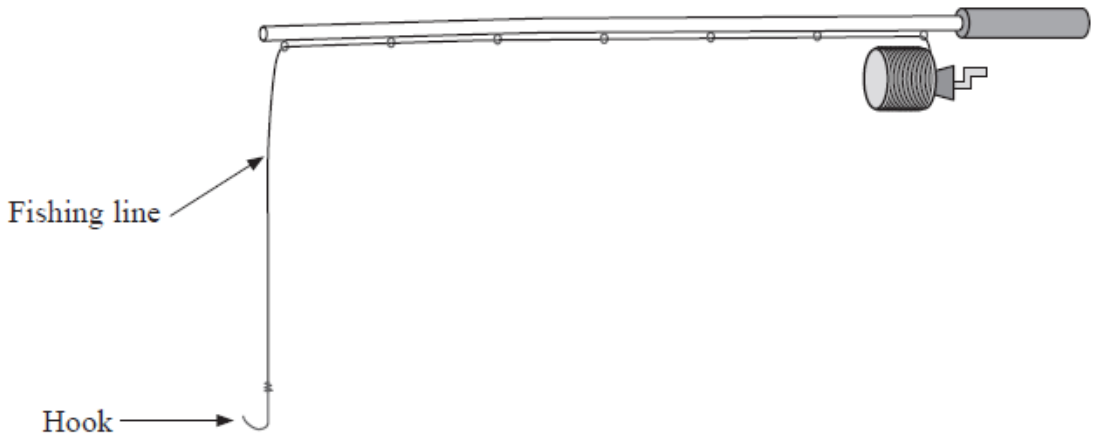
**(Total for question = 1 mark)**

Q11.

The following three properties can be used to describe copper.

Ductile      Malleable      Tough

(a) Both nylon and copper can be used to make fishing lines. Copper fishing lines sink faster than those made of nylon. This makes copper fishing lines more suitable for deep water fishing.



(i) By considering the forces acting on the submerged line, explain why nylon is less suitable than copper for deep water fishing. Include a suitable calculation in your answer.

Both lines have the same cross-sectional area.

cross-sectional area of lines =  $1.30 \times 10^{-7} \text{ m}^2$

density of saltwater =  $1030 \text{ kg m}^{-3}$

weight of 20.0 m of copper line = 0.220 N

weight of 20.0 m of nylon line = 0.0280 N

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(ii) A fish becomes caught on the hook and the copper line extends. Calculate the extension produced.

cross-sectional area of copper line =  $1.30 \times 10^{-7} \text{ m}^3$

load on line = 65.0 N

original length of line = 20.0 m

Young modulus of copper = 129 GPa

(3)

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Extension = .....

(b) Some people use fishing lines that have been pre-stretched by loading and unloading.

(i) Sketch the force-extension graph for a copper line during the process of pre-stretching.

(3)



(ii) Suggest a reason why some people prefer to use this type of line.

(1)

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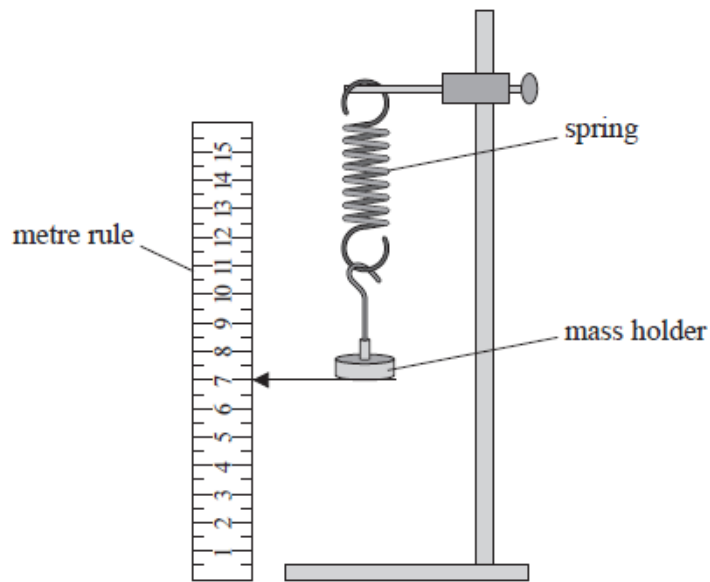
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**(Total for question = 11 marks)**

Q12.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.

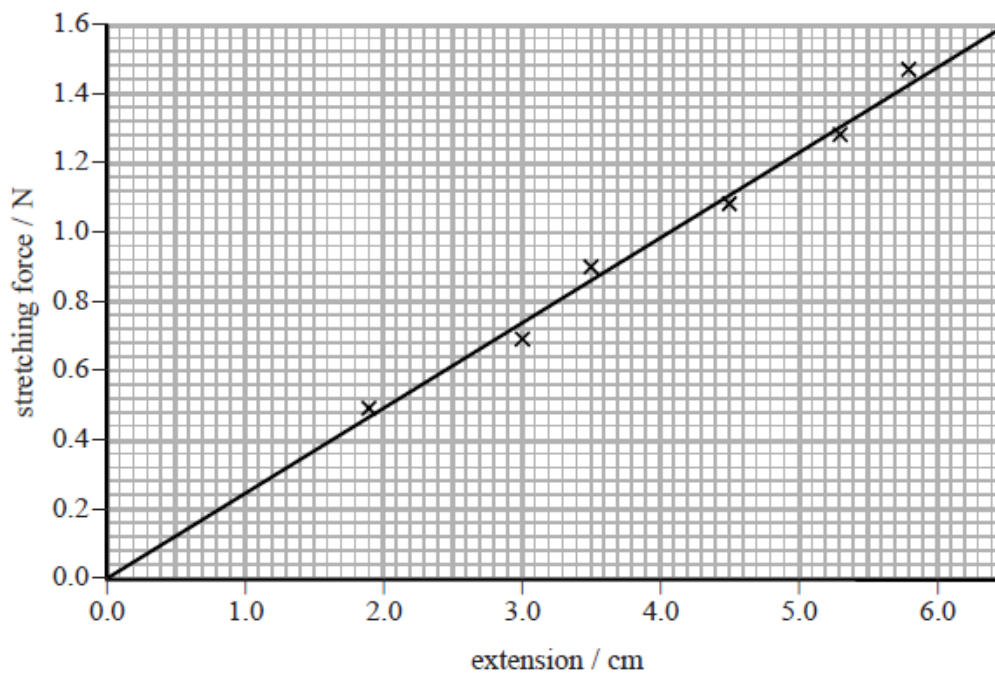


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

| Mass added / g | Extension / cm | Stretching force / N |
|----------------|----------------|----------------------|
| 50             | 1.9            | 0.49                 |
| 70             | 3              | 0.69                 |
| 90             | 3.5            | 0.9                  |
| 110            | 4.5            | 1.08                 |
| 130            | 5.3            | 1.28                 |
| 150            | 5.8            | 1.47                 |

The student used her data to plot a graph as shown.



Determine a value for the force constant  $k$  of the spring.

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$k =$  .....

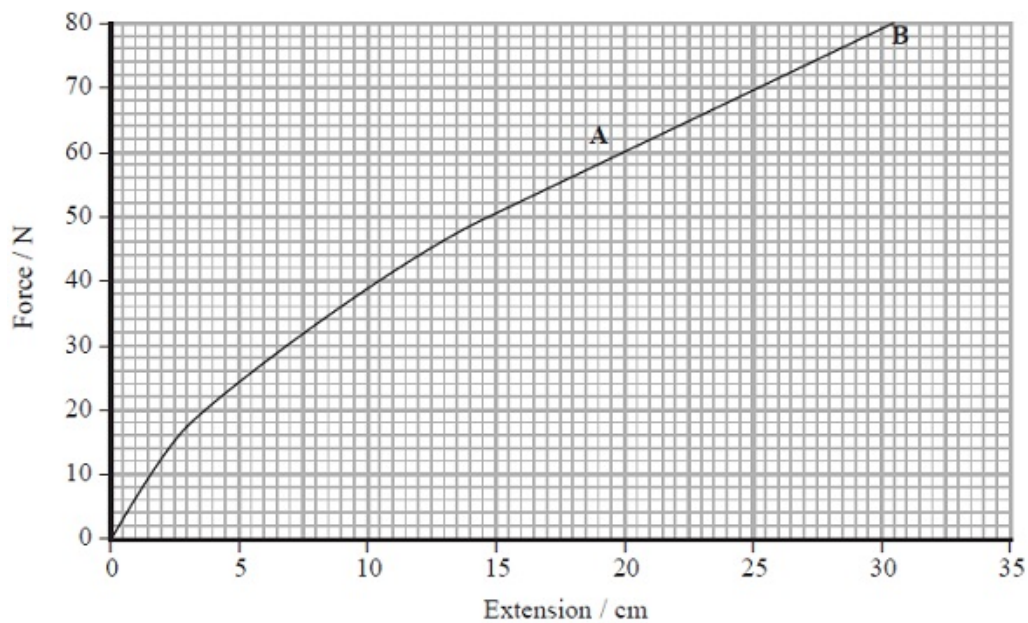
**(Total for question = 2 marks)**

Q13. The photographs show an exercise device and someone using it. The device contains two rubber cords which are extended when the device is used.



A student investigates the properties of the device by hanging weights on it and measuring the extension.

The student obtains the following graph for her results.



(a) The student notices that her graph is a straight line between A and B and concludes that the device obeys Hooke's law.

Comment on this conclusion.

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(b) (i) Describe how the student could use the graph to obtain an estimate of the total work done.

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(ii) The student sets up a spreadsheet to investigate the work done in stretching the device each time a weight is added.

|    | A                          | B              | C                       | D  |
|----|----------------------------|----------------|-------------------------|--|
| 1  | Total stretching force / N | Extension / cm | Change in extension / m | Work done<br>(force × change in extension) / J |
| 2  | 0                          | 0.0            | 0.000                   | 0.00   |
| 3  | 10                         | 1.6            | 0.016                   | 0.16   |
| 4  | 20                         | 3.5            | 0.019                   | 0.38   |
| 5  | 30                         | 7.0            | 0.035                   | 1.05   |
| 6  | 40                         | 10.5           | 0.035                   | 1.40   |
| 7  | 50                         | 14.5           | 0.040                   | 2.00   |
| 8  | 60                         | 20.0           | 0.055                   | 3.30   |
| 9  | 70                         | 25.2           | 0.052                   | 3.64   |
| 10 | 80                         | 30.5           | 0.053                   | 4.24   |
| 11 |                            |                | Total work done         | 16.17  |

Explain why this spreadsheet results in an over-estimate for the total work done.

(2)

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(c) The student eats a packet of crisps and then uses the exercise device. The energy content in a packet of crisps is 540 kJ. During exercise this energy is converted and 25% of it is transferred to mechanical work.

The student extends the device fully 15 times in 1 minute. An accurate value for the work done in fully extending the device is 14.7 J.

Calculate the time it would take the student, working at this rate, to transfer 25% of the energy from the crisps to mechanical work.

(3)

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Time = .....

(d) Explain whether more or less work would be done applying the same maximum total stretching force to a similar exercise device with rubber cords of twice the cross-sectional area.

(2)

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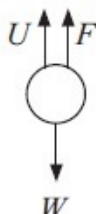

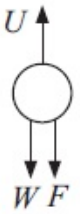

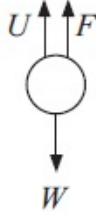
**(Total for Question = 11 marks)**

Q14.

When beer is being brewed it can contain bubbles of gas rising through it as well as solid particles, such as grain particles, falling through it.

Which row of the table correctly shows the forces on a rising gas bubble and a falling solid particle?

$F$  = viscous drag,  $U$  = upthrust,  $W$  = weight

|                                       | Gas bubble  | Solid particle   |
|---------------------------------------|---|--|
| <input checked="" type="checkbox"/> A |  |  |
| <input checked="" type="checkbox"/> B |  |  |
| <input checked="" type="checkbox"/> C |  |  |
| <input checked="" type="checkbox"/> D |  |  |

**(Total for question = 1 marks)**

Q15.

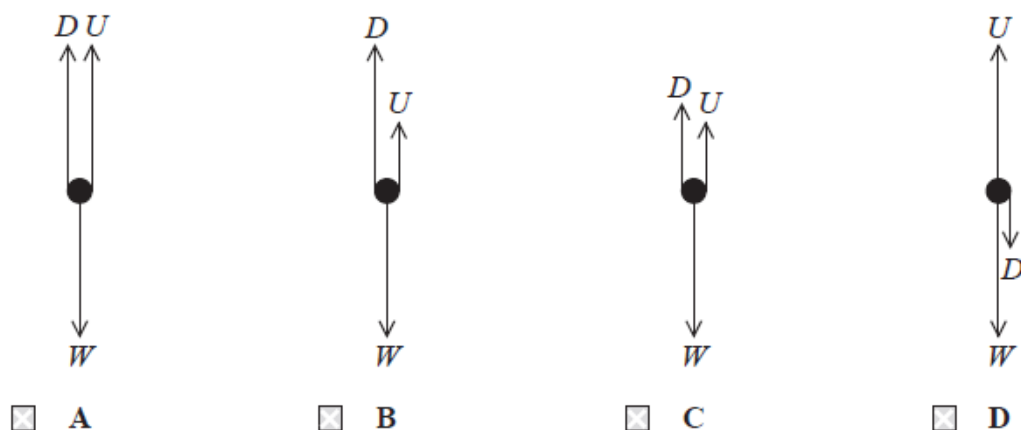
A small object is falling at terminal velocity in a large container of oil.

Which diagram correctly represents, in magnitude and direction, the forces acting on the object as it reaches terminal velocity?

$W$  = weight

$U$  = upthrust

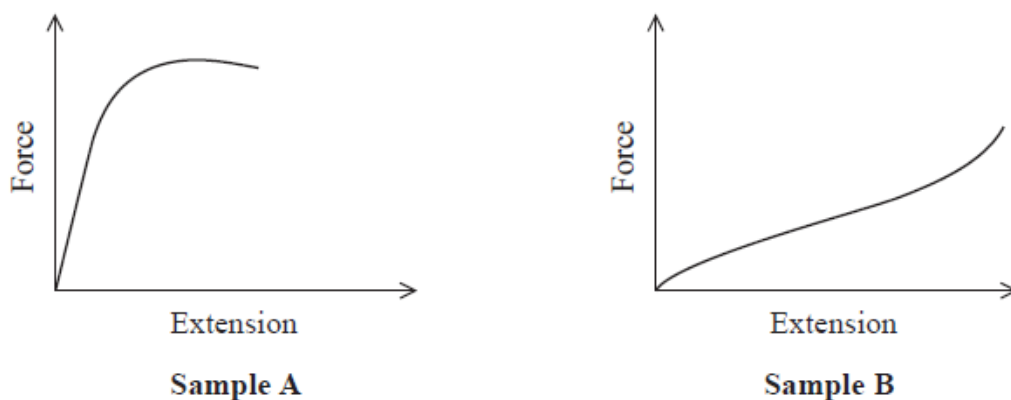
$D$  = drag



**(Total for question = 1 mark)**

Q16.

In a physics lesson the following graphs are given to the students. The graphs show the relationship between force and extension for samples of two different materials, A and B.



A student states that sample A obeys Hooke's law for small extensions and sample B does not.

Use the graphs to explain the validity of the student's statement.

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(Total for question = 3 marks)

## Mark Scheme

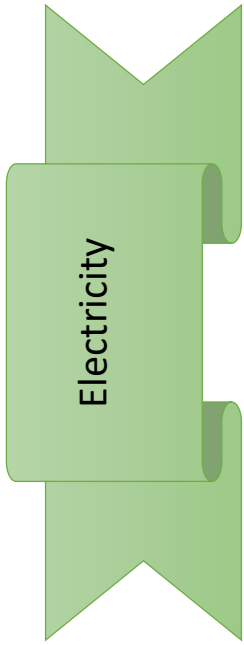
Q1.

| Question Number | Acceptable answers   | Additional guidance   | Mark |
|-----------------|--|---|------|
| (a)             | <ul style="list-style-type: none"> <li>• use of <math>\rho = m/V</math> and <math>W = mg</math> to calculate upthrust (1)</li> <li>• use of downward force of lid = upthrust – weight of diver (1)</li> <li>• downward force of lid = 0.021 (N) (1)</li> </ul> | <p><u>Example of calculation</u></p> $m_{\text{displaced}} = 1.0 \times 10^3 \text{ kg m}^{-3} \times 8.0 \times 10^{-6} \text{ m}^3$ $= 8.0 \times 10^{-3} \text{ kg}$ $U = 8.0 \times 10^{-3} \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.0785 \text{ N}$ $W = 0.0059 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.0579 \text{ N}$ $\text{Lid force} = 0.0785 \text{ N} - 0.0579 \text{ N}$ $= 0.0206 \text{ N}$ | 3    |

| Question Number | Acceptable answers   | Additional guidance   | Mark |
|-----------------|--|---|------|
| (b)             | <p><b>Either</b></p> <ul style="list-style-type: none"> <li>• use of force of lid = <math>V\rho g</math> (1)</li> <li>• volume of air = <math>8.0 \times 10^{-6} \text{ m}^3</math> - their value (1)</li> <li>• volume of air = <math>5.9 \times 10^{-6} \text{ (m}^3\text{)}</math> (1)</li> </ul> <p><b>Or</b></p> <ul style="list-style-type: none"> <li>• use of upthrust on diver = weight of diver (1)</li> <li>• use of upthrust = <math>V\rho g</math> (1)</li> <li>• volume of air = <math>5.9 \times 10^{-6} \text{ (m}^3\text{)}</math> (1)</li> </ul> | <p><u>Example of calculation</u></p> $\text{volume} = 0.0206 \text{ N} \div 9.81 \text{ N kg}^{-1} \div 1.0 \times 10^3 \text{ kg m}^{-3}$ $= 2.1 \times 10^{-6} \text{ m}^3$ $\text{new volume of air} = 8.0 \times 10^{-6} \text{ m}^3 - 2.1 \times 10^{-6} \text{ m}^3$ $= 5.9 \times 10^{-6} \text{ m}^3$ | 3    |

# Week 6





**Charge and current**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 4.1.1 a                 | Can you define electric current as rate of flow of charge?   | <input type="checkbox"/> |
| 4.1.1 b                 | Can you describe the coulomb as the unit of charge?  | <input type="checkbox"/> |
| 4.1.1 c                 | Can you recall the elementary charge $e$ equals $1.6 \times 10^{-19} \text{ C}$ ?                        | <input type="checkbox"/> |
| 4.1.1 d                 | Can you explain why the net charge on a particle or an object is quantised and a multiple of $e$ ?       | <input type="checkbox"/> |
| 4.1.1 e                 | Can you explain current as the movement of electrons in metals and movement of ions in electrolytes?     | <input type="checkbox"/> |
| 4.1.1 f                 | Can you describe the difference between conventional current and electron flow?                          | <input type="checkbox"/> |
| 4.1.1 g                 | Can you recall and apply Kirchhoff's first law?  | <input type="checkbox"/> |
| 4.1.2 a                 | Can you describe what is meant by mean drift velocity of charge carriers?                                | <input type="checkbox"/> |
| 4.1.2 b                 | Can you carry out calculations using $I = A n e v$ , where $n$ is the number density of charge carriers? | <input type="checkbox"/> |
| 4.1.2 c                 | Can you explain the distinction between conductors, semiconductors, and insulators in terms of $n$ ?     | <input type="checkbox"/> |

## Energy, power, and resistance

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.2.1 a                 | Can you recognise and draw circuit symbols?   | <input type="checkbox"/> |
| 4.2.1 b                 | Can you draw circuit diagrams using circuit symbols?  | <input type="checkbox"/> |
| 4.2.2 a                 | Can you define potential difference (p.d.) and the unit volt?   | <input type="checkbox"/> |
| 4.2.2 b                 | Can you describe the electromotive force (e.m.f.) of a source such as a cell or a power supply?   | <input type="checkbox"/> |
| 4.2.2 c                 | Can you explain the distinction between e.m.f. and p.d. in terms of energy transfer?  | <input type="checkbox"/> |
| 4.2.2 d                 | Can you describe and calculate energy transfer using $W = VQ$ and $W = EQ$ ?  | <input type="checkbox"/> |
| 4.2.2 e                 | Can you describe and calculate energy transfer using $eV = \frac{1}{2} m v^2$ for electrons and other charged particles?                              | <input type="checkbox"/> |
| 4.2.3 a                 | Can you define resistance and the unit ohm?   | <input type="checkbox"/> |
| 4.2.3 b                 | Can you explain Ohm's law?  | <input type="checkbox"/> |
| 4.2.3 c i               | Can you describe the $I$ – $V$ characteristics of the resistor, filament lamp, thermistor, diode, and light-emitting diode (LED)?                     | <input type="checkbox"/> |
| 4.2.3 c ii              | Can you list and describe techniques and procedures used to investigate the electrical characteristics for a range of ohmic and non-ohmic components? | <input type="checkbox"/> |
| 4.2.3 d                 | Can you explain the variation of resistance with light intensity for a light-dependent resistor (LDR)?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.2.4 a i               | Can you explain the resistivity of a material and use the equation $R = \frac{\rho L}{A}$ ?                     | <input type="checkbox"/> |
| 4.2.4 a ii              | Can you list and describe techniques and procedures used to determine the resistivity of a metal?               | <input type="checkbox"/> |
| 4.2.4 b                 | Can you explain how resistivity varies with temperature for metals and semiconductors?                          | <input type="checkbox"/> |
| 4.2.4 c                 | Can you explain how resistance varies with temperature for a negative temperature coefficient (NTC) thermistor? | <input type="checkbox"/> |
| 4.2.5 a                 | Can you use the equations $P = VI$ , $P = I^2 R$ and $P = \frac{V^2}{R}$ ?                                      | <input type="checkbox"/> |
| 4.2.5 b                 | Can you describe energy transfer using the equation $W = VIt$ ?   | <input type="checkbox"/> |
| 4.2.5 c                 | Can you describe the kilowatt-hour (kW h) as a unit of energy and calculate the cost of energy?                 | <input type="checkbox"/> |

## Electrical circuits

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.3.1 a                 | Can you explain Kirchhoff's second law and the conservation of energy?  | <input type="checkbox"/> |
| 4.3.1 b                 | Can you describe Kirchhoff's first and second laws applied to electrical circuits?  | <input type="checkbox"/> |
| 4.3.1 c                 | Can you determine the total resistance of two or more resistors in series using $R = R_1 + R_2 + \dots$ ?                                   | <input type="checkbox"/> |
| 4.3.1 d                 | Can you determine the total resistance of two or more resistors in parallel using $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$ ?   | <input type="checkbox"/> |
| 4.3.1 e                 | Can you analyse circuits with components both in series and in parallel?  | <input type="checkbox"/> |
| 4.3.1 f                 | Can you analyse circuits with more than one source of e.m.f.?   | <input type="checkbox"/> |
| 4.3.2 a                 | Can you define source of e.m.f. and internal resistance?  | <input type="checkbox"/> |
| 4.3.2 b                 | Can you define terminal p.d. and 'lost volts'?  | <input type="checkbox"/> |
| 4.3.2 c i               | Can you use the equations $\mathcal{E} = I(R + r)$ and $\mathcal{E} = V + Ir$ ?   | <input type="checkbox"/> |
| 4.3.2 c ii              | Can you list and describe techniques and procedures used to determine the internal resistance of a chemical cell or other source of e.m.f.? | <input type="checkbox"/> |
| 4.3.3 a                 | Can you analyse a potential divider circuit with components?  | <input type="checkbox"/> |
| 4.3.3 b                 | Can you use potential divider circuits with variable components, e.g., LDRs and thermistors?  | <input type="checkbox"/> |

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 4.3.3 c i               | Can you use potential divider equations $V_{\text{out}} = \frac{R_2}{R_1 + R_2} \times V_{\text{in}}$ and $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ ?              | <input type="checkbox"/> |
| 4.3.3 c ii              | Can you list and describe techniques and procedures used to investigate potential divider circuits which may include a sensor such as a thermistor or a LDR? | <input type="checkbox"/> |

## Charge and Current

|  |  |
|--|--|
| What is a charge carrier?  | A charged particle capable of transferring electric current.   |
| What do we mean when we say charge is quantised?                       | It can only take certain values (always $ne$ )   |
| If $n$ electrons are removed from a neutral object what is its charge? | $ne$   |
| What is an electrolyte?  | A liquid containing charged ions.  |
| What is a metallic conductor?  | A material comprising a lattice of positive ions and delocalised electrons that carry electrical current       |
| Which direction does conventional current flow?                        | From positive to negative.   |
| Which direction do electrons flow in a circuit?                        | From negative to positive.   |
| What is an ion?  | A non-neutral atom or molecule.  |
| What is a cation?  | A positively charged ion   |
| What is an anion?  | A negatively charged ion.  |
| What is an anode?  | A positive electrode.  |
| What is a cathode?   | A negative electrode.  |
| How is an ammeter connected?   | In series  |
| What is the resistance of an ideal ammeter?                            | Zero.  |
| State Kirchoff's first law.  | At any point in a circuit the sum of the currents entering that point is equal to sum of the currents leaving. |
| What is $n$ in the equation $I = nAve$ and what are its units?         | Number density of free charge carriers ( $m^{-3}$ )  |
| What is $A$ in the equation $I = nAve$ ?                               | Cross-sectional area of the conductor.   |
| What is $e$ in the equation $I = nAve$ ?                               | The elementary charge ( $1.6 \times 10^{-19}C$ )   |
| What is $v$ in the equation $I = nAve$ ?                               | The drift velocity of the charge carriers.   |
| What is a conductor?   | A material with a large number density of charge carriers $\sim 10^{28}m^{-3}$                                 |
| What is an insulator?  | A material with a low number density of charge carriers.   |
| What is a semiconductor?   | A material with an intermediate number density of charge carriers $\sim 10^{17}m^{-3}$                         |

### Key ideas:

A – What is meant when we say a physical quantity is quantised? Why is charge on an object quantised?

B - Many people believe that electric currents are always made up of electrons. In reality...

C – Both metals and electrolytes can carry electrical current. Using diagrams explain as fully as possible what is happening when a current flows in a metal and an electrolyte.

D – Materials can be classified as insulators, semiconductors and conductors. Provide examples of each type of material and explain what determines which category a material falls into?

E - It is often assumed that electrons must travel really fast along wires because when you switch on a light it lights up almost instantly but really...

## Questions

Q1.

A student investigates how the efficiency of an electric motor being used to raise a load varies with the weight of the load.

The time taken for the motor to lift a load from the floor to the maximum height was measured using a stopwatch. The load was varied by adding weights, each marked '1.00 N'.

The spreadsheet shows the student's results (columns A to E) and calculation (column F).

|    | A        | B           | C                        | D        | E                    | F          |
|----|----------|-------------|--------------------------|----------|----------------------|------------|
|    | load / N | current / A | potential difference / V | time / s | change in height / m | efficiency |
| 1  |          |             |                          |          |                      |            |
| 2  | 2.00     | 1.8         | 4.6                      | 1.52     | 0.825                | 0.13       |
| 3  | 3.00     | 1.9         | 4.4                      | 2.05     | 0.825                | 0.14       |
| 4  | 4.00     | 2.1         | 4.3                      | 2.19     | 0.825                | 0.17       |
| 5  | 5.00     | 2.3         | 5.1                      | 2.26     | 0.825                | 0.16       |
| 6  | 6.00     | 2.5         | 4.5                      | 2.48     | 0.825                | 0.18       |
| 7  | 7.00     | 3.1         | 5.2                      | 2.17     | 0.825                | 0.17       |
| 8  | 8.00     | 3.7         | 4.8                      | 2.68     | 0.825                | 0.14       |
| 9  | 9.00     | 3.9         | 4.8                      | 3.36     | 0.825                | 0.12       |
| 10 | 10.00    | 4.2         | 4.7                      | 3.72     | 0.825                | 0.11       |

Explain how the value in cell F4 has been determined using the results obtained.

(3)

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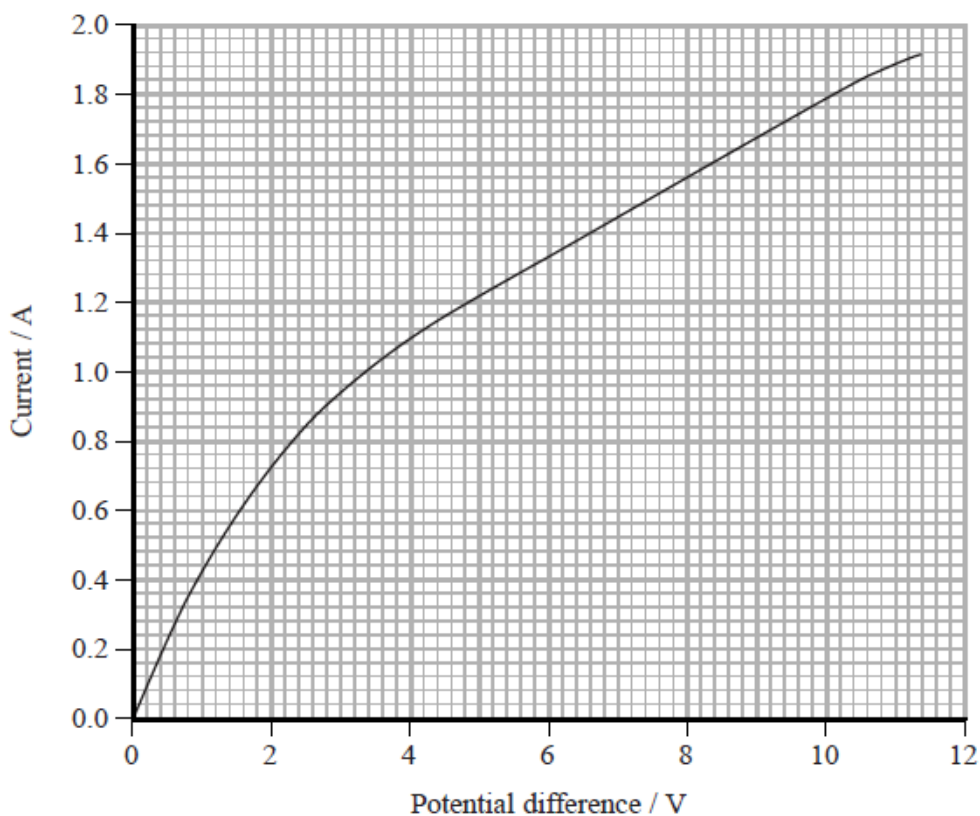
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**(Total for question = 3 marks)**

Q2.

The graph shows how the current through a filament bulb varies with the potential difference across the bulb.



(a) Determine the resistance of the filament bulb when the potential difference is 7.0 V.

(2)

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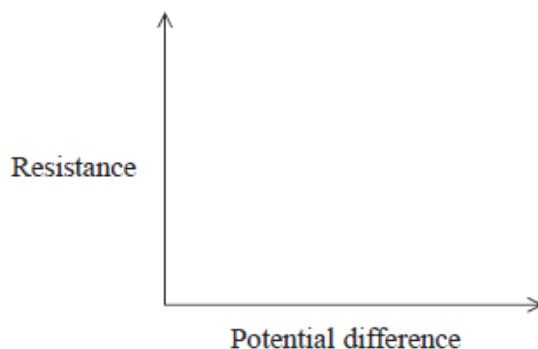
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Resistance = .....

(b) Sketch a graph of resistance against potential difference for the filament bulb over the range 0 V to 7 V.

(3)



\* (c) Explain the variation of resistance with potential difference for the filament bulb in terms of particle behaviour.

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**(Total for question = 11 marks)**

Q3.

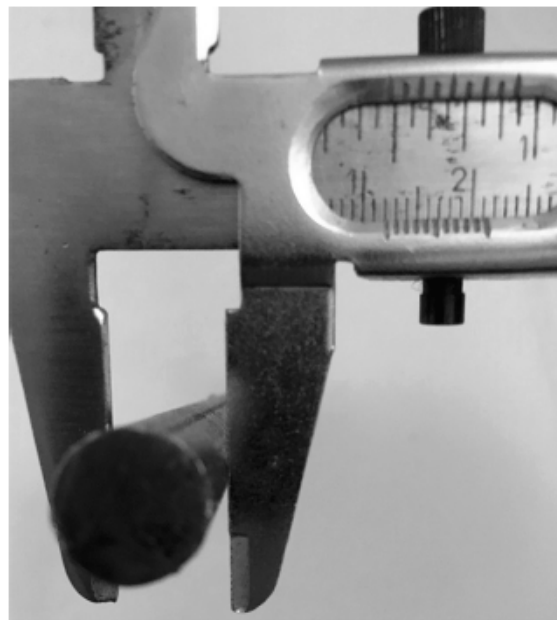
The photographs show two types of caliper being used, in turn, to measure the diameter of an iron rod.

Caliper 1



diameter = 12.17 mm

Caliper 2



diameter = 12.2 mm

The value obtained from caliper 2 was used to determine the cross-sectional area of the rod and the electrical properties of the rod were investigated.

Calculate the drift velocity for the charge carriers in the rod when the current in the rod is 1.9 A.

diameter of rod = 12.2 mm

charge carrier density for iron =  $1.7 \times 10^{29} \text{ m}^{-3}$

(3)

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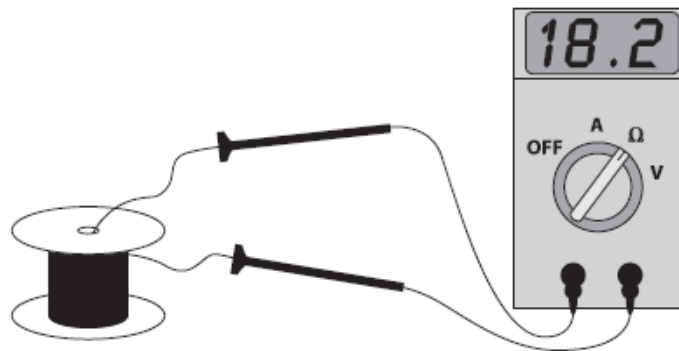
Drift velocity = .....

**(Total for question = 3 marks)**

Q4.

A student carried out an experiment to determine the resistivity of nichrome wire.

He used an ohmmeter to measure the resistance of a length of nichrome wire as shown.



The diameter of the wire was measured as  $0.27 \text{ mm} \pm 0.01 \text{ mm}$ .

The length of the wire was measured as  $1.25 \text{ m} \pm 0.05 \text{ m}$ .

Calculate the minimum value of resistivity possible from the student's data.

**(4)**

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Minimum resistivity = .....

**(Total for question = 4 marks)**

Q5.

A hair dryer is used for 3 minutes. The operating current is 6 A.

What charge flows in this time?

(1)

- A** 0.03 C
- B** 2 C
- C** 18 C
- D** 1080 C

**(Total for question = 1 mark)**

Q6.

A light dependent resistor and a negative temperature coefficient thermistor are connected in series.

Which of the following combinations of illumination and temperature will result in the highest combined resistance?

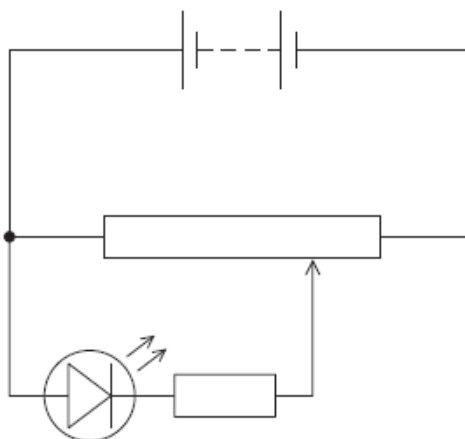
(1)

- A** dark and cold
- B** dark and hot
- C** light and cold
- D** light and hot

**(Total for question = 1 mark)**

Q7.

A student wanted to plot a graph of current against potential difference for a light emitting diode (LED). He used the circuit shown.



Add an ammeter and a voltmeter to the circuit diagram that would enable the data to be collected.

(1)

**(Total for question = 1 mark)**

Q8.

A student is deriving an equation for the total resistance of resistors in series.

She writes the following steps but does not justify them.

Step 1  $V = V_1 + V_2$

Step 2 *but*  $V = IR$

Step 3 *so*  $IR = I_1R_1 + I_2R_2$

Step 4 *but*  $I = I_1 = I_2$

Step 5 *Therefore*  $R = R_1 + R_2$

Which step is justified using conservation of charge?

(1)

**A** Step 1

**B** Step 2

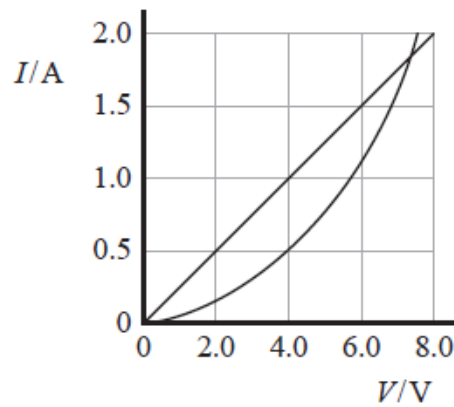
**C** Step 3

**D** Step 4

(Total for question = 1 mark)

Q9.

The current-potential difference graphs for a resistor and a thermistor are shown.



The resistor and thermistor are connected in series to a 6 V battery.

What is the current, in amps, in the resistor?

(1)

- A 0.5
- B 1.0
- C 1.5
- D 2.0

(Total for question = 1 mark)

Q10.

A volt can be defined as a

(1)

- A coulomb per joule.

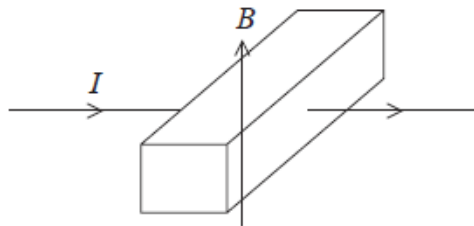


(Total for question = 5 marks)

Q12.

Some liquids conduct electricity. This property can be used to pump these liquids through pipes.

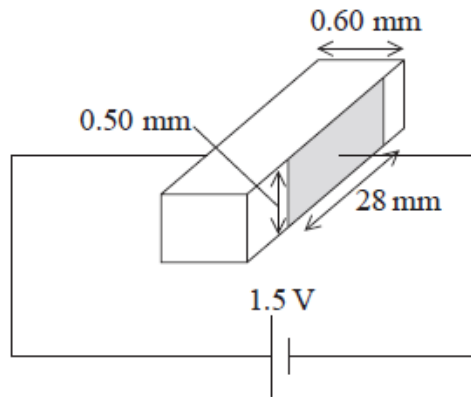
A short section of a rectangular pipe containing a liquid is shown in the diagram. The pipe is placed in a magnetic field of flux density  $B$  and a current  $I$  is passed through the liquid as shown.



A practical demonstration of this principle used two rectangular electrodes, opposite each other on either side of the pipe, a distance of 0.60 mm apart. The dimensions of the electrodes are shown in the diagram.

The electrodes were connected to a 1.5 V cell.

Salt water was pumped using a magnetic field of magnetic flux density 0.40 T.



(i) Show that the current through the salt water is about 20 mA.

resistivity of salt water =  $1.6 \Omega \text{ m}$

(4)

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(ii) Hence calculate the force on the salt water.

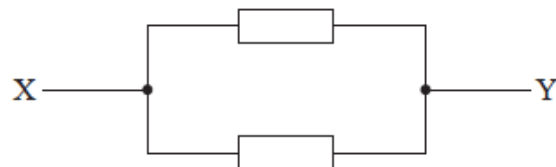
(2)

Force = .....

**(Total for question = 6 marks)**

Q13.

The two resistors shown each have resistance  $R$ .



Which expression gives the correct resistance between point X and point Y?

(1)

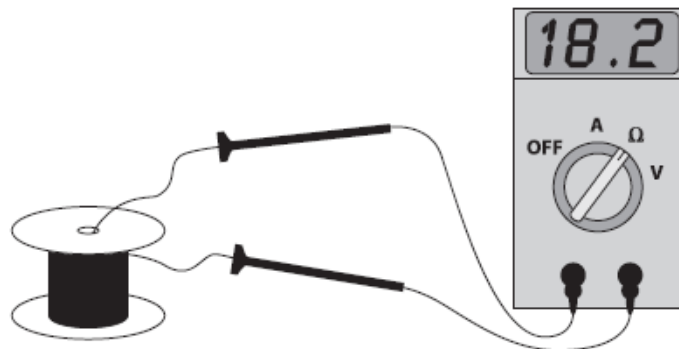
- A  $\frac{R}{2}$
- B  $R$
- C  $2R$
- D  $R^2$

**(Total for question = 1 mark)**

Q14.

A student carried out an experiment to determine the resistivity of nichrome wire.

He used an ohmmeter to measure the resistance of a length of nichrome wire as shown.



The diameter of the wire was measured as  $0.27 \text{ mm} \pm 0.01 \text{ mm}$ .

The length of the wire was measured as  $1.25 \text{ m} \pm 0.05 \text{ m}$ .

Determine which of the three measurements introduces the greatest uncertainty into the value for the resistivity.

Your answer should include calculations.

(4)

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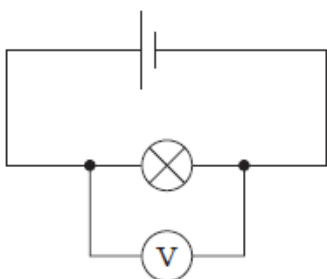
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**(Total for question = 4 marks)**

Q15.

A torch uses a 1.5 V dry cell. Over time, the light intensity produced by the torch decreases as the cell 'goes flat'.

Student A sets up the following circuit in an attempt to measure the e.m.f. of a cell.



Explain why the voltmeter reading will **not** be the e.m.f. of the cell.

(2)

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**(Total for question = 2 marks)**

Q16.

A series circuit consists of two resistors with resistances  $R_1$  and  $R_2$  and a battery of potential difference  $V$ .

Which of the following gives the potential difference across the resistor with resistance  $R_2$ ?

(1)



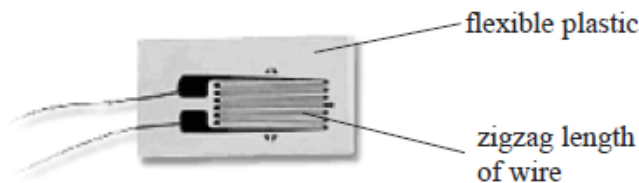
(Total for question = 4 marks)

Q18.

A medical scanner uses a moving table to position the patient. Strain gauges are used to monitor the shape of the table which enables a more precise positioning of the patient.



Strain gauges consist of a thin length of wire attached, in a zigzag pattern, to a small flexible piece of plastic. The strain gauge is attached to the table. When the table is subjected to forces, the dimensions of the plastic change. This causes a change in the length of the wire and hence a change in the resistance of the wire.



(a) Resistance can be measured directly using an ohmmeter or indirectly using measurements from a voltmeter and ammeter.

Describe **two** benefits of using an ohmmeter compared to using a voltmeter and an ammeter.

(2)

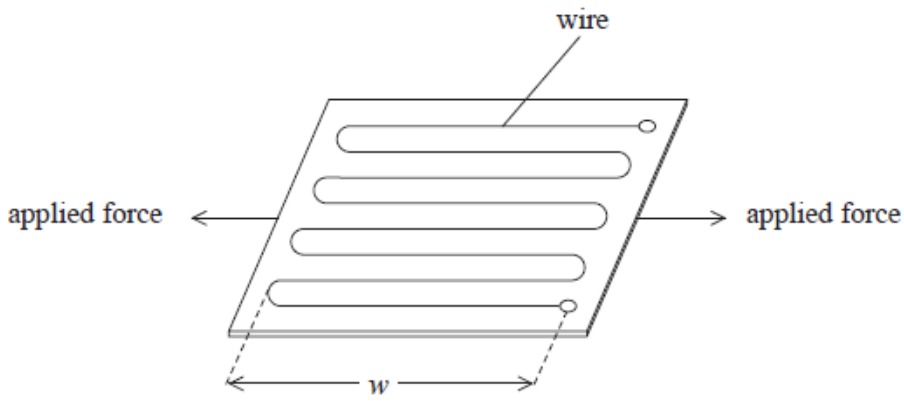
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(b) The diagram shows forces applied to a strain gauge. The 'width' of the strain gauge is defined by the distance  $w$ .



(i) State and justify how the applied forces change the resistance of the wire.

(2)

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(ii) The gauge factor  $GF$  of a strain gauge is given by

$$GF = \frac{\Delta R}{\epsilon R}$$

where  $\epsilon$  is the strain

$R$  is the initial resistance

$\Delta R$  is the change in resistance

When forces are applied to the strain gauge, the resistance of the gauge changes by 0.10%.

Calculate the change in the width of the strain gauge.

$w = 5.0 \text{ cm}$

$GF = 2.0$

(3)

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Change in width = .....

(c) Explain the benefit of arranging the wire in a zigzag pattern.

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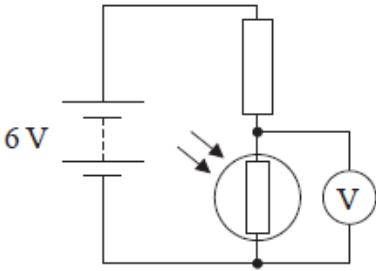
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**(Total for question = 9 marks)**

Q19.

A light-dependent resistor (LDR) and resistor are connected in series with a 6V battery as shown. A voltmeter measures the potential difference across the LDR.



In daylight the voltmeter reads 3.0V.

Which reading is most likely if the circuit is now in total darkness?

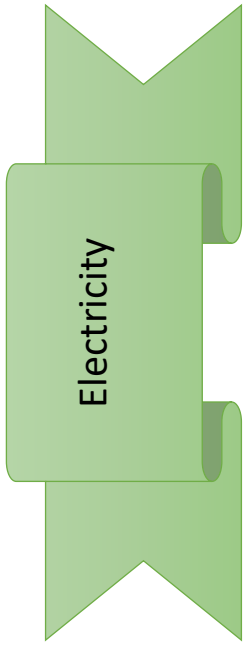
(1)

- A** a little above 0 V
- B** a little below 3 V
- C** a little above 3 V
- D** a little below 6 V

**(Total for question = 1 mark)**

# Week 7





## Capacitance

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 6.1.1 a                 | Can you explain capacitance, $C = \frac{Q}{V}$ ?  | <input type="checkbox"/> |
| 6.1.1 a                 | Can you define the unit farad?  | <input type="checkbox"/> |
| 6.1.1 b                 | Can you describe charging and discharging of capacitors in terms of the flow of electrons?                                    | <input type="checkbox"/> |
| 6.1.1 c                 | Can you demonstrate the total capacitance of capacitors in series,<br>$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$ ? | <input type="checkbox"/> |
| 6.1.1 d                 | Can you demonstrate the total capacitance of capacitors in parallel, $C = C_1 + C_2 + \dots$ ?                                | <input type="checkbox"/> |
| 6.1.1 e i               | Can you describe an analysis of circuits containing capacitors?   | <input type="checkbox"/> |
| 6.1.1 e ii              | Can you understand an investigation of circuits containing capacitors?  | <input type="checkbox"/> |
| 6.1.2 a                 | Can you understand p.d.–charge graphs for capacitors?   | <input type="checkbox"/> |
| 6.1.2 b                 | Can you describe how energy is stored by capacitors?  | <input type="checkbox"/> |
| 6.1.2 b                 | Can you demonstrate that $W = \frac{1}{2} QV = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} V^2 C$ ?                               | <input type="checkbox"/> |
| 6.1.2 c                 | Can you describe the use of capacitors to store energy?   | <input type="checkbox"/> |
| 6.1.3 a i               | Can you describe discharging a capacitor through a resistor?  | <input type="checkbox"/> |
| 6.1.3 a ii              | Can you investigate the charge and the discharge of a capacitor?  | <input type="checkbox"/> |

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 6.1.3 b                 | Can you explain the time constant $CR$ of a capacitor–resistor circuit?  | <input type="checkbox"/> |
| 6.1.3 c                 | Can you demonstrate $x = x_0 e^{-\frac{t}{CR}}$ and $x = x_0 (1 - e^{-\frac{t}{CR}})$ for capacitor–resistor circuits?     | <input type="checkbox"/> |
| 6.1.3 d                 | Can you demonstrate the modelling of the equation $\frac{\Delta Q}{\Delta t} = \frac{-Q}{CR}$ for a discharging capacitor? | <input type="checkbox"/> |
| 6.1.3 e                 | Can you explain exponential decay and the constant-ratio property of decay graphs?   | <input type="checkbox"/> |

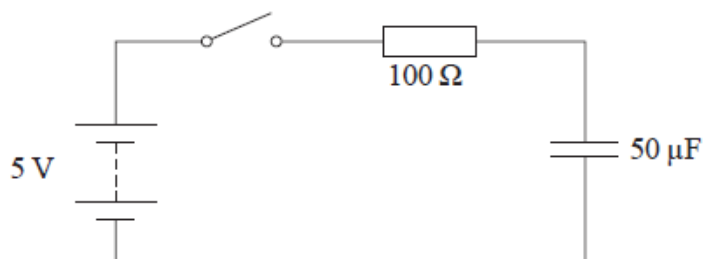
## 21 Capacitance

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|--|--|
| Describe the construction of a capacitor.  | Two conducting plates separated by an insulator.   |
| What is the relationship between charge stored and pd across a capacitor?  | Charge is proportional to voltage  |
| Describe what happens to the two plates of an uncharged capacitor when a p.d. is applied to it?                    | Electrons/charge flows off of one plate and flows on to the other causing one to become positive and the other negative. |
| What units are equivalent to a Farad?  | $\text{CV}^{-1}$ or coulombs per volt  |
| How do you calculate the total capacitance for capacitors in parallel?   | $C_T = C_1 + C_2 + C_3 + \dots$  |
| How do you calculate the total capacitance for capacitors in series?   | $1/C_T = 1/C_1 + 1/C_2 + 1/C_3 \dots$  |
| If capacitors are connected in series what quantity is the same for all capacitors?                                | Charge stored  |
| If capacitors are connected in parallel what quantity is the same for all capacitors?                              | p.d.   |
| What is represented by the area under a p.d. - charge graphs?  | Electrical energy transferred OR work done.  |
| What is represented by the gradient of a charge-p.d. graph for a capacitor?  | Capacitance  |
| What is the relationship between energy stored and p.d. on a capacitor?  | Energy stored is proportional to p.d. squared  |
| What is the relationship between energy stored and charge on a capacitor?  | Energy stored is proportional to charge squared  |
| Out of Q, V and I which variable(s) follow the relationship $x = x_0 e^{-(t/RC)}$ when discharging a capacitor?    | Q, V and I   |
| Out of Q, V and I which variable(s) follow the relationship $x = x_0 e^{-(t/RC)}$ when charging a capacitor?       | I  |
| Out of Q, V and I which variable(s) follow the relationship $x = x_0 (1 - e^{-(t/RC)})$ when charging a capacitor? | Q and V  |
| How do you calculate time constant in a capacitor circuit?   | RC   |
| What is meant by the constant-ratio nature of exponential decay?   | In equal time intervals the quantity decreases by equal factors.   |
| How much charge remains after one time constant when discharging a capacitor?                                      | $e^{-1}$ OR 0.37 OR 37%  |
| How much charge remains after n time constants when discharging a capacitor?                                       | $e^{-n}$   |
| What is represented by the gradient of charge-time graph when charging a capacitor?                                | Charging current.  |
| State two uses of capacitors.  | Energy storage e.g. for camera flashes, spot welding..., timing circuits, voltage smoothing, audio filters.              |

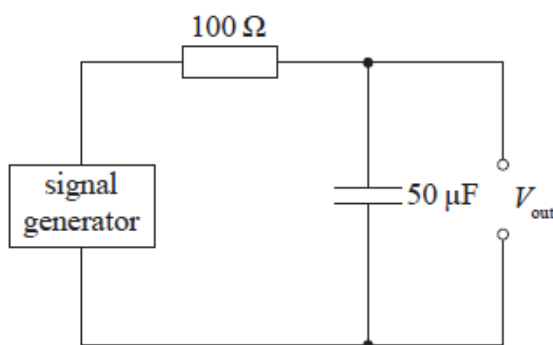
## Questions

Q1.

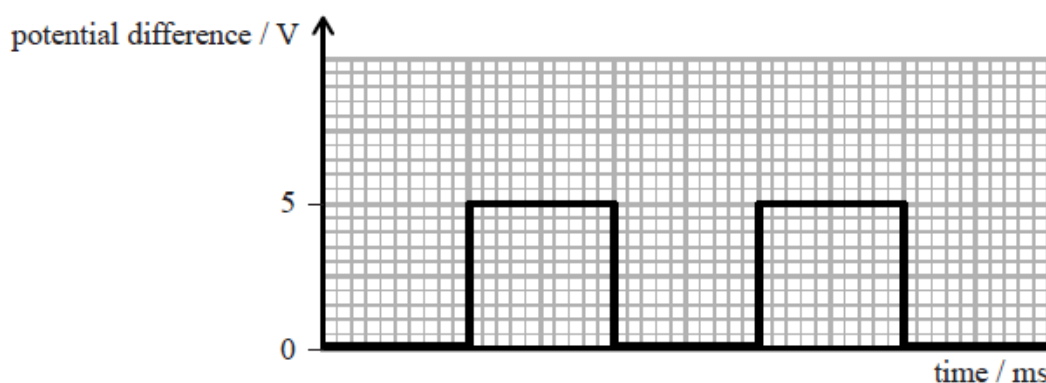
A circuit consists of a battery of e.m.f. 5 V and negligible internal resistance, a switch, a  $100\ \Omega$  resistor and an uncharged  $50\ \mu\text{F}$  capacitor.



The battery and switch are replaced by a signal generator providing a square wave output of peak potential difference 5 V. The signal generator has negligible internal resistance.



The graph shows the square wave output of the signal generator. The frequency of the square wave is 20 Hz.



On the graph add values to the time axis and sketch a graph of the potential difference,  $V_{\text{out}}$ , across the capacitor for two cycles of the square wave. Assume the capacitor is initially uncharged.

(5)

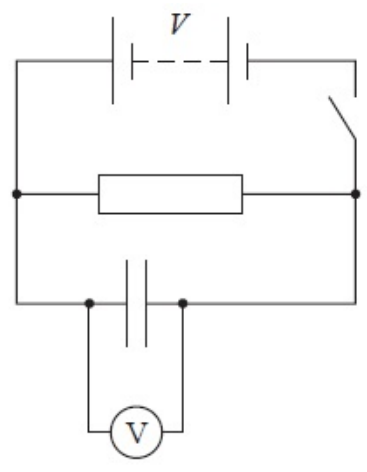
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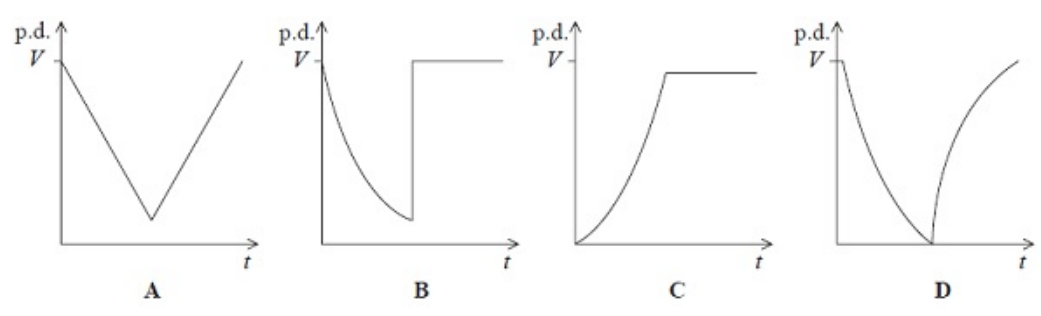
**(Total for question = 5 marks)**

Q2. The capacitor shown in the circuit below is initially charged to a potential difference (p.d.)  $V$  by closing the switch.

The power supply has negligible internal resistance.



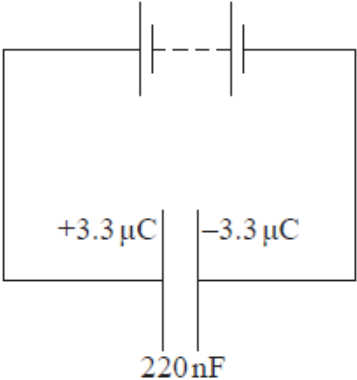
The switch is opened and the p.d. across the capacitor allowed to fall. A short time later the switch is closed again. Select the graph that shows how the p.d. across the capacitor varies with time, after the switch is opened.



- A
- B
- C
- D

Q3.

A capacitor is charged by a battery as shown in the circuit diagram.



(a) Calculate the e.m.f. of the battery and the energy stored in the charged capacitor.

(4)

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E.m.f. = .....

Energy = .....

(b) The capacitor is disconnected from the battery and discharged through a 20 MΩ resistor.

Calculate the time taken for 80% of the charge on the capacitor to discharge through the resistor.

(3)

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Time taken = .....

(c) Use an equation to explain whether the time taken for the capacitor to lose half its energy is greater or less than the time taken to lose half its charge.

(3)

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(d) A student carries out an experiment to record data so that she can plot a graph of potential difference against time as the capacitor discharges.

State **two** advantages of using a datalogger rather than a voltmeter and stopwatch to record this data.

(2)

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**(Total for question = 12 marks)**

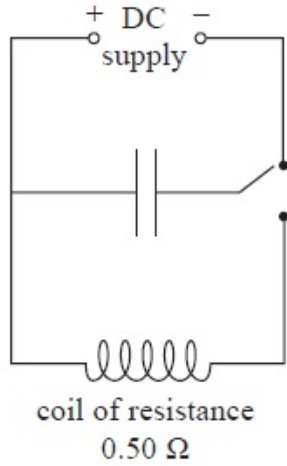
Q4. A particular experiment requires a very large current to be provided for a short time.

(a) An average current of  $2.0 \times 10^3$  A is to be supplied to a coil of wire for a time of  $1.4 \times 10^{-3}$  s. The resistance of the coil is  $0.50 \Omega$ .

(i) Show that the charge that flows through the coil during this time is about 3 C.

(2)

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 .....  
 (ii) The circuit shows how a capacitor could be charged and then discharged through the coil to provide the current.



The circuit contains a capacitor of capacitance  $600 \mu\text{F}$ . This capacitor is suitable to provide the current for  $1.4 \times 10^{-3} \text{ s}$ .

Explain why the capacitor is suitable.

(3)

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(b) It can be assumed that the  $600 \mu\text{F}$  capacitor completely discharges in  $1.4 \times 10^{-3} \text{ s}$ .

(i) Calculate the potential difference of the power supply.

(2)

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Potential difference = .....

(ii) Calculate the average power delivered to the coil in this time.

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Average power = .....

**(Total for Question = 10 marks)**

Q5. A student is investigating how the potential difference across a capacitor varies with time as the capacitor is charging.

He uses a 100  $\mu\text{F}$  capacitor, a 5.0 V d.c. supply, a resistor, a voltmeter and a switch.

(a) (i) Draw a diagram of the circuit he should use.

(2)

(ii) Suggest why a voltage sensor connected to a data logger might be a suitable instrument for measuring the potential difference across the capacitor in this investigation.

(1)

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(b) Calculate the maximum charge stored on the capacitor.

(2)

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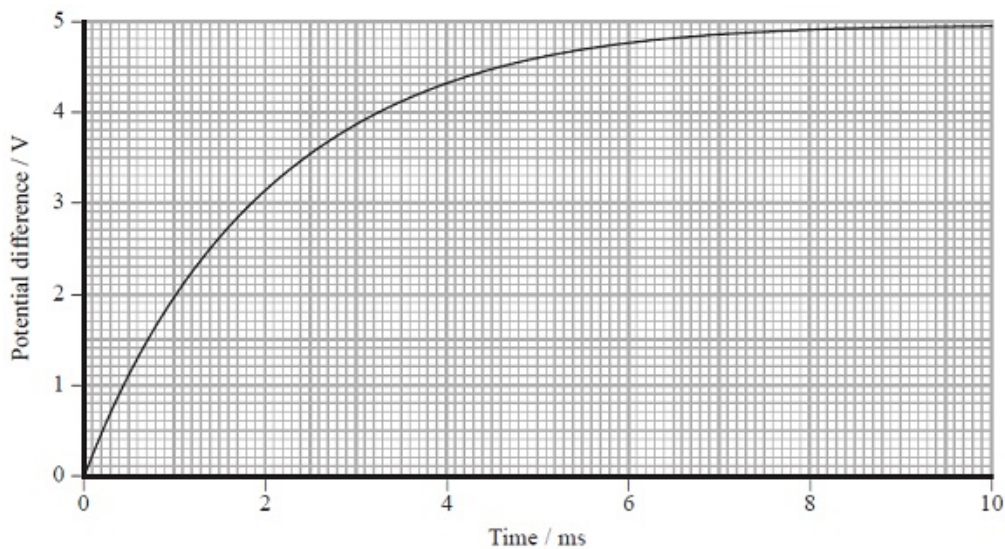
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Charge = .....

(c) The graph shows how the potential difference across the capacitor varies with time as the capacitor is charging.



(i) Estimate the average charging current over the first 10 ms.

(2)

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Average charging current = .....

(ii) Use the graph to estimate the initial rate of increase of potential difference across the capacitor and hence find the initial charging current.

(3)

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Initial charging current = .....

(iii) Use the value of the initial charging current to find the resistance of the resistor.

(2)

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Resistance = .....

**(Total for Question = 12 marks)**

Q6.

In recent years there has been a development of ultracapacitors which have much higher capacitance than traditional capacitors. Capacitors store energy due to charge in an electric field whereas batteries store energy due to a chemical reaction. There are several applications where ultracapacitors have an advantage over batteries; for example storing energy from rapidly fluctuating supplies or delivering charge very quickly.

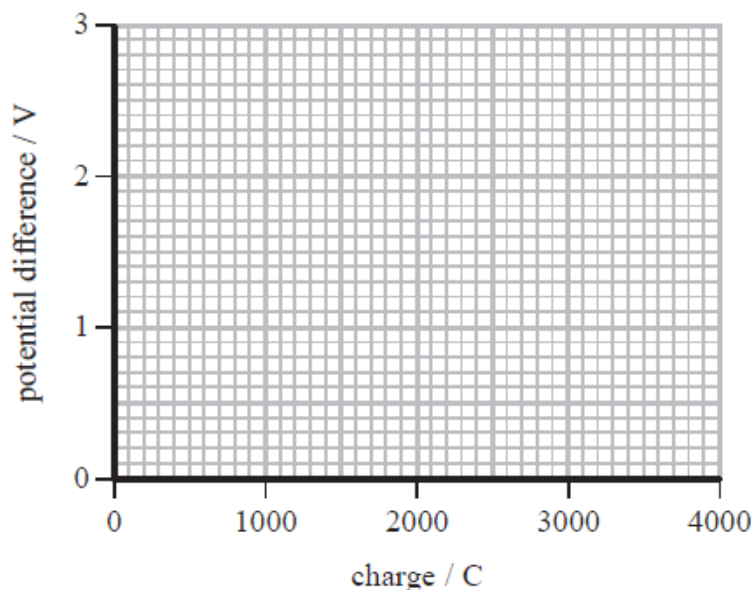
(a) A typical ultracapacitor has a capacitance of 1500 F and a maximum operating potential difference of 2.6 V.

(i) Show that the charge on this capacitor when fully charged is about 4000 C.

(2)

(ii) Complete the graph on the axes below to show how the potential difference varies with charge for this capacitor.

(2)



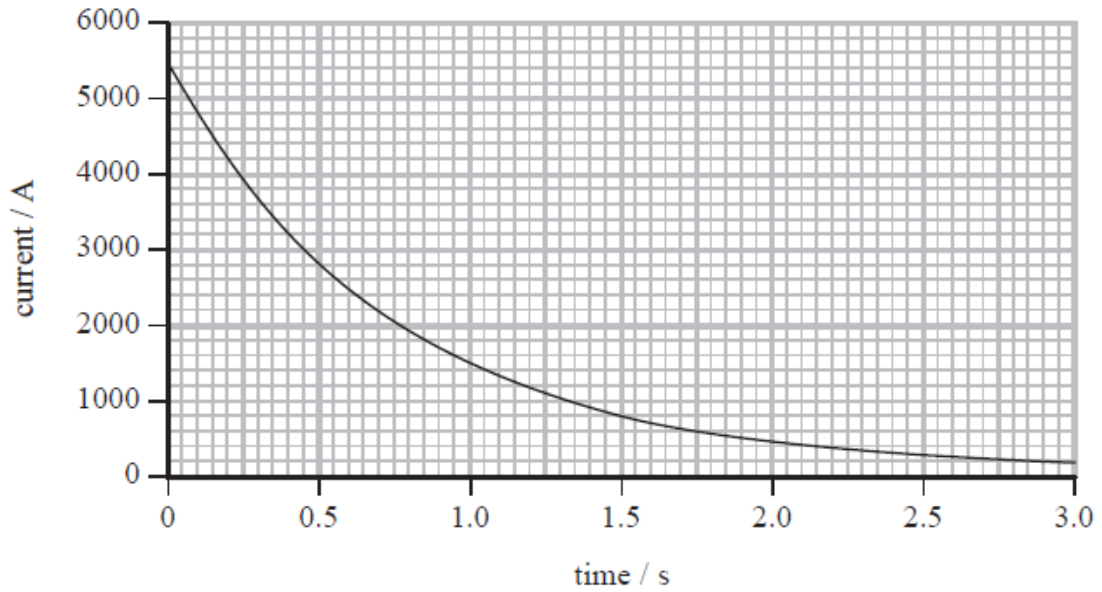
(iii) Calculate the energy stored in this capacitor when fully charged.

(2)

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Energy = .....

(b) The graph below shows how the current varies with time as the capacitor is discharged through a circuit.



(i) Describe and explain the shape of the graph.

(2)

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(ii) Calculate the resistance of the circuit.

(4)

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Resistance = .....

(c) There is a limit to the amount of charge an ultracapacitor can hold but it can deliver the charge very quickly. A battery can deliver much more charge but only at a slower rate. For electric powered vehicles it is suggested that using a combination of batteries and ultracapacitors would give the best performance.

Suggest, with reasons, which stages of a journey would be more suited to ultracapacitors and which would be more suited to batteries.

(3)

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**(Total for question = 15 marks)**

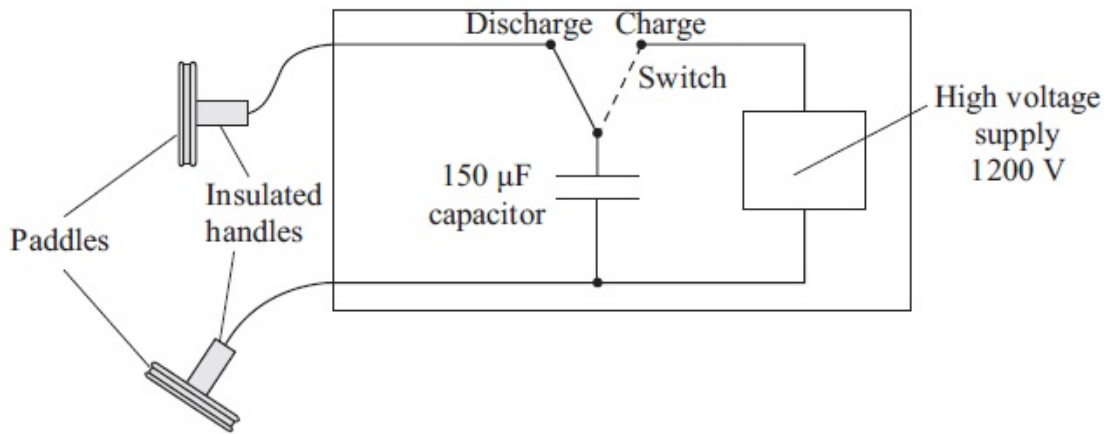
Q7.

A defibrillator is a machine that is used to correct an irregular heartbeat or to start the heart of someone who is in cardiac arrest.



The defibrillator passes a large current through the heart for a short time.

The machine includes a high voltage supply which is used to charge a capacitor. Two defibrillation 'paddles' are placed on the chest of the patient and the capacitor is discharged through the patient.



(a) The 150 μF capacitor is first connected across the 1200 V supply

Calculate the charge on the capacitor.

(2)

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Charge = .....

(b) Calculate the energy stored in the capacitor.

(2)

.....  
 .....

Energy stored = .....

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω

(1)

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(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

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Time = .....

(iii) Body resistance varies from person to person. If the body resistance was lower, the initial current would be greater.

State how this lower body resistance affects the charge passed through the body from the defibrillator.

(1)

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**(Total for question = 9 marks)**

Q8.

A capacitor of capacitance  $C$  has a potential difference  $V$  across it. The energy stored on the capacitor is  $Z$  joules. A second capacitor of capacitance  $C/2$  has a potential difference  $2V$  across it.

The energy stored on the second capacitor is

- A**  $Z$
- B**  $2Z$
- C**  $4Z$
- D**  $8Z$

**(Total for question = 1 mark)**

Q9.

A capacitor of capacitance  $C$  is charged to a potential difference  $V$  by a power supply. The energy stored on the charged capacitor is  $W$ .

What would be the energy stored if the potential difference were 2V?

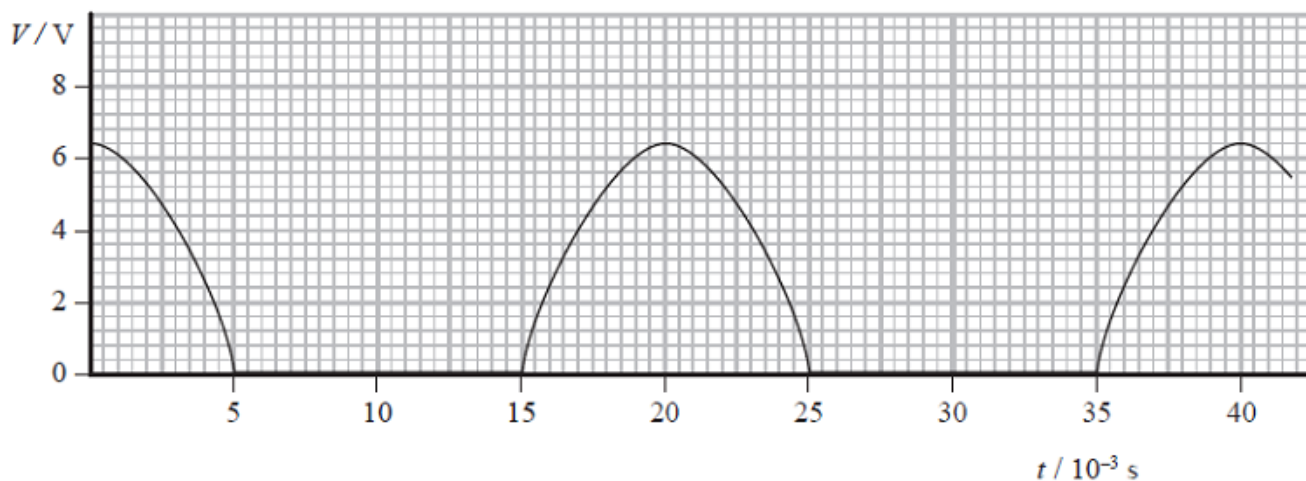
(1)

- A  $\frac{W}{4}$
- B  $\frac{W}{2}$
- C  $2W$
- D  $4W$

(Total for question = 1 mark)

Q10.

The graph shows how the output  $V$  from the terminals of a power supply labelled d.c. (direct current) varies with time  $t$ . This type of supply will not allow current to flow backwards through it.



(a) A student connects a capacitor across the terminals of this power supply in order to try to produce a constant voltage.

Suggest how this produces a constant voltage.

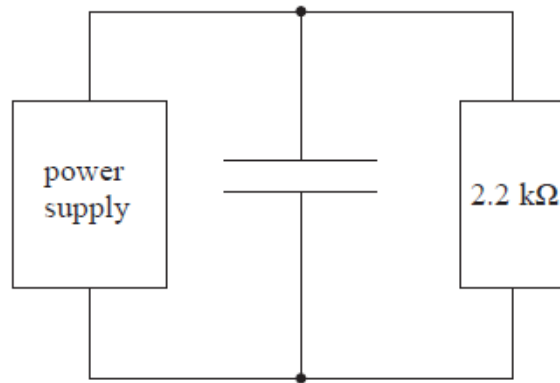
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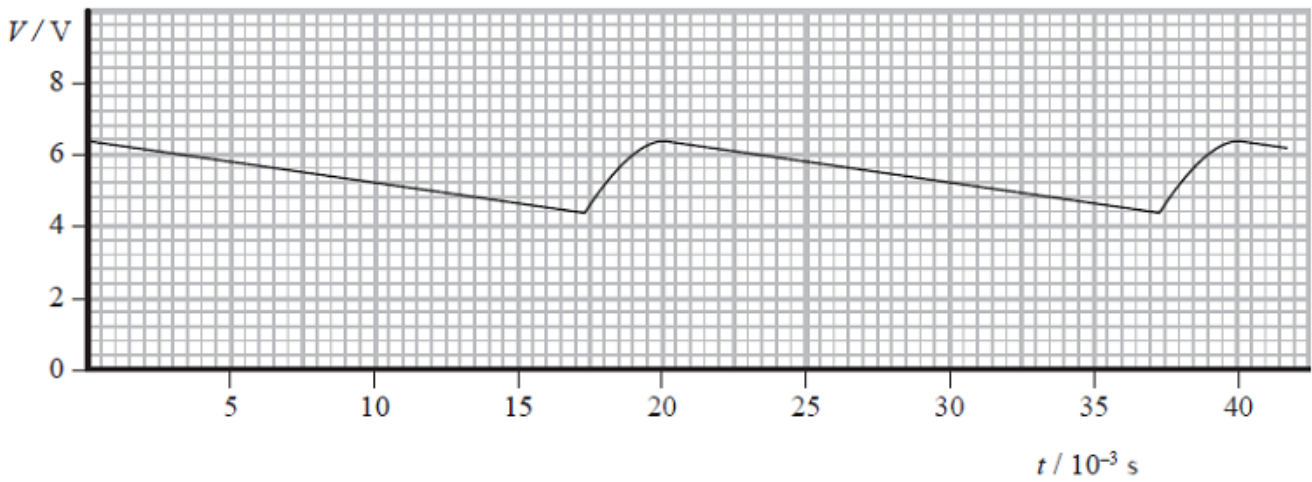
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(b) The student then connects a resistor across the capacitor as shown.



The graph shows the variation of the potential difference  $V$  across the resistor with time  $t$ .



(i) Estimate the average potential difference across the resistor.

(1)

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Average potential difference = .....

(ii) Calculate the average current in the resistor.

(2)

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Average current = .....

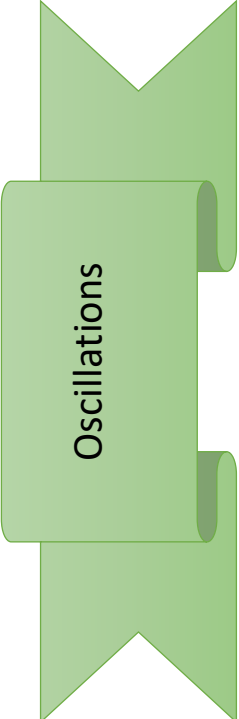
(iii) Determine the time in each cycle for which the capacitor discharges through the resistor.

(1)



# Week 8





Oscillations

**Circular motion**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 5.2.1 a                 | Can you describe the radian as a measure of angle?   | <input type="checkbox"/> |
| 5.2.1 b                 | Can you explain the period and frequency of an object in circular motion?  | <input type="checkbox"/> |
| 5.2.1 c                 | Can you understand angular velocity $\omega$ , $\omega = \frac{2\pi}{T}$ , or $\omega = 2\pi f$ ?                                | <input type="checkbox"/> |
| 5.2.2 a                 | Can you calculate a constant net force perpendicular to the velocity of an object, which causes it to travel in a circular path? | <input type="checkbox"/> |
| 5.2.2 b                 | Can you describe constant speed in a circle, $v = r\omega$ ?   | <input type="checkbox"/> |
| 5.2.2 c                 | Can you understand centripetal acceleration, $a = \frac{v^2}{r}$ and $a = \omega^2 r$ ?  | <input type="checkbox"/> |
| 5.2.2 d i               | Can you explain centripetal force, $F = \frac{mv^2}{r}$ and $F = m\omega^2 r$ ?  | <input type="checkbox"/> |
| 5.2.2 d ii              | Can you describe techniques and procedures used to investigate circular motion?  | <input type="checkbox"/> |

**Oscillations**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 5.3.1 a                 | Can you describe displacement, amplitude, period, frequency, angular frequency, and phase difference?                              | <input type="checkbox"/> |
| 5.3.1 b                 | Can you calculate angular frequency $\omega = 2\pi/T$ or $\omega = 2\pi f$ ?   | <input type="checkbox"/> |
| 5.3.1 f                 | Can you understand isochronous oscillators (the period of a simple harmonic oscillator is independent of its amplitude)?           | <input type="checkbox"/> |
| 5.3.1 c i               | Can you calculate simple harmonic motion, $a = -\omega^2 x$ ?  | <input type="checkbox"/> |
| 5.3.1 c ii              | Can you describe techniques and procedures used to determine the period and frequency of simple harmonic oscillations?             | <input type="checkbox"/> |
| 5.3.1 d                 | Can you calculate solutions to the equation $a = -\omega^2 x$ ?  | <input type="checkbox"/> |
| 5.3.1 e                 | Can you calculate velocity $v = \pm\omega \sqrt{A^2 - x^2}$ , hence $v_{\max} = \omega A$ ?  | <input type="checkbox"/> |
| 5.3.1 g                 | Can you explain graphical methods to relate the changes in displacement, velocity, and acceleration during simple harmonic motion? | <input type="checkbox"/> |
| 5.3.2 a                 | Can you describe the interchange between kinetic and potential energy during simple harmonic motion?                               | <input type="checkbox"/> |
| 5.3.2 b                 | Can you describe energy–displacement graphs for a simple harmonic oscillator?  | <input type="checkbox"/> |
| 5.3.3 b i               | Can you explain the effects of damping on an oscillatory system?   | <input type="checkbox"/> |
| 5.3.3 a                 | Can you define free and forced oscillations?   | <input type="checkbox"/> |
| 5.3.3 c                 | Can you explain natural frequency and resonance?   | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 5.3.3 b ii              | Can you describe observing forced and damped oscillations for a range of systems? | <input type="checkbox"/> |
| 5.3.3 d                 | Can you describe amplitude-driving frequency graphs for forced oscillators?       | <input type="checkbox"/> |
| 5.3.3 e                 | Can you explain practical examples of forced oscillations and resonance?          | <input type="checkbox"/> |

## Circular Motion

|  |  |
|--|--|
| How many radians are there in 360 degrees?   | $2\pi$   |
| What are the SI units of angular velocity?   | Radians per second.  |
| What is the definition of angular velocity?  | The rate of change of angle.   |
| How do you calculate angular velocity from time period (T)?                                    | Angular velocity = $2\pi / T$  |
| How do you calculate angular velocity from frequency (f)?                                      | Angular velocity = $2\pi f$  |
| What is required for uniform circular motion?  | A force that always acts perpendicular to velocity.  |
| Why doesn't a centripetal force do any work on an object in circular motion!                   | The force has no component in the direction of motion/is always perpendicular to motion.                   |
| How do you calculate linear velocity from the time period (T) of an object in circular motion? | $v = 2\pi r / T$   |
| How do you calculate linear velocity from angular velocity?                                    | $v = \text{angular velocity} \times \text{radius}$   |
| How is it possible for an object to experience an acceleration but travel at a constant speed? | If acceleration is perpendicular to velocity, the velocity will change direction whilst speed is constant. |
| What provides the centripetal force for a car turning a corner?                                | Friction from the road on the tyres.   |
| What provides the centripetal force on the moon?   | The gravitational attraction of the Earth.   |
| Apart from friction what contributes to the centripetal force on a banked track?               | The horizontal component of the normal reaction.   |
| If a mass on a string is swung in a vertical circle where is the tension greatest?             | At the bottom of the circle.   |
| If a mass on a string is swung in a vertical circle where is the tension least?                | At the top of the circle.  |

## Oscillations

|   |   |
|---|---|
| What is the equilibrium position in an oscillation?                                 | The point at which an object experiences no resultant force and thus no acceleration (the 'rest' position of an object).  |
| How many radians of phase are there in one complete oscillation?                    | $2\pi$  |
| How do you calculate the angular frequency of an oscillation?                       | $2\pi \times \text{the frequency of the oscillation}$   |
| What are the conditions required for SHM?   | The acceleration of an object is proportional, to its displacement from equilibrium and always in the opposite direction. |
| What is the acceleration of an object undergoing SHM when its displacement is zero? | Zero  |
| What is an Isochronous oscillator?  | An oscillator with a period/frequency that is not dependent on amplitude.   |
| What is a fiducial marker?  | A pin or pointer placed at the equilibrium position of an oscillation.  |

|   |   |
|---|---|
| What measures can be taken to improve the accuracy when measuring the time period of SHM? | Time over multiple oscillations and calculate the average of several repeats. |
| What is the kinetic energy of an SHM oscillator at maximum displacement?                  | Zero  |
| How does the total energy in an SHM oscillator vary with time?                            | It is constant.   |
| At what displacement is the potential energy of an SHM oscillator at a maximum?           | At maximum displacement ( $x=\pm A$ ).  |
| How do you calculate the total energy of an SHM oscillator from its amplitude?            | $E = \frac{1}{2} k A^2$   |

## Damping, driven oscillations and resonance

|   |   |
|---|---|
| What is a free oscillation?   | An oscillation in which no external driving force is present  |
| What causes damping of an oscillation?  | An external force opposing motion.  |
| What effect does damping of an oscillation have in terms of energy?                   | It transfers the KE of the oscillation to other forms, usually thermal energy.  |
| What is light damping of an oscillation?  | A small damping force causing the amplitude of the oscillations to decrease slowly.   |
| What is heavy damping of an oscillation?  | A damping force that results in a rapid decrease in the amplitude of oscillations.  |
| What is very heavy damping of an oscillation?   | A large damping force that prevents any oscillations of the system when its displaced.  |
| What is the natural frequency of an oscillator?                                       | The frequency at which oscillation will occur in a system with no external driving forces (free oscillations)                                 |
| What is a forced oscillation?   | An oscillation in which a (periodic) external driving force is present  |
| What is a driving frequency in oscillations?  | The frequency of the external driving force in a forced oscillation   |
| What is resonance?  | When the driving frequency of a forced oscillation is close to the natural frequency of the system resulting in large amplitude oscillations. |
| What is likely to occur when a mechanical system with little or no damping resonates? | The amplitude of the oscillations will increase until the object breaks.  |
| What occurs in terms of energy during resonance?                                      | There is the greatest possible transfer of energy from the driver to the forced oscillation.  |
| What effects does increasing damping have on resonance?                               | It reduces the maximum amplitude and it reduces the frequency of maximum amplitude.   |

A – What are the conditions required for circular motion?

B – An object undergoing uniform circular motion experiences a centripetal acceleration. Explain how it is possible that an object is constantly accelerating whilst its kinetic energy remains constant.

C – People often assume that when a car turns a sharp corner this creates a force throwing them outwards, in reality...

D - State the two conditions required for SHM

E – It is often assumed that oscillations of a mass on a spring have a smaller time period as the amplitude dies down since the mass travels a smaller distance in each oscillation but in reality...

## Questions

Q1. A mass is bouncing on the end of a vertical spring. Its motion will be simple harmonic if the spring

- A** can store energy.
- B** has elasticity.
- C** is hung vertically.
- D** obeys Hooke's law.

**(Total for Question = 1 mark)**

Q2.

Fission and fusion are both nuclear processes.

Which of the following statements is correct for both processes?

- A** Neutrons are released.
- B** No harmful radiation is produced.
- C** The binding energy per nucleon increases.
- D** The total mass increases.

**(Total for Question = 1 mark)**

Q3.

An object is hung from a vertical spring and undergoes undamped simple harmonic motion.

It is correct to say that there are **no** changes in the

- A** elastic potential energy of the oscillating system.
- B** gravitational potential energy of the oscillating system.

- C kinetic energy of the oscillating system.
- D total energy of the oscillating system.

**(Total for Question = 1 mark)**

Q4.

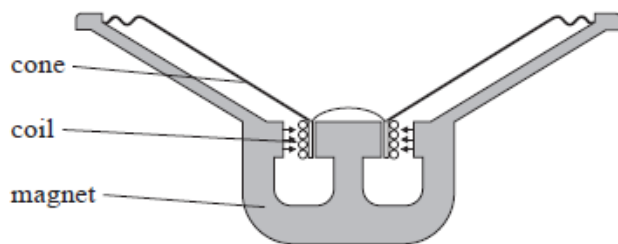
The damping force acting on an oscillating system is always

- A in the opposite direction to the acceleration.
- B in the opposite direction to the velocity.
- C in the same direction as the acceleration.
- D in the same direction as the velocity.

**(Total for question = 1 mark)**

Q5.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate.



The loudspeaker cone undergoes simple harmonic motion.

(i) State what is meant by simple harmonic motion.

(2)

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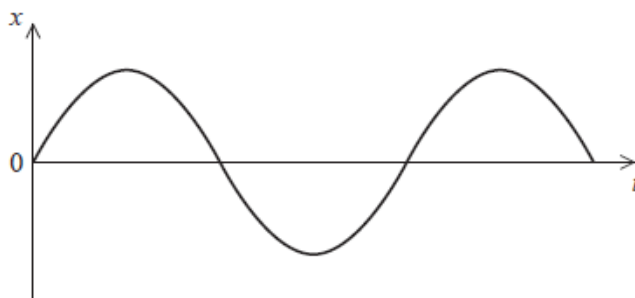
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(ii) The graph below shows how the displacement  $x$  of the cone varies with time  $t$ .

Add another line to the graph to show how the acceleration of the cone varies over the same time interval.

(1)



Q6.

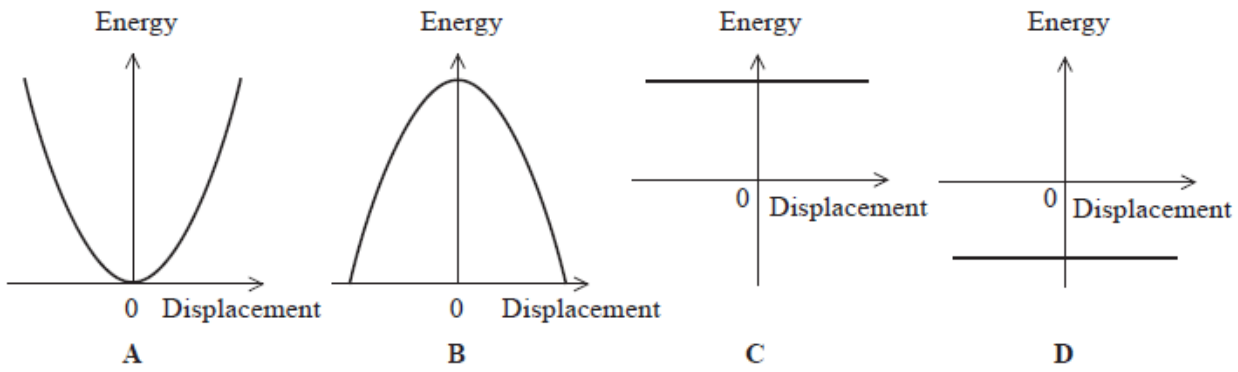
A very long pendulum set into oscillation continues to swing for several hours. During this time, as a result of the Earth's rotation, the pendulum will appear to change its direction of swing.

The movement of this pendulum is an example of

- A** critical oscillation.
- B** forced oscillation.
- C** free oscillation.
- D** resonant oscillation.

**(Total for question = 1 mark)**

Q7.

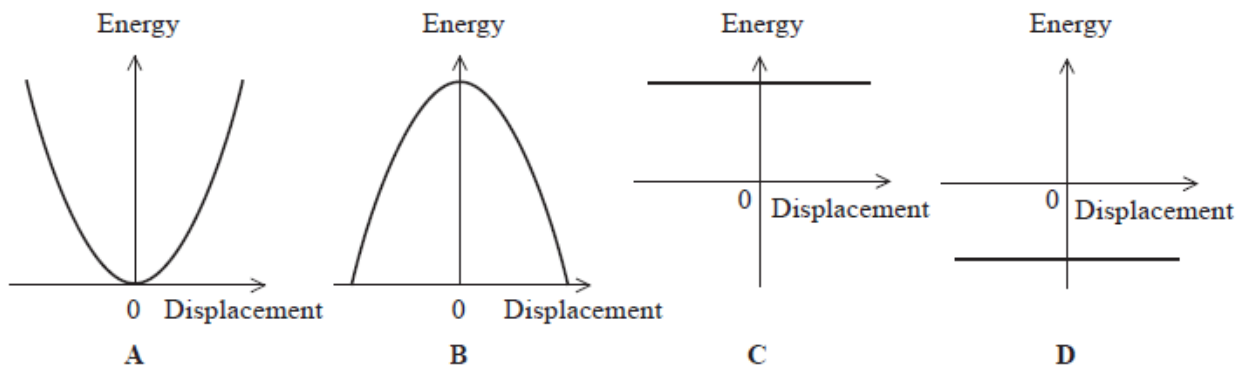


Which graph correctly shows the variation of potential energy with displacement for a particle undergoing simple harmonic motion?

- A
- B
- C
- D

(Total for question = 1 mark)

Q8.



Which graph correctly shows the variation of total energy with displacement for a particle undergoing simple harmonic motion?

- A
- B
- C
- D

**(Total for question = 1 mark)**

Q9.

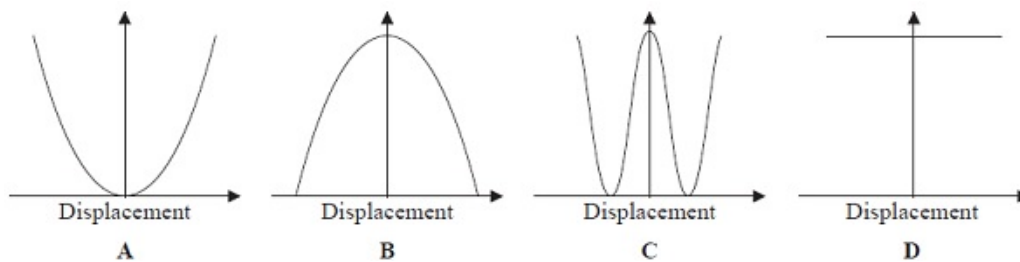
New buildings in earthquake zones are often designed to be earthquake resistant. Such buildings incorporate mechanisms to reduce the transfer of kinetic energy from the ground to the building.

Which of the following would be the most important property of a material used in such a mechanism?

- A** density
- B** ductility
- C** stiffness
- D** strength

**(Total for question = 1 marks)**

Q10.

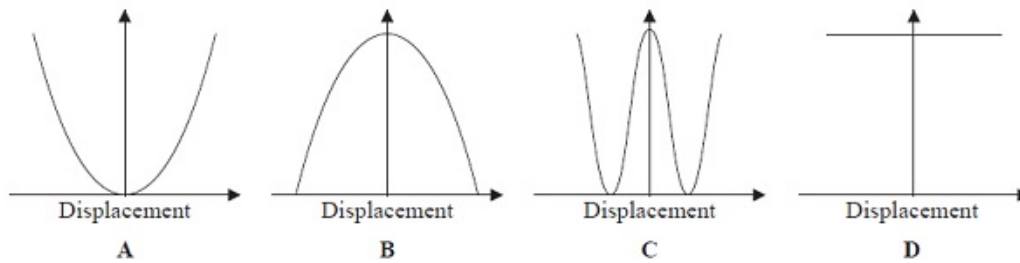


For an object undergoing simple harmonic motion select the graph that represents the variation of kinetic energy with displacement.

- A**
- B**
- C**
- D**

**(Total for Question = 1 mark)**

Q11.



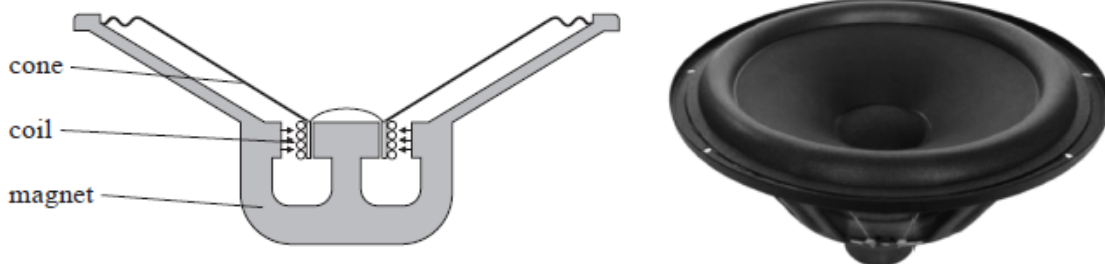
For an object undergoing simple harmonic motion select the graph that represents the variation of the total energy with displacement.

- A
- B
- C
- D

**(Total for Question = 1 mark)**

Q12.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate.



Some sand is sprinkled onto the cone. The sand oscillates vertically with the frequency of the cone. Keeping the frequency constant, the current is increased. This increases the amplitude of oscillation of the cone.

At a particular amplitude of oscillation the sand begins to lose contact with the cone.

(i) By considering the forces acting on a grain of sand, explain why this happens.

**(3)**

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(ii) At a particular frequency, when the amplitude of the cone is 0.25 mm, a grain of sand loses contact with the cone.

Calculate this frequency.

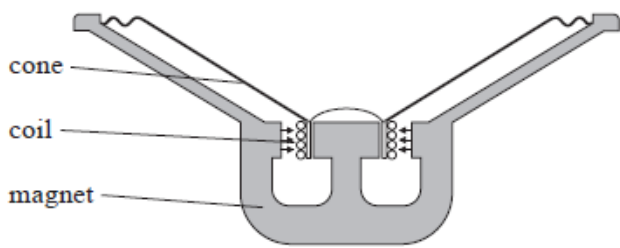
(3)

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Frequency = .....

Q13.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate.



\* Explain why an alternating current in the coil causes the cone to oscillate with the frequency of the alternating current.

(3)

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Q14.

A playground swing completes 24 oscillations in 1 minute.

Which of the following is the frequency of the oscillations?

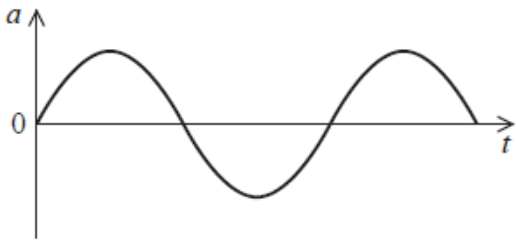
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- A** 0.042 Hz
- B** 0.40 Hz
- C** 2.5 Hz
- D** 24 Hz

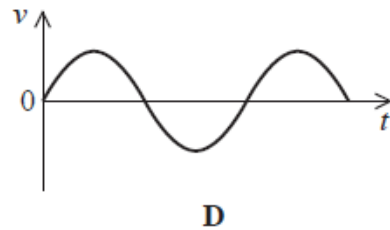
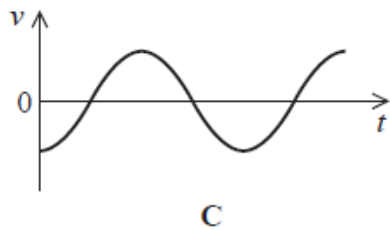
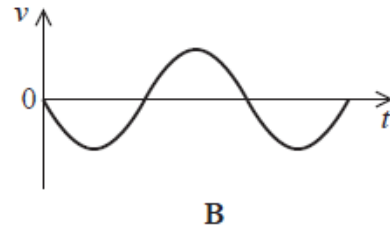
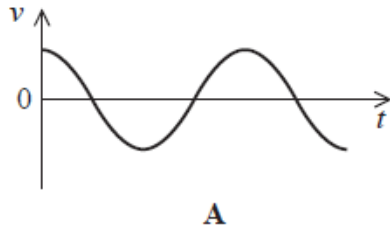
**(Total for question = 1 mark)**

Q15.

The graph shows how the acceleration varies with time for an object undergoing simple harmonic motion.



Which of the following graphs, **A**, **B**, **C** or **D**, shows how the velocity of the object varies with time?



- A**
- B**
- C**
- D**

**(Total for question = 1 mark)**

Q16.

A baby-bouncer is a light harness, into which a baby can be placed, suspended by a vertical spring.



The height of the baby-bouncer is adjusted so that the baby's feet are a few centimetres above the floor when the baby is in equilibrium in the harness. If the baby is then displaced downwards and released, the system oscillates vertically with simple harmonic motion.

It is stated in a textbook that "a mass-spring system that obeys Hooke's law will lead to simple harmonic motion when the mass is displaced."

\*(a) Explain why a system consisting of a mass and a spring that obeys Hooke's law may be set into simple harmonic motion.

(3)

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(b) The acceleration experienced by a baby of mass 8.2 kg is  $0.49 \text{ m s}^{-2}$  when the displacement from the equilibrium position is 3.0 cm.

Show that the period of vertical oscillations for this baby is about 1.6 s.

(3)

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(c) The amplitude of the oscillations quickly decreases, so the baby has to keep kicking on the floor to maintain them.

(i) State the name given to oscillations that die away quickly.

(1)

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(ii) State the name that is given to oscillations such as those that are kept going by the baby kicking on the floor.

(1)

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(iii) If the baby kicks on the floor at a certain frequency, the amplitude of the bounces can be made to increase to a maximum.

Name this effect and calculate the frequency at which it occurs.

(2)

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Frequency = .....

(d) The baby is replaced by a baby of less mass. This baby also kicks to produce maximum amplitude of oscillation. Without further calculation, explain how the frequency at which the baby must kick compares to that for the larger mass baby.

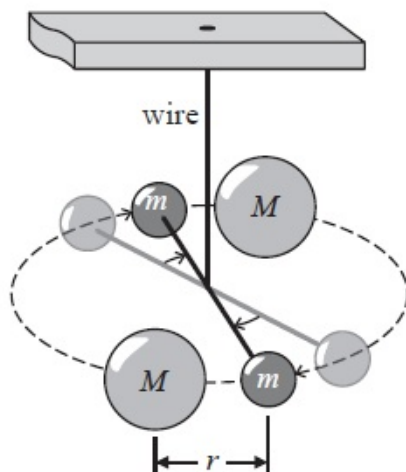
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**(Total for Question = 12 marks)**

Q17. In the 18th century Henry Cavendish devised an experiment to determine the average density of the Earth. This involved the first laboratory determination of the universal gravitational constant  $G$ .

A light horizontal rod with a small metal sphere at each end was hung from a fixed point by a very thin wire. Two large lead spheres were then brought close to the small spheres causing the rod to oscillate and then settle into a new position of equilibrium.



(a) In a modern version of the experiment the following data was obtained:

mass of large lead sphere  $M = 160 \text{ kg}$

mass of small sphere  $m = 0.75 \text{ kg}$

distance  $r = 0.23 \text{ m}$

gravitational force between adjacent large and small spheres  $F = 1.5 \times 10^{-7} \text{ N}$ .

Use this data to calculate a value for  $G$ .

(2)

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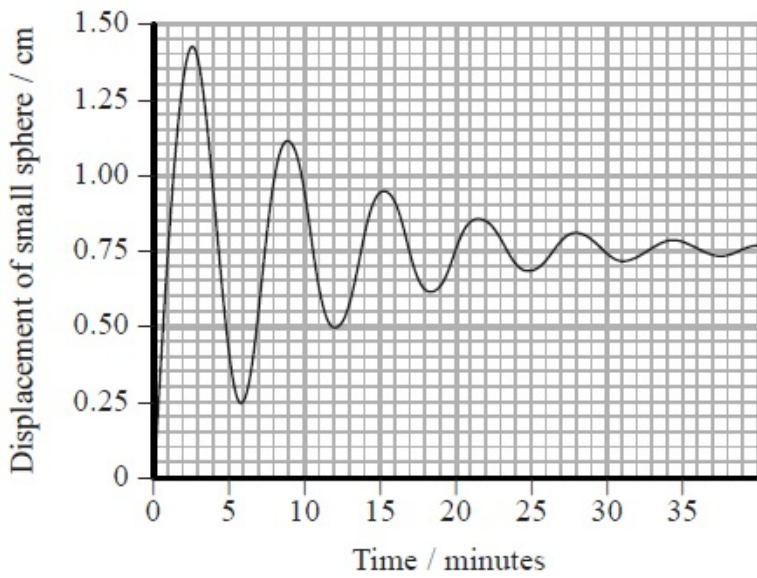
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$G = \dots\dots\dots \text{Nm}^2 \text{kg}^{-2}$

(b) The graph shows how the displacement of one of the small spheres varies with time.



(i) Use the graph to determine the period of oscillation of the sphere.

(2)

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Period = .....

(ii) The amplitude of the oscillation decreases with each cycle.

Explain why this effect is observed.

(2)

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(iii) It is suggested that the decrease in amplitude is exponential. Use the graph to determine if this is approximately true.

(3)

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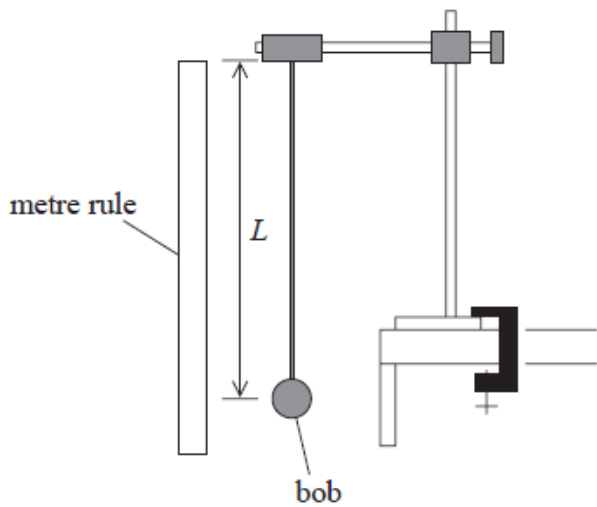
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**(Total for Question = 9 marks)**

Q18.

A student set up a "seconds pendulum". This is a simple pendulum for which the time taken to move from the bob's highest position on one side to its highest position on the opposite side is 1.00 s.



(a) Calculate the length  $L$  required for the pendulum to be a "seconds pendulum".

(2)

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$L =$  .....

(b) The student set the pendulum into oscillation. She used a stopwatch to check the accuracy of the pendulum's period  $T$ .



Q19.

Figure 1 shows a wine glass being driven into oscillation at its natural frequency by a high-power loudspeaker. The loudspeaker is close to, but not touching, the glass. The loudspeaker is driven by a sine-wave generator.



Figure 1



Figure 2

In Figure 2, the amplitude of vibration of the glass has become so large that the glass shatters.

(a) (i) Name the effect being demonstrated.

(1)

.....

(ii) Explain why this effect occurs.

(2)

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(b) A rubber band may be placed around the glass to provide some damping. This would reduce the amplitude of vibration and prevent the glass from shattering.

Explain how a rubber band around the glass would provide damping.

(2)

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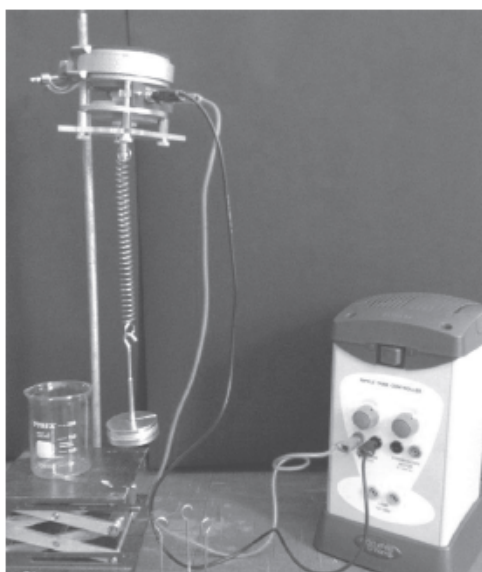
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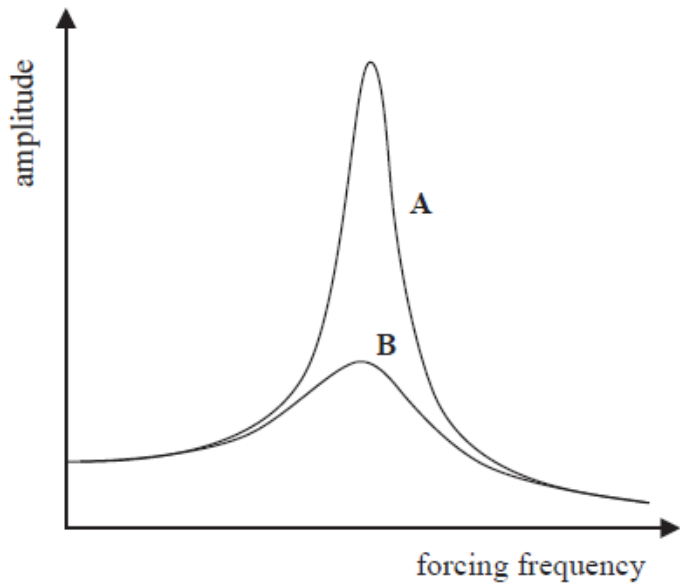
**(Total for question = 5 marks)**

Q20.

\* A student uses the apparatus shown below to investigate the behaviour of a mass-spring system when it is forced into oscillation.



The graph shows how the amplitude of the oscillating mass varies over a range of forcing frequencies.



Curve A shows the results of the investigation using the apparatus as shown.

The student repeats the investigation with the oscillating mass in a beaker of water. Curve B shows these results.

Making reference to important features in the graph, describe and explain the two sets of results.

(4)

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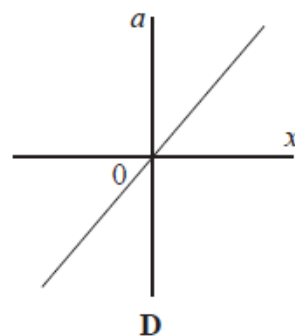
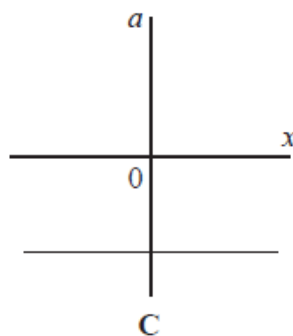
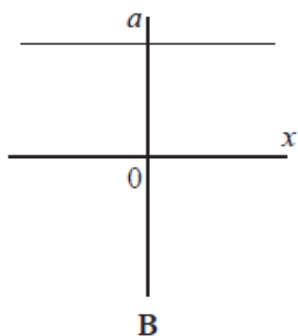
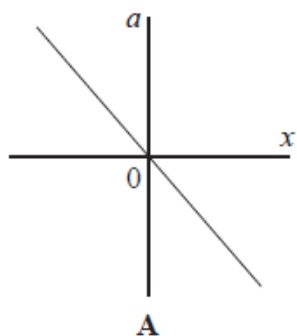
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**(Total for question = 4 marks)**

An object is undergoing simple harmonic motion.

Which graph shows how the acceleration  $a$  varies with displacement  $x$  from the equilibrium position?



A

B

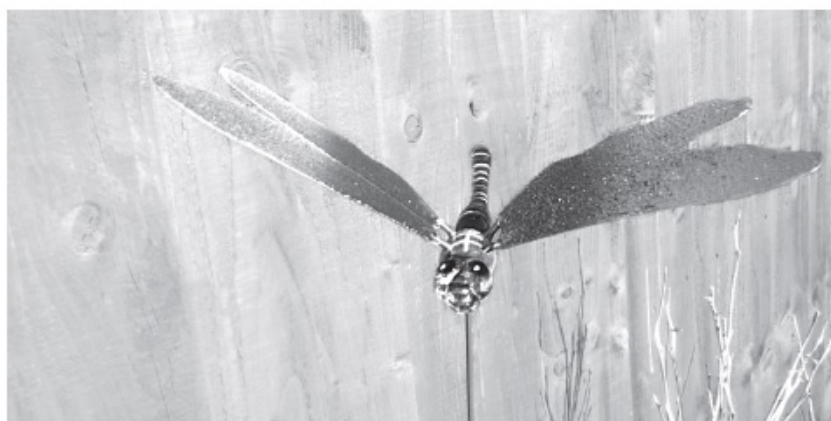
C

D

**(Total for question = 1 mark)**

Q22.

A garden ornament consists of a plastic dragonfly mounted on a stick. The dragonfly's wings are attached to the body with springs, and they flutter up and down in a gentle breeze.



(a) When the air is not moving and the wings are displaced through a small vertical distance, they oscillate. The time for 10 oscillations is recorded. This is repeated twice more.

| Time / s |       |       |
|----------|-------|-------|
| $t_1$    | $t_2$ | $t_3$ |
| 6.2      | 6.6   | 6.9   |

(i) Calculate the frequency of oscillation of the wings

(3)

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Frequency = .....

(ii) The oscillation of the wings is thought to be simple harmonic motion.

State the conditions required for the oscillations to be simple harmonic.

(2)

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(b) The amplitude of the wings' oscillation dies down after only a small number of oscillations.

Explain why this happens

(2)

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(c) In certain breezy conditions the wings are seen to oscillate with a very large amplitude.

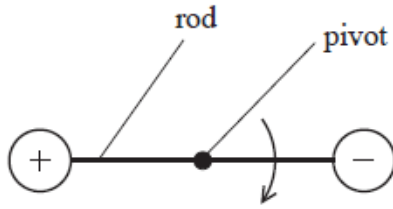
Name this effect and state the condition for it to occur.


(2)

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stationary charged sphere 



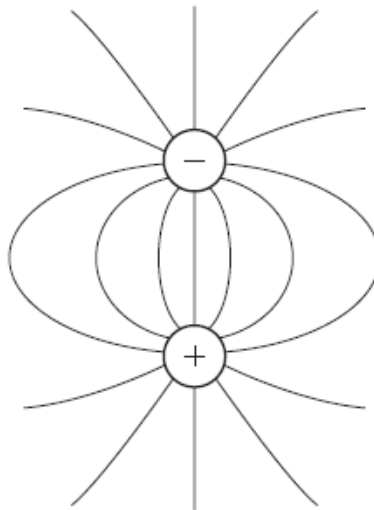
 stationary charged sphere

(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere =  $0.10 \mu\text{C}$

(2)

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

|                 | Power / W         | Angular velocity / rad s <sup>-1</sup> |
|-----------------|-------------------|--|
| Electric car    | $2.0 \times 10^4$ | 300                                    |
| Vacuum cleaner  | $1.4 \times 10^3$ | 1000                                   |
| Small pond pump | 0.5               | 200                                    |

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

(4)

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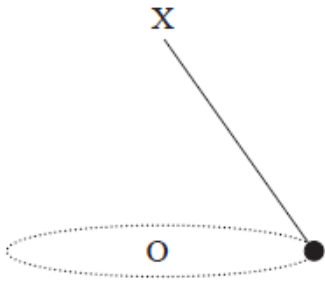
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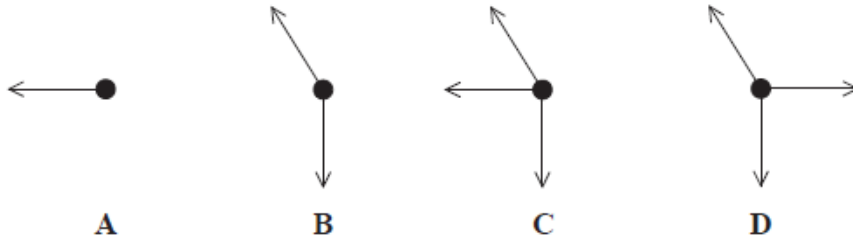
**(Total for question = 13 marks)**

Q24.

A mass is attached to a light thread which is fixed at X.  
The mass is moving at constant speed in a horizontal circle, centre O.



Which of the following is a correct free-body force diagram for this mass?



(1)

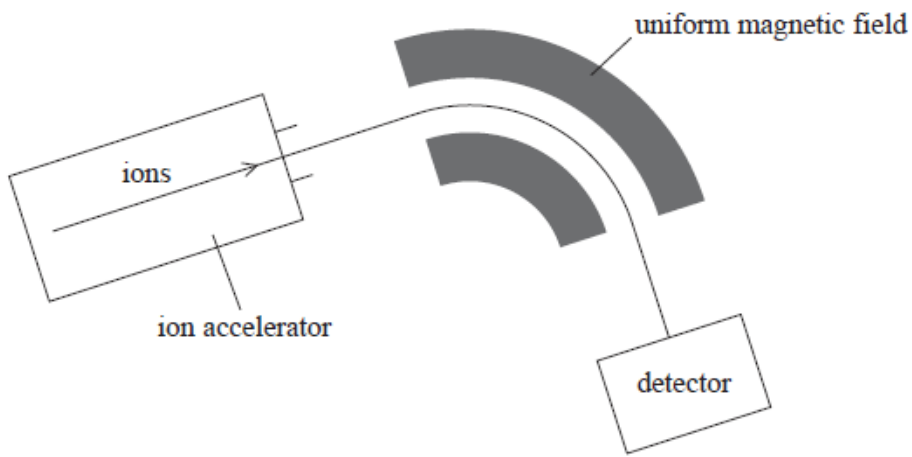
- A
- B
- C
- D

**(Total for question = 1 mark)**

Q25.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam. This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

After passing through the velocity selector the ion beam enters a region of uniform magnetic flux density 0.35 T with the ions travelling at right angles to the field direction.

(i) Explain why the ions travel in a circular path.

(2)

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(ii) Calculate the radius of the circular path.

(2)

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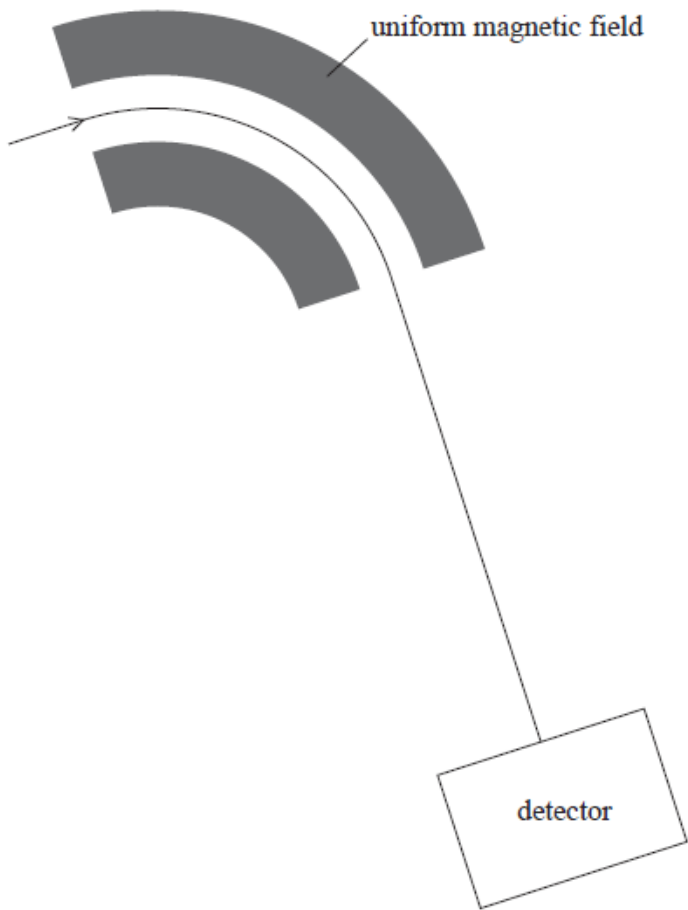
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Radius = .....

(iii) The diagram shows the path of the chlorine-35 ions in the field. Chlorine-37 ions enter the magnetic field with the same velocity.



1. Add another line to the diagram to show the path of these chlorine-37 ions.

(1)

2. Explain any differences in the paths.

(2)

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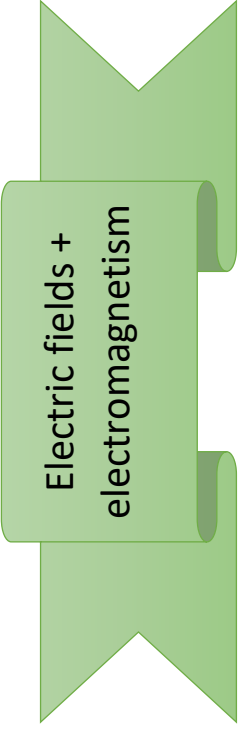
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**(Total for question = 7 marks)**

**Mark Scheme**

# Week 9





Electric fields +  
electromagnetism

## Electric fields

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 6.2.1 a                 | Can you explain electric fields being due to charges?  | <input type="checkbox"/> |
| 6.2.1 b                 | Can you understand a uniformly charged sphere modelled as a point charge at its centre?  | <input type="checkbox"/> |
| 6.2.1 c                 | Can you describe using electric field lines to map electric fields?  | <input type="checkbox"/> |
| 6.2.1 d                 | Can you demonstrate that electric field strength is $E = \frac{F}{Q}$ ?  | <input type="checkbox"/> |
| 6.2.2 a                 | Can you demonstrate Coulomb's law, $F = \frac{Qq}{4\pi\epsilon_0 r^2}$ , for the force between two point charges?  | <input type="checkbox"/> |
| 6.2.2 b                 | Can you calculate electric field strength, $E = \frac{Q}{4\pi\epsilon_0 r^2}$ , for a point charge?  | <input type="checkbox"/> |
| 6.2.2 c                 | Can you describe the similarities and differences between the gravitational field of a point mass and the electric field of a point charge?                    | <input type="checkbox"/> |
| 6.2.3 a                 | Can you calculate uniform electric field strength, $E = \frac{V}{d}$ ?   | <input type="checkbox"/> |
| 6.2.3 b                 | Can you explain parallel-plate capacitor and permittivity: $C = \frac{\epsilon_0 A}{d}$ ,<br>$C = \frac{\epsilon A}{d}$ , $\epsilon = \epsilon_r \epsilon_0$ ? | <input type="checkbox"/> |
| 6.2.3 c                 | Can you describe the motion of charged particles in a uniform electric field?  | <input type="checkbox"/> |

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 6.2.4 a                 | Can you describe electric potential as the work done in bringing a unit charge from infinity to a point? | <input type="checkbox"/> |
| 6.2.4 b                 | Can you calculate electric potential, $V = \frac{Q}{4\pi\epsilon_0 r}$ ?                                 | <input type="checkbox"/> |
| 6.2.4 c                 | Can you calculate capacitance, $C = 4\pi\epsilon_0 R$ , for an isolated sphere?                          | <input type="checkbox"/> |
| 6.2.4 d                 | Can you demonstrate force–distance graphs for point or spherical charges?                                | <input type="checkbox"/> |
| 6.2.4 e                 | Can you calculate electric potential energy, $E = Vq = \frac{Qq}{4\pi\epsilon_0 r}$ ?                    | <input type="checkbox"/> |

## Magnetic fields

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 6.3.1 a                 | Can you explain moving charges or permanent magnets as causes of magnetic fields?   | <input type="checkbox"/> |
| 6.3.1 b                 | Can you demonstrate using magnetic field lines to map magnetic fields?  | <input type="checkbox"/> |
| 6.3.1 c                 | Can you describe magnetic field patterns for a long straight current-carrying conductor, a flat coil, and a long solenoid?  | <input type="checkbox"/> |
| 6.3.1 d                 | Can you define Fleming's left-hand rule?  | <input type="checkbox"/> |
| 6.3.1 e i               | Can you calculate the force on a current-carrying conductor, $F = BIL \sin\theta$ ?   | <input type="checkbox"/> |
| 6.3.1 e ii              | Can you describe the techniques and procedures used to determine the uniform magnetic flux density between the poles of a magnet using a current-carrying wire and digital balance? | <input type="checkbox"/> |
| 6.3.1 f                 | Can you define magnetic flux density and the unit tesla?  | <input type="checkbox"/> |
| 6.3.2 a                 | Can you calculate the force on a charged particle travelling at right angles to a uniform magnetic field, $F = BQV$ ?   | <input type="checkbox"/> |
| 6.3.2 b                 | Can you describe the movement of charged particles in a uniform magnetic field?   | <input type="checkbox"/> |
| 6.3.2 c                 | Can you describe the movement of charged particles moving in a region occupied by both electric and magnetic fields?  | <input type="checkbox"/> |
| 6.3.2 c                 | Can you define velocity selector?   | <input type="checkbox"/> |
| 6.3.3 a                 | Can you explain magnetic flux $\phi$ , the unit weber and $\phi = BA \cos\theta$ ?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 6.3.3 b                 | Can you define magnetic flux linkage?   | <input type="checkbox"/> |
| 6.3.3 c                 | Can you describe Faraday’s law of electromagnetic induction?  | <input type="checkbox"/> |
| 6.3.3 c                 | Can you define Lenz’s law?  | <input type="checkbox"/> |
| 6.3.3 d                 | Can you demonstrate that e.m.f. = – rate of change of magnetic flux linkage, $\varepsilon = - \frac{\Delta(N\phi)}{\Delta t}$ , and explain techniques and procedures used to investigate magnetic flux using search coils? | <input type="checkbox"/> |
| 6.3.3 e                 | Can you describe a simple a.c. generator?   | <input type="checkbox"/> |
| 6.3.3 f i               | Can you describe a simple laminated, iron-cored transformer?  | <input type="checkbox"/> |
| 6.3.3 f i               | Can you explain $\frac{n_s}{n_p} = \frac{V_s}{V_p} = \frac{I_s}{I_p}$ for an ideal transformer?   | <input type="checkbox"/> |
| 6.3.3 f ii              | Can you explain the techniques and procedures used to investigate transformers?   | <input type="checkbox"/> |

## Electric Fields

|   |  |
|---|--|
| What is an electric field?  | A region of space where a charge will experience an electrostatic force.   |
| What is the definition of electric field strength?  | The force per unit charge on a positive test charge placed at that point   |
| What are the units of electric field strength?  | $\text{NC}^{-1}$ (or $\text{Vm}^{-1}$ )  |
| What does $\epsilon_0$ represent?   | permittivity of free space   |
| What does $\epsilon_r$ represent?   | Relative permittivity (of a dielectric).   |
| What does the direction of an electric field line show?   | The direction of the force exerted on a positive test charge.  |
| What does the spacing of electric field lines show?   | Field strength.  |
| Are test charges positive or negative?  | positive   |
| What units equivalent to $\text{Vm}^{-1}$   | $\text{N C}^{-1}$  |
| When is the equation $E = V/d$ used?  | To find the uniform field strength between two parallel plates.  |
| What is a dipole?   | A pair of opposite sign charges separated by a small distance (e.g. a polar molecule like HCl)   |
| State Coulomb's law in words.   | The force between two point charges is proportional to the product of the two charges and inversely proportional to the square of their separation distance. |
| What is electric potential difference?  | The work done per unit positive charge in moving between two points  |
| What is the definition of absolute electric potential of a point?   | The work done per unit positive charge to move from infinity to that point in the field.   |
| What is the absolute electric potential an infinite distance from a 1C charge?                                    | 0  |
| What units are equivalent to a V?   | $\text{J C}^{-1}$  |
| What is the relationship between the electrostatic force between two point charges and their separation distance? | It is inversely proportional to the square of separation OR inverse square law   |
| What is the relationship between potential and distance from a point charge?                                      | Potential $\propto 1/\text{distance}$  |
| What is a uniform electric field?   | A region of space in which the electric field strength is the same at all points   |

|  |   |
|--|---|
| What is a radial field?  | An electric field generated by a point charge OR a field that obeys the inverse square law.   |
| What is a neutral point in an electric field?                                      | A point at which the resultant field strength is zero   |
| Is electric field strength a vector or a scalar quantity?                          | Vector  |
| Is electrical potential a vector or scalar quantity?                               | Scalar  |
| State a similarity between electric and gravitational fields.                      | Both obey inverse square law for field strength (around a point mass/charge). Both have infinite range. Both act between two objects at a distance.   |
| State two differences between electric and gravitational fields?                   | Gravitational fields act on masses, electric fields on charges: electric fields are much stronger than gravitational fields: electric fields can be attractive or repulsive, gravitational fields are always attractive: potential is always negative in a gravitational field. |
| When is the equation $V = Q / (4 \pi \epsilon_0 r)$ used?                          | To find the potential around a point charge/in a radial field.  |
| When is the equation $C = 4 \pi \epsilon_0 \times R$ used?                         | To calculate the capacitance on an isolated sphere.   |
| What is represented by R in the equation $C = 4 \pi \epsilon_0 \times R$ used?     | The radius of an isolated sphere.   |
| What is the relationship between electric potential energy and electric potential? | $EPE = V \times q$ where q is the charge in the field.  |

### Key Ideas:

A – State the equations for field strength and potential around a point charge and sketch what the graphs of these quantities look like around a positive and negative charge.

B – It is sometimes assumed that electric fields only exist close to charged objects but in reality...

C – Electric fields are similar in many ways to gravitational fields. List below ways in which g fields and E fields are similar and ways in which they are different.

D – Why does a current carrying wire experience a force when placed in a magnetic field? How do you determine the magnitude and direction of the force?

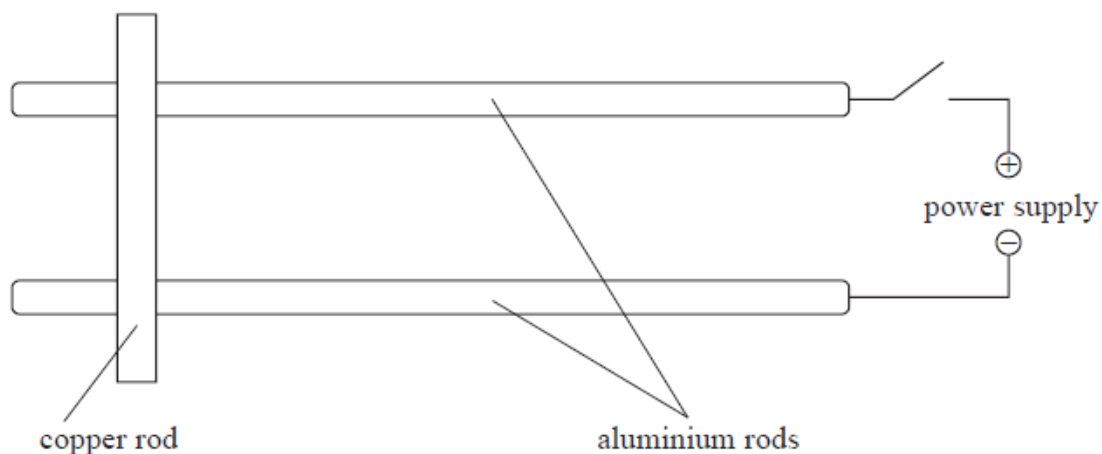
E – Flux, flux density, flux linkage and Induced EMFs are all closely related concepts. Write down all equations relevant to determining these quantities and summarise the relationships between them.

F – Faraday's and Lenz's laws tell us how the process of Electromagnetic induction works. State both laws and then describe 1 or 2 examples that show the two laws in action and explain how they apply.

## Questions

Q1.

The apparatus shown in the diagram can be used to demonstrate that a force acts on a current-carrying conductor when the conductor is in a magnetic field.



The apparatus is placed in a magnetic field. When the switch is closed, the copper rod rolls along the aluminium rods.

(a) Add to the diagram to indicate the direction of the current in the copper rod.

(1)

(b) State the direction of the magnetic field that will make the copper rod move to the right.

(2)

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**(Total for question = 3 marks)**

Q2.

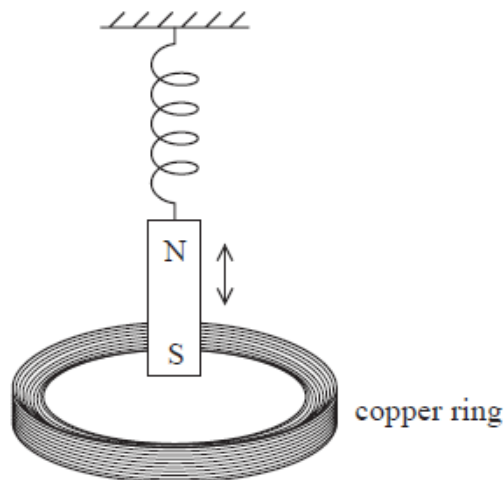
What is the acceleration of an electron at a point in an electric field where the electric field strength is  $2.0 \times 10^4 \text{ N C}^{-1}$ ?

- A**  $2.8 \times 10^{-16} \text{ m s}^{-2}$
- B**  $3.2 \times 10^{-15} \text{ m s}^{-2}$
- C**  $1.8 \times 10^{11} \text{ m s}^{-2}$
- D**  $3.5 \times 10^{15} \text{ m s}^{-2}$

**(Total for question = 1 mark)**

Q3.

\* A magnet is attached to the end of a spring as shown in the diagram.



The magnet is displaced vertically and released so that it oscillates.

The average vertical component of the magnetic flux density through the coil varies at a maximum rate of  $0.035 \text{ T s}^{-1}$ .

Calculate the maximum current in the copper ring.

radius of copper ring = 5.0 cm

resistance of copper ring =  $6.7 \times 10^{-5} \Omega$

**(4)**

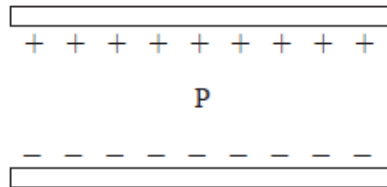
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**(Total for question = 2 marks)**

Q5.

The diagram shows two metal plates with uniformly distributed electric charge.



Explain the direction of the electric field at point P due to all of the charges on the plates.

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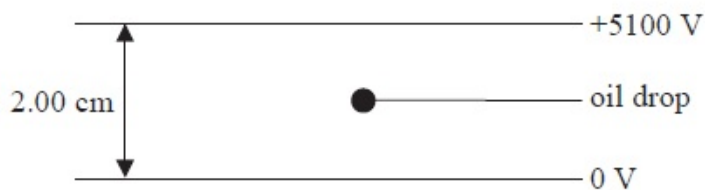
**(Total for question = 4 marks)**

Q6. The charge on an electron was originally measured in an experiment called the Millikan Oil Drop experiment.

In a simplified version of this experiment, an oil drop with a small electric charge is placed between two horizontal, parallel plates with a large potential difference (p.d.) across them. The

p.d. is adjusted until the oil drop is stationary.

For a particular experiment, a p.d. of 5100 V was required to hold a drop of mass  $1.20 \times 10^{-14}$  kg stationary.



(a) Add to the diagram to show the electric field lines between the plates.

(3)

(b) State whether the charge on the oil drop is positive or negative.

(1)

.....  
(c) Complete the free-body force diagram to show the forces acting on the oil drop. You should ignore upthrust.

(2)



(d) (i) Calculate the magnitude of the charge on the oil drop.

(4)

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Charge = .....

(ii) Calculate the number of electrons that would have to be removed or added to a neutral oil drop for it to acquire this charge.

(2)

Number of electrons = .....

**(Total for Question = 12 marks)**

Q7. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.



(a) Mark on the diagram the direction of the electric field.

(1)

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

(3)

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Force = .....

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

(3)

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(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

(1)

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of  $1.2 \times 10^7 \text{ m s}^{-1}$ .

Calculate the potential difference required to accelerate an electron from rest to this speed.

(3)

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Potential difference = .....

**(Total for Question = 11 marks)**

Q8.

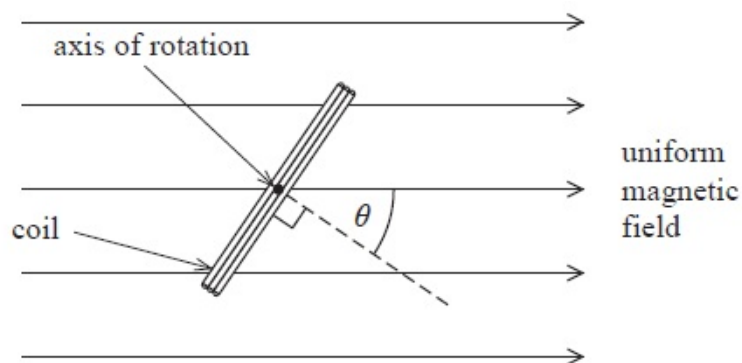
A potential difference of 50 V is applied between two identical parallel aluminium plates. The plates are separated by a distance of 10 mm.

Which combination of potential difference and separation would double the electric field strength?

|                            | Separation/mm | Potential difference/ V |
|----------------------------|---------------|-------------------------|
| <input type="checkbox"/> A | 20            | 100                     |
| <input type="checkbox"/> B | 20            | 25                      |
| <input type="checkbox"/> C | 10            | 100                     |
| <input type="checkbox"/> D | 10            | 25                      |

(Total for question = 1 mark)

Q9. The diagram shows an end view of a simple electrical generator. A rectangular coil of wire is rotated in a uniform magnetic field of magnetic flux density  $3.0 \times 10^{-2}$  T. The axis of rotation is at right angles to the field direction.



(a) The coil has 200 turns and an area of  $2.0 \times 10^{-4}$  m<sup>2</sup>.

Calculate the magnetic flux linkage for the coil when  $\theta = 0^\circ$ .

(2)

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Flux linkage = .....

(b) The coil is rotated at a constant rate of 2 revolutions per second.

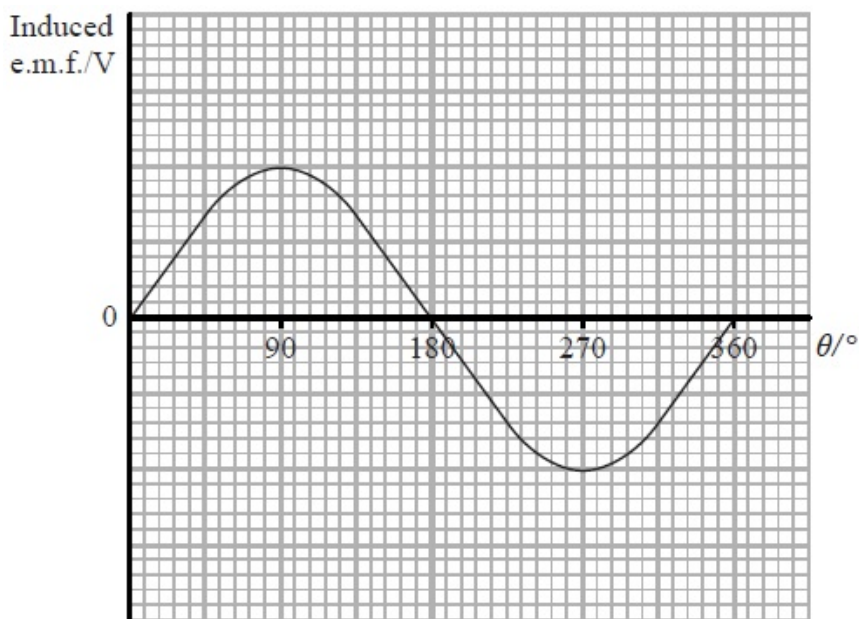
(i) Calculate the average e.m.f. induced in the time taken for the coil to rotate from  $\theta = 0^\circ$  to  $\theta = 90^\circ$

(3)

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Average e.m.f. = .....

(ii) The graph shows how the induced e.m.f. varies over one cycle of rotation of the coil.



Explain why the magnitude of the e.m.f. is smallest and greatest at the values of  $\theta$  shown in the graph.

(3)

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(iii) State and explain how the graph would differ if the coil rotated at a slower rate.

(2)

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(c) Vehicles such as electric cars are driven by electric motors. These vehicles use regenerative braking to reduce the speed of the vehicle. The motor is operated as a generator during braking and the output from the generator is used to recharge the batteries of the car.

(i) Explain how using the motor as a generator slows the car down.

(2)

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(ii) In practice, these vehicles also use friction braking as well as regenerative braking. This is because regenerative braking on its own will not fully stop a car. Suggest why.

(2)

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**(Total for Question = 14 marks)**

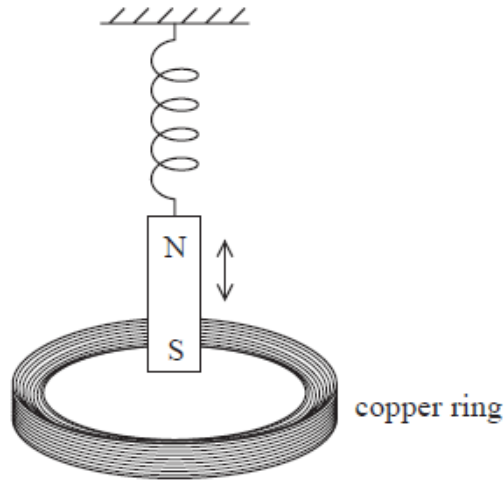
Q10.

(a) State Faraday's law of electromagnetic induction.

(2)

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\*(b) A magnet is attached to the end of a spring as shown in the diagram.



The magnet is displaced vertically and released so that it oscillates. Explain why this produces an alternating current in the copper ring.

(4)

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Q11.

A capacitor of capacitance  $C$  has a potential difference  $V$  across it. The energy stored on the capacitor is  $Z$  joules. A second capacitor of capacitance  $C/2$  has a potential difference  $2V$  across it.

The energy stored on the second capacitor is

**A**  $Z$

**B** 2Z

**C** 4Z

**D** 8Z

**(Total for question = 1 mark)**

Q12.

A proton in a particle detector is travelling in a direction perpendicular to the magnetic field. The proton moves in a curved path. At one point the radius of the path is 0.091 m.

Calculate the force acting on the proton at this point.

**(2)**

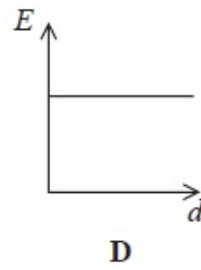
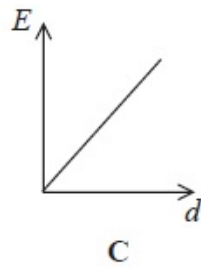
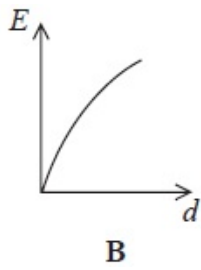
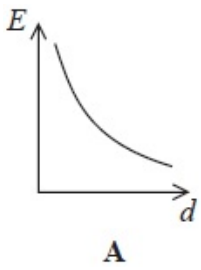
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Force = .....

**(Total for question = 2 marks)**

Q13. Two parallel, conducting plates are connected to a battery. One plate is connected to the positive terminal and the other plate to the negative terminal. The plate separation  $d$  is gradually increased while the plates stay connected to the battery.

Select the graph that shows how the electric field strength  $E$  between the plates varies with separation  $d$ .

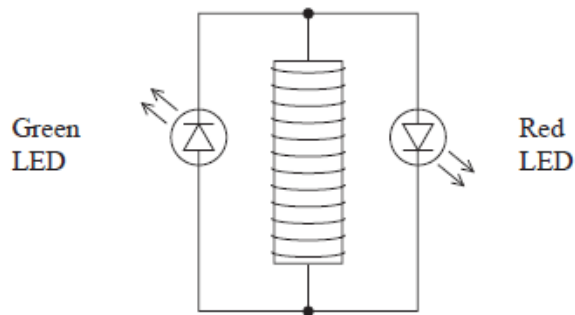


- A
- B
- C
- D

**(Total for Question = 1 mark)**

Q14.

Red and green light emitting diodes (LED) are connected in parallel across a coil of wire as shown.



A magnet is pushed into the coil and then withdrawn.

The following observations are made:

- as the north pole of a magnet is pushed into the coil the green LED lights briefly
- the red LED lights briefly as the north pole is withdrawn
- neither LED lights when the magnet is moving completely within the coil.

Explain, with reference to Lenz's law, how the magnet does work as it enters the coil.

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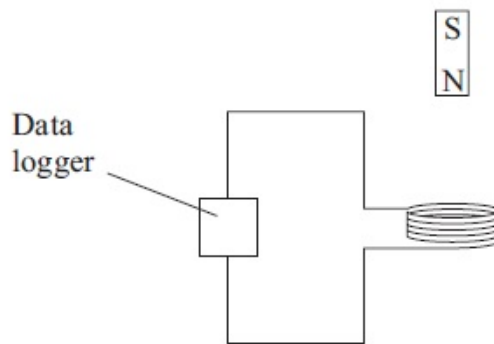
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**(Total for question = 4 marks)**

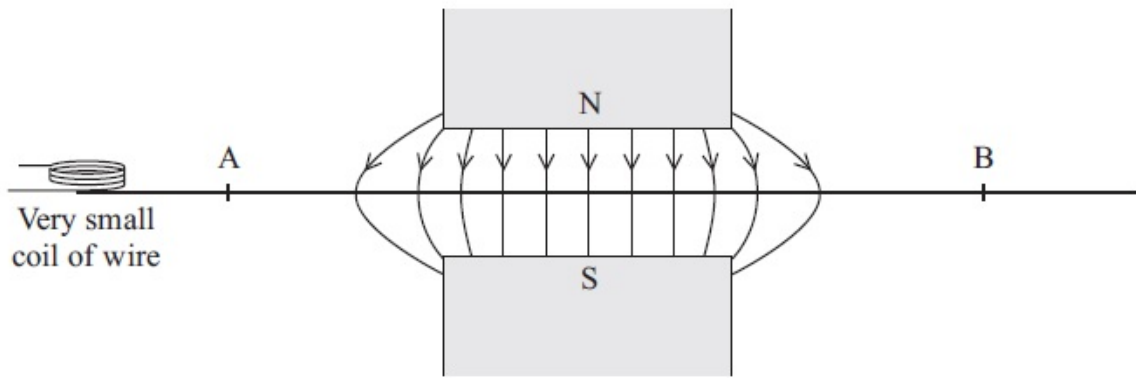
Q15.

A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



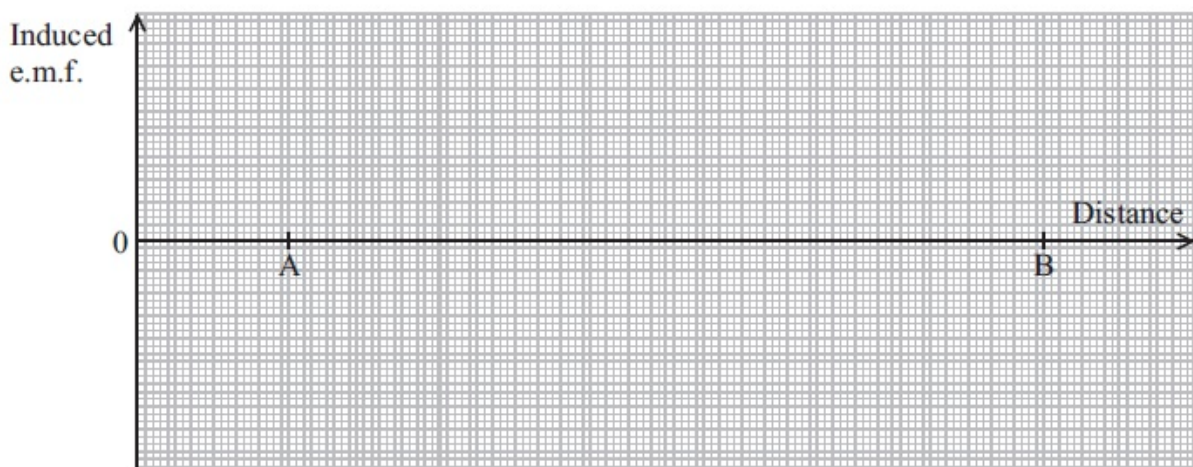
The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.





Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

(4)



**(Total for question = 10 marks)**

Q16.

A student investigating the motor effect places a wire between two magnets on a holder, as shown in the photograph.



The arrangement is placed on a digital balance calibrated to display force. The reading on the

balance is 1.4776 N.

When there is a current of 0.82 A in the wire, the reading on the balance becomes 1.4772 N.

Determine the magnetic flux density between the two magnets.

length of wire in the field = 5.0 cm

(2)

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.....  
.....

Magnetic flux density = .....

**(Total for question = 2 marks)**

Q17. A charged, non-magnetic particle is moving in a magnetic field.

Which of the following would **not** affect the magnetic force acting on the particle

- A** the magnitude of the charge on the particle
- B** the strength of the magnetic field
- C** the velocity component parallel to the magnetic field direction
- D** the velocity component perpendicular to the magnetic field direction

**(Total for Question = 1 mark)**

Q18. The magnetic force  $F$  that acts on a current-carrying conductor in a magnetic field is given by the equation

$$F = BIl.$$

(a) State the condition under which this equation applies.

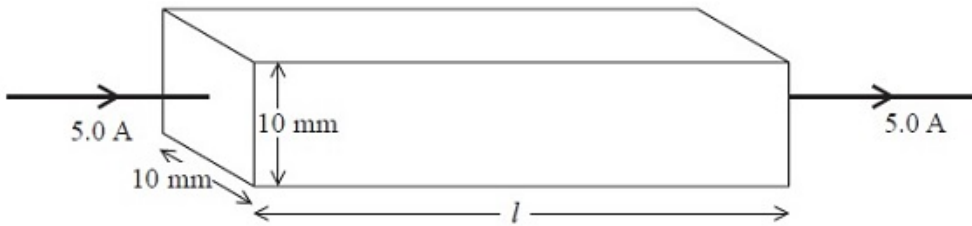
(1)

(b) The unit for magnetic flux density  $B$  is the tesla.

Express the tesla in base units.

(2)

(c) The diagram shows a rectangular bar of aluminium which has a current of 5.0 A through it.



The bar is placed in a magnetic field so that its weight is supported by the magnetic field.

Calculate the minimum value of the magnetic flux density  $B$  needed for this to occur.

density of aluminium =  $2.7 \times 10^3 \text{ kg m}^{-3}$

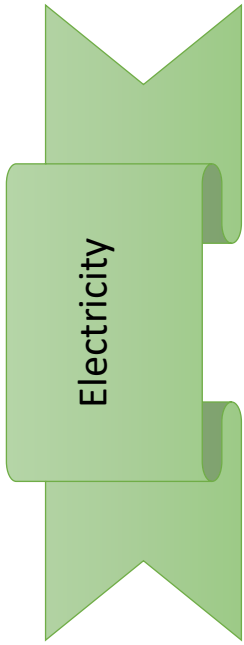
(3)

(d) State the direction of the magnetic field.

Minimum  $B = \dots\dots\dots$

# Week 10





**Charge and current**

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 4.1.1 a                 | Can you define electric current as rate of flow of charge?   | <input type="checkbox"/> |
| 4.1.1 b                 | Can you describe the coulomb as the unit of charge?  | <input type="checkbox"/> |
| 4.1.1 c                 | Can you recall the elementary charge $e$ equals $1.6 \times 10^{-19} \text{ C}$ ?                        | <input type="checkbox"/> |
| 4.1.1 d                 | Can you explain why the net charge on a particle or an object is quantised and a multiple of $e$ ?       | <input type="checkbox"/> |
| 4.1.1 e                 | Can you explain current as the movement of electrons in metals and movement of ions in electrolytes?     | <input type="checkbox"/> |
| 4.1.1 f                 | Can you describe the difference between conventional current and electron flow?                          | <input type="checkbox"/> |
| 4.1.1 g                 | Can you recall and apply Kirchhoff's first law?  | <input type="checkbox"/> |
| 4.1.2 a                 | Can you describe what is meant by mean drift velocity of charge carriers?                                | <input type="checkbox"/> |
| 4.1.2 b                 | Can you carry out calculations using $I = A n e v$ , where $n$ is the number density of charge carriers? | <input type="checkbox"/> |
| 4.1.2 c                 | Can you explain the distinction between conductors, semiconductors, and insulators in terms of $n$ ?     | <input type="checkbox"/> |

## Energy, power, and resistance

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.2.1 a                 | Can you recognise and draw circuit symbols?   | <input type="checkbox"/> |
| 4.2.1 b                 | Can you draw circuit diagrams using circuit symbols?  | <input type="checkbox"/> |
| 4.2.2 a                 | Can you define potential difference (p.d.) and the unit volt?   | <input type="checkbox"/> |
| 4.2.2 b                 | Can you describe the electromotive force (e.m.f.) of a source such as a cell or a power supply?   | <input type="checkbox"/> |
| 4.2.2 c                 | Can you explain the distinction between e.m.f. and p.d. in terms of energy transfer?  | <input type="checkbox"/> |
| 4.2.2 d                 | Can you describe and calculate energy transfer using $W = VQ$ and $W = EQ$ ?  | <input type="checkbox"/> |
| 4.2.2 e                 | Can you describe and calculate energy transfer using $eV = \frac{1}{2} m v^2$ for electrons and other charged particles?                              | <input type="checkbox"/> |
| 4.2.3 a                 | Can you define resistance and the unit ohm?   | <input type="checkbox"/> |
| 4.2.3 b                 | Can you explain Ohm's law?  | <input type="checkbox"/> |
| 4.2.3 c i               | Can you describe the $I$ – $V$ characteristics of the resistor, filament lamp, thermistor, diode, and light-emitting diode (LED)?                     | <input type="checkbox"/> |
| 4.2.3 c ii              | Can you list and describe techniques and procedures used to investigate the electrical characteristics for a range of ohmic and non-ohmic components? | <input type="checkbox"/> |
| 4.2.3 d                 | Can you explain the variation of resistance with light intensity for a light-dependent resistor (LDR)?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.2.4 a i               | Can you explain the resistivity of a material and use the equation $R = \frac{\rho L}{A}$ ?                     | <input type="checkbox"/> |
| 4.2.4 a ii              | Can you list and describe techniques and procedures used to determine the resistivity of a metal?               | <input type="checkbox"/> |
| 4.2.4 b                 | Can you explain how resistivity varies with temperature for metals and semiconductors?                          | <input type="checkbox"/> |
| 4.2.4 c                 | Can you explain how resistance varies with temperature for a negative temperature coefficient (NTC) thermistor? | <input type="checkbox"/> |
| 4.2.5 a                 | Can you use the equations $P = VI$ , $P = I^2 R$ and $P = \frac{V^2}{R}$ ?                                      | <input type="checkbox"/> |
| 4.2.5 b                 | Can you describe energy transfer using the equation $W = VIt$ ?   | <input type="checkbox"/> |
| 4.2.5 c                 | Can you describe the kilowatt-hour (kW h) as a unit of energy and calculate the cost of energy?                 | <input type="checkbox"/> |

## Electrical circuits

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 4.3.1 a                 | Can you explain Kirchhoff's second law and the conservation of energy?  | <input type="checkbox"/> |
| 4.3.1 b                 | Can you describe Kirchhoff's first and second laws applied to electrical circuits?  | <input type="checkbox"/> |
| 4.3.1 c                 | Can you determine the total resistance of two or more resistors in series using $R = R_1 + R_2 + \dots$ ?                                   | <input type="checkbox"/> |
| 4.3.1 d                 | Can you determine the total resistance of two or more resistors in parallel using $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$ ?   | <input type="checkbox"/> |
| 4.3.1 e                 | Can you analyse circuits with components both in series and in parallel?  | <input type="checkbox"/> |
| 4.3.1 f                 | Can you analyse circuits with more than one source of e.m.f.?   | <input type="checkbox"/> |
| 4.3.2 a                 | Can you define source of e.m.f. and internal resistance?  | <input type="checkbox"/> |
| 4.3.2 b                 | Can you define terminal p.d. and 'lost volts'?  | <input type="checkbox"/> |
| 4.3.2 c i               | Can you use the equations $\mathcal{E} = I(R + r)$ and $\mathcal{E} = V + Ir$ ?   | <input type="checkbox"/> |
| 4.3.2 c ii              | Can you list and describe techniques and procedures used to determine the internal resistance of a chemical cell or other source of e.m.f.? | <input type="checkbox"/> |
| 4.3.3 a                 | Can you analyse a potential divider circuit with components?  | <input type="checkbox"/> |
| 4.3.3 b                 | Can you use potential divider circuits with variable components, e.g., LDRs and thermistors?  | <input type="checkbox"/> |

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 4.3.3 c i               | Can you use potential divider equations $V_{\text{out}} = \frac{R_2}{R_1 + R_2} \times V_{\text{in}}$ and $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ ?              | <input type="checkbox"/> |
| 4.3.3 c ii              | Can you list and describe techniques and procedures used to investigate potential divider circuits which may include a sensor such as a thermistor or a LDR? | <input type="checkbox"/> |

## Energy, Power and Resistance 1

|  |  |
|--|--|
| What is potential difference?  | The work done per unit charge between two points   |
| What is the SI unit for potential difference?                                  | Volt (V)   |
| What units are equivalent to the volt?   | Joules per Coulomb ( $JC^{-1}$ )   |
| What is EMF (Electromotive force)?   | The work done per unit charge supplied to the charge carriers  |
| How is a voltmeter connected?  | In parallel.   |
| What is the resistance of an ideal voltmeter?                                  | Infinite.  |
| What is thermionic emission?   | The emission of electrons from the surface of a heated metal.  |
| What is the work done on an electron when it passes through a p.d. of V volts? | eV where e is the charge on the electron.  |
| What is Ohm's Law?   | For a metallic conductor at constant temperature the p.d. is proportional to current.  |
| What is electrical resistance?   | The opposition of an object to a flow of current through it.   |
| How is resistance calculated?  | $V/I$  |
| What units are equivalent to an Ohm?   | $VA^{-1}$  |
| Why does resistance increase with temperature?                                 | The amplitude of lattice ion vibrations increases causing more frequent collisions between electrons and lattice ions, leading to the electrons doing more work as they move through the wire. |
| Why does current flow lead to heating in components?                           | Electrons collide with the lattice ions and transfer some of their kinetic energy to the lattice ion's vibrations.   |
| What is an Ohmic conductor?  | An object for which p.d. is proportional to current.   |
| What is meant by the threshold pd of a diode?                                  | The pd at which resistance starts to fall rapidly as pd increases.   |

## Energy, Power and Resistance 2

|  |   |
|--|---|
| What are the units of resistivity?                                     | $\Omega m$  |
| What is $\rho$ in $R = \rho L / A$ ?                                   | The resistivity of the material.                                  |
| What is L in $R = \rho L / A$ ?  | The length of the wire.   |
| What is A in $R = \rho L / A$ ?  | The cross-sectional area of the wire                              |
| As a metal gets hotter what happens to its resistivity?                | It increases.   |
| What is meant by a negative temperature coefficient component?         | One in which the resistance drops as temperature increases.       |
| Why does resistance of a thermistor fall as temperature increases?     | The number density of charge carriers increases.                  |
| What are thermistors commonly used in?                                 | Temperature sensors.  |
| Why does the resistance of an LDR as light intensity changes?          | Light increases the number density of charge carriers in the LDR. |
| What are LDRs commonly used in?  | Light intensity sensors.  |
| What happens to the resistance of an LDR as light intensity increases? | It decreases.   |
| What is a kilowatt-hour (kWh)?   | The energy supplied when 1kW of power is supplied for 1 hour.     |
| How many Joules are equivalent to a kWh                                | 3.6MJ   |

## Measurements, errors and uncertainties

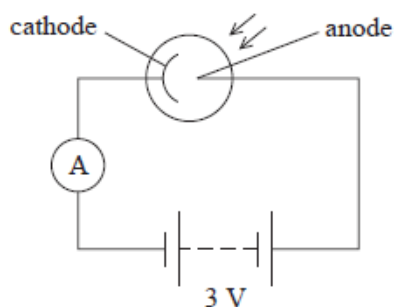
|  |  |
|--|--|
| State Kirchoff's second law.   | Sum of the EMFs is equal to the sum of the potential drops around a closed circuit loop.             |
| What law is Kirchoff's second law a consequence of?                                  | Conservation of Energy   |
| What can we say about the current through components in series?                      | Same for each component  |
| What can we say about the current on different parallel branches?                    | It depends on the resistance of each branch.   |
| What can we say about the pd across parallel branches in a circuit?                  | It is the same for each branch   |
| How do find the total pd across several components in series?                        | It is equal to the sum of the pds across each component  |
| How do you find the total EMF from cells connected in series with the same polarity? | Their EMFs are added   |
| How do you find the total EMF from cells connected in series with opposite polarity? | The total EMF is the difference between their EMFs   |
| How do you calculate the total resistance of resistors in series?                    | Sum of the individual resistances  |
| What is the total resistance of n identical resistors in series?                     | $n \times R$   |
| What is the total resistance of n identical resistors in parallel?                   | $R \div n$   |
| How do you calculate the resistance of resistors in parallel?                        | $1/RT=1/R1+1/R2...$  |
| How does the total resistance change when a resistor is added in series?             | It always increases  |
| How does the total resistance change when a resistor is added in parallel?           | It always decreases  |
| What is the effect of connecting two identical resistors in parallel?                | Resistance is halved   |
| What is the effect of connecting two identical resistors in series?                  | Resistance is doubled  |
| What is internal resistance?   | The opposition to current created by the charge carriers having to flow through the source of EMF    |
| What are the lost volts for a power supply?  | The pd dropped across the internal resistance OR the difference between the EMF and the terminal pd. |
| What happens to the terminal pd of a source as the current supplied increases?       | It falls due to the increasing lost volts to the internal resistance.                                |
| How do you calculate lost volts for a supply?  | $Ir$ where $r$ is the internal resistance.   |
| What is the relationship between EMF, terminal pd and lost volts?                    | $EMF = \text{terminal pd} + \text{lost volts}$   |
| How do you find the internal resistance from a graph or terminal pd against current? | -gradient  |
| How do you find the EMF from a graph or terminal pd against current?                 | y-intercept  |
| What is a potential divider?   | Two or resistances in series with a fixed source of EMF.   |
| What determines the ratio of the pd across the resistors in a potential divider?     | It is equal to the ratio of their resistances.   |
| How can a light sensor be made?  | By creating a potential divider containing an LDR.   |
| How can a temperature sensor be made?  | By creating a potential divider containing a thermistor.   |
| What component can be used to supply an adjustable output pd?                        | A potentiometer.   |

## Questions

Q1.

Some light meters make use of the photoelectric effect.

The circuit shows a light meter.



When light is incident on the cathode, electrons are released. These electrons are attracted to the anode causing a reading on the ammeter.

(i) Explain how the reading on the ammeter is a measure of the intensity of the light.

(3)

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(ii) The cathode has an area of  $4.1 \times 10^{-3} \text{ m}^2$ . The reading on the ammeter is 0.61 A.

Determine the minimum intensity of the light in  $\text{W m}^{-2}$ .

(3)

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Minimum light intensity = .....  $\text{W m}^{-2}$

(iii) Caesium has a work function of 4.32 eV.

Determine whether caesium can be used as the cathode in the light meter to measure the intensity of light of frequency  $2.2 \times 10^{14}$  Hz.

(4)

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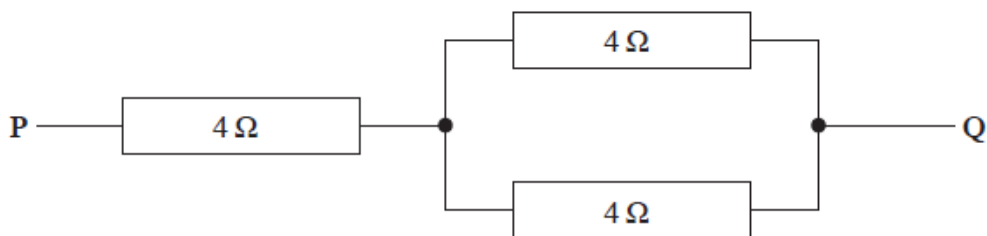
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**(Total for question = 10 marks)**

Q2.

The diagram shows a combination of three identical resistors.



What is the combined resistance between P and Q?

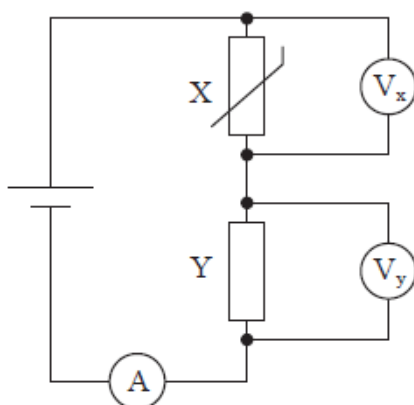
- A**  $4 \Omega$
- B**  $6 \Omega$
- C**  $8 \Omega$

D 12  $\Omega$

(Total for question = 1 mark)

Q3.

The diagram shows a potential divider circuit that contains a negative temperature coefficient thermistor.



The temperature of the room containing the circuit increases.

Select the row of the table that correctly shows the changes in readings on the meters.

|                                       | $V_x$    | $V_y$    | A        |
|---------------------------------------|----------|----------|----------|
| <input checked="" type="checkbox"/> A | decrease | increase | decrease |
| <input checked="" type="checkbox"/> B | decrease | increase | increase |
| <input checked="" type="checkbox"/> C | increase | decrease | decrease |
| <input checked="" type="checkbox"/> D | increase | decrease | increase |

(Total for question = 1 mark)

Q4.

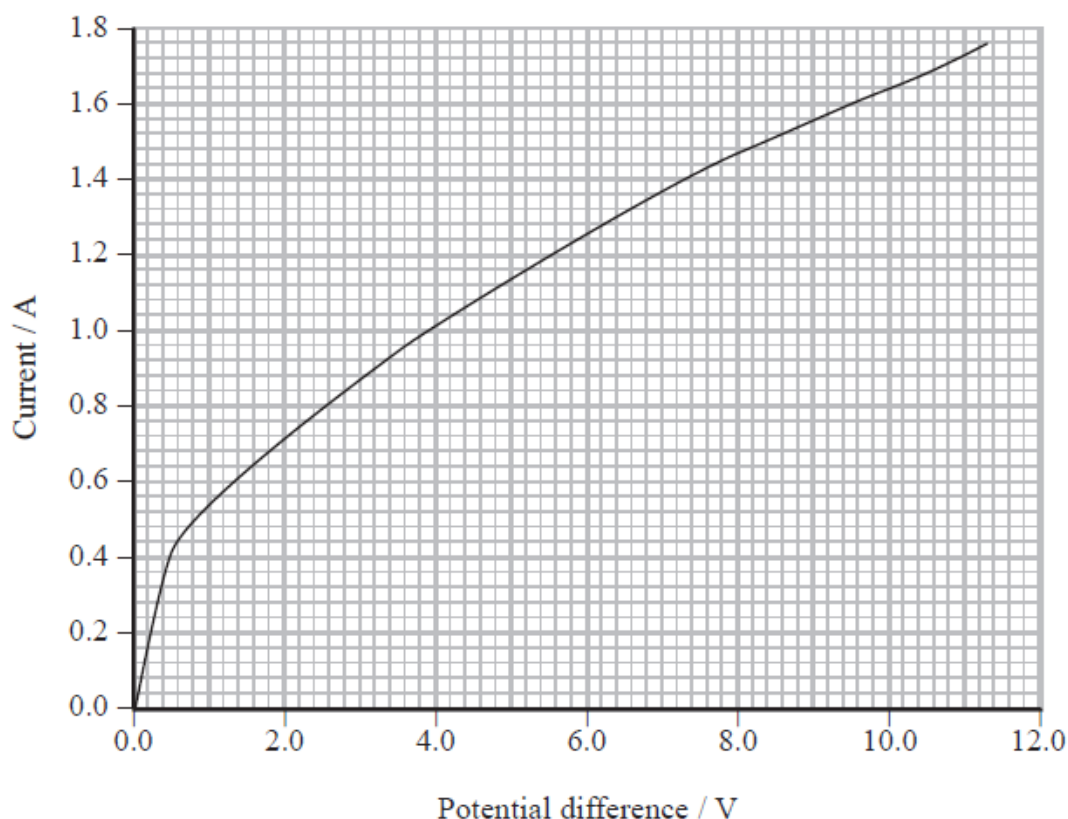
A student investigates how the current through a filament light bulb varies with the potential difference across it.

(a) Draw a diagram of a circuit the student could use to obtain suitable measurements for a

range of potential difference from 0 V to 12 V.

(3)

(b) The student's results are shown on the graph.



The student decides to draw a tangent to the curve at a potential difference of 6 V and use the gradient of the tangent to determine the resistance of the bulb.

(i) Explain why this is **not** a correct method to determine the resistance.

(2)

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(ii) Calculate the resistance of the bulb when the potential difference across it is 6 V.

(2)

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Resistance = .....

\*(c) Describe and explain the change in the resistance of the bulb as the potential difference across it is increased.

(4)

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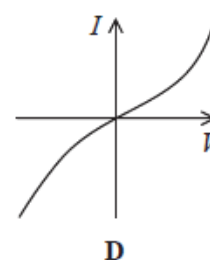
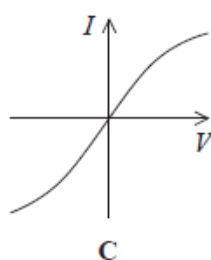
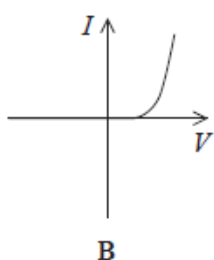
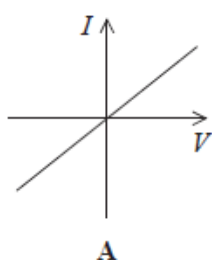
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**(Total for question = 11 marks)**

Q5.

Which of the following graphs shows the current-potential difference characteristics of a negative temperature coefficient (NTC) thermistor?



- A
- B
- C
- D

**(Total for question = 1 mark)**

Q6.

The current in a filament lamp is 250 mA.

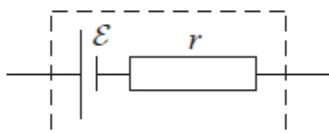
How much charge flows through the lamp in 3 minutes?

- A** 0.75 C
- B** 45 C
- C** 750 C
- D** 45 000 C

**(Total for question = 1 mark)**

Q7.

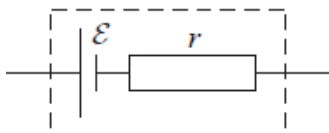
A cell may be represented as an e.m.f.  $\mathcal{E}$  in series with an internal resistance  $r$ .



A student used the relationship  $V = \mathcal{E} - Ir$  and a graphical method to determine  $\mathcal{E}$  and  $r$ . She connected a cell in a circuit and took a series of measurements of the current  $I$  in the cell and the potential difference  $V$  across the terminals of the cell.

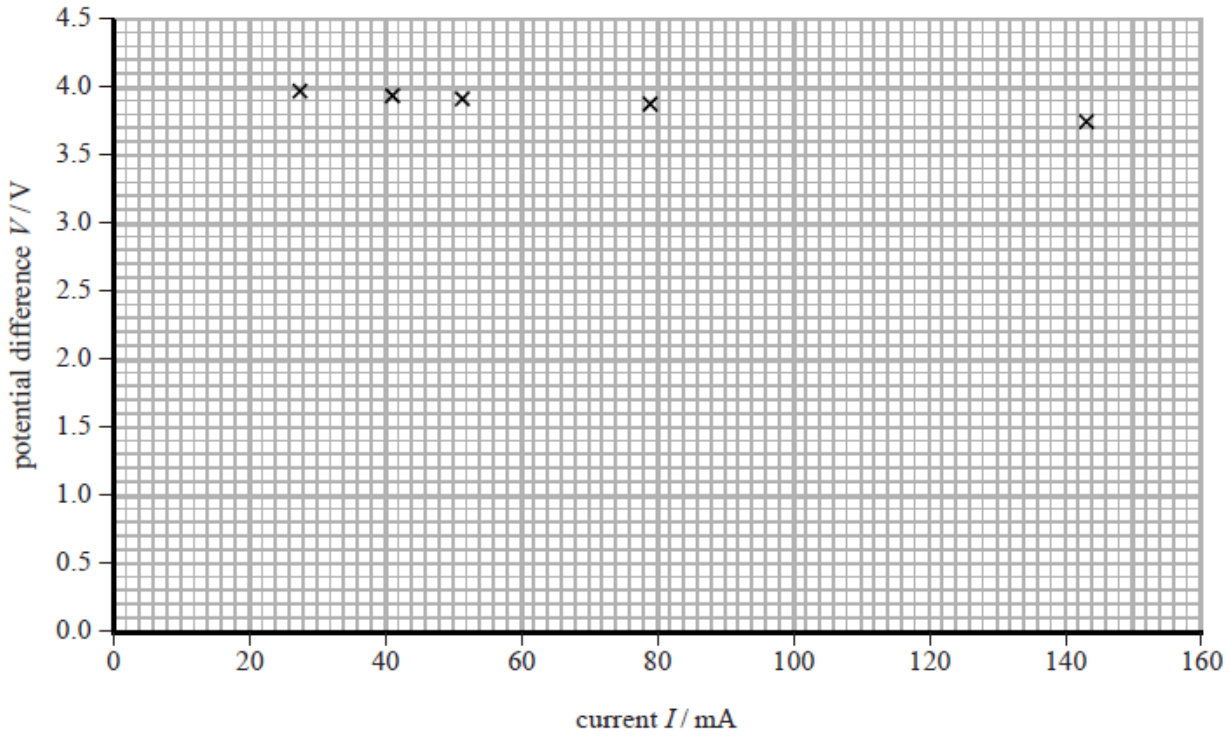
(a) Complete a circuit diagram of a circuit she could have used.

**(2)**



(b) The student's measurements are shown in the table and plotted on the graph.

| $I / \text{mA}$ | $V / \text{V}$ |
|-----------------|----------------|
| 27.5            | 3.97           |
| 41.0            | 3.94           |
| 51.6            | 3.90           |
| 78.6            | 3.88           |
| 143.0           | 3.75           |



Determine values for  $\varepsilon$  and  $r$  from the graph and show how you obtained your answers.

(4)

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$\varepsilon =$  .....

$r =$  .....

(c) Explain how the graph could be constructed to obtain better values for  $\varepsilon$  and  $r$ .

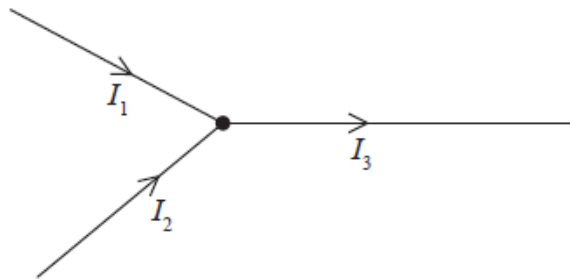
(2)

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Q8.

The diagram shows the current in part of an electrical circuit.



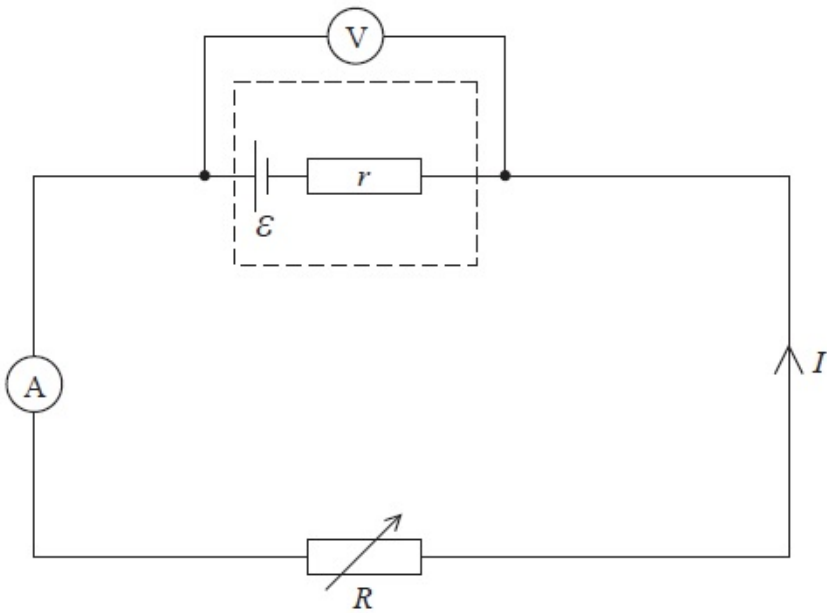
State the relationship between  $I_1$ ,  $I_2$  and  $I_3$  and explain it in terms of charge.

(3)

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**(Total for question = 3 marks)**

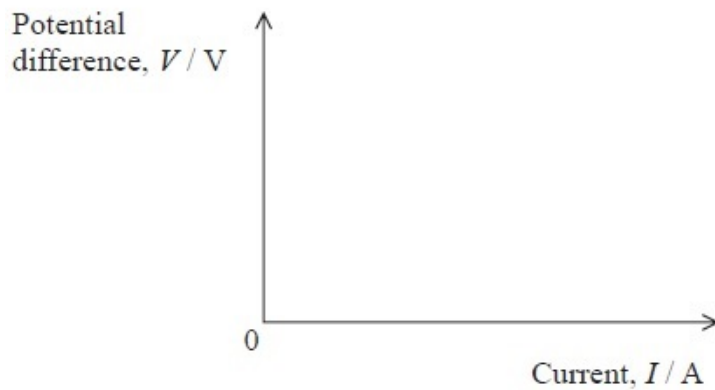
Q9. The diagram shows a circuit which may be used to find the emf  $\epsilon$  and internal resistance  $r$  of a cell.



(a) As the resistance  $R$  of the variable resistor is varied, values of the current  $I$  in the circuit and the terminal potential difference  $V$  across the cell are recorded.

Sketch the graph of  $V$  against  $I$  and explain how it may be used to determine  $\epsilon$  and  $r$ .

(5)



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\*(b) We usually assume that ammeters have negligible resistance and voltmeters have infinite resistance.

The determination of  $\epsilon$  and  $r$  is not affected by using an ammeter with non-negligible resistance but is affected by using a voltmeter with a low resistance.

Explain why.

(4)

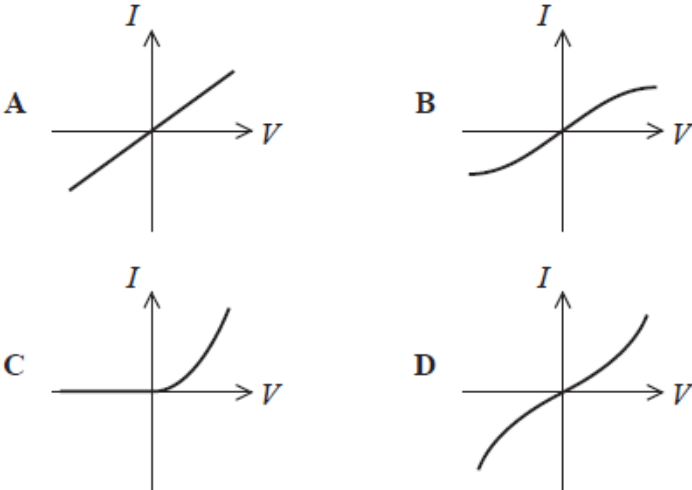
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**(Total for Question = 9 marks)**

Q10.

Which of the following current-potential difference ( $I$ - $V$ ) graphs correctly shows the behaviour of a diode?

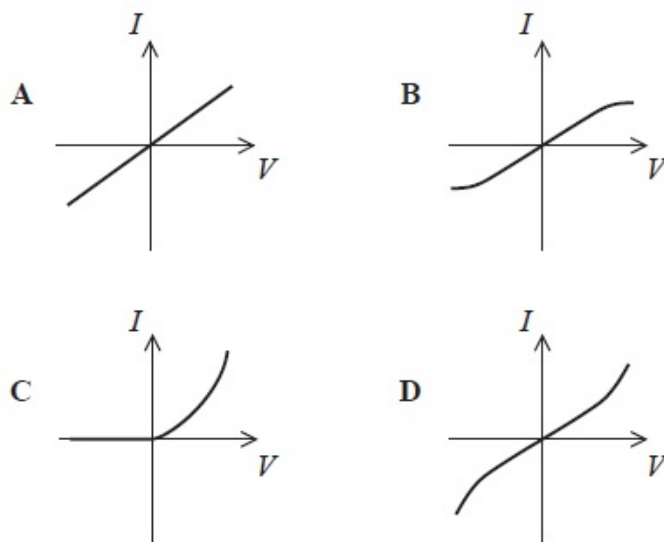


- A
- B
- C
- D

**(Total for question = 1 mark)**

Q11. Which of the following current - potential difference ( $I$ - $V$ ) graphs shows the correct

behaviour for a filament bulb?



A

B

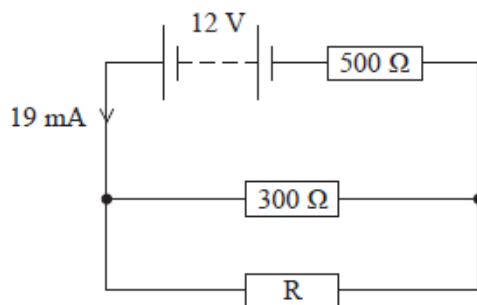
C

D

(Total for Question = 1 mark)

Q12.

A circuit is shown.



Calculate the potential difference across the  $500\ \Omega$  resistor.

(2)

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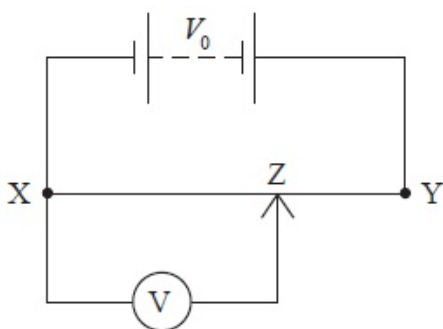
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Potential difference = .....

**(Total for question = 2 marks)**

Q13. The diagram shows a uniform wire XY across which a potential difference  $V_0$  is applied.



Which of the following correctly shows the output potential difference across XZ?

- A  $V = \frac{XY}{XZ} V_0$
- B  $V = \frac{XZ}{XY} V_0$
- C  $V = \frac{XZ}{ZY} V_0$
- D  $V = \frac{ZY}{XY} V_0$

**(Total for Question = 1 mark)**

Q14. A current of 0.2 A flows through a lamp for 3 hours.

The total charge passing through the lamp in this time is

- A 2160 C
- B 600 C
- C 36 C
- D 0.6 C

Q15. A rechargeable AA cell is labelled 2.0 Ah (ampere hours), 1.2 V.

(a) Show that Ah is a unit of charge.

(2)

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.....  
.....

(b) When charging the cell, the current is 0.19 A and the potential difference is 1.5 V for 10 hours.

Calculate the electrical energy supplied while the cell is being charged.

(2)

.....  
.....  
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Electrical energy supplied = .....

(c) The maximum charge that can be delivered from a fully charged cell is 7200 C.

Calculate the maximum energy which could be transferred by the cell if the output potential difference remained constant at 1.2 V.

(2)

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Maximum energy = .....

(d) Calculate the efficiency of the charging process.

(2)

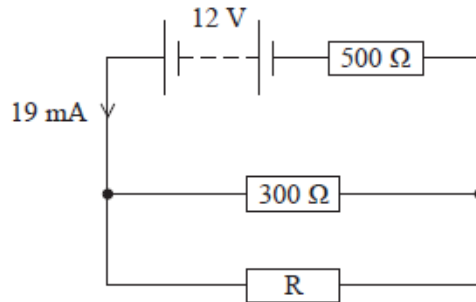
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Efficiency = .....

**(Total for Question = 8 marks)**

Q16.

A circuit is shown.



Calculate the resistance of resistor R.

**(4)**

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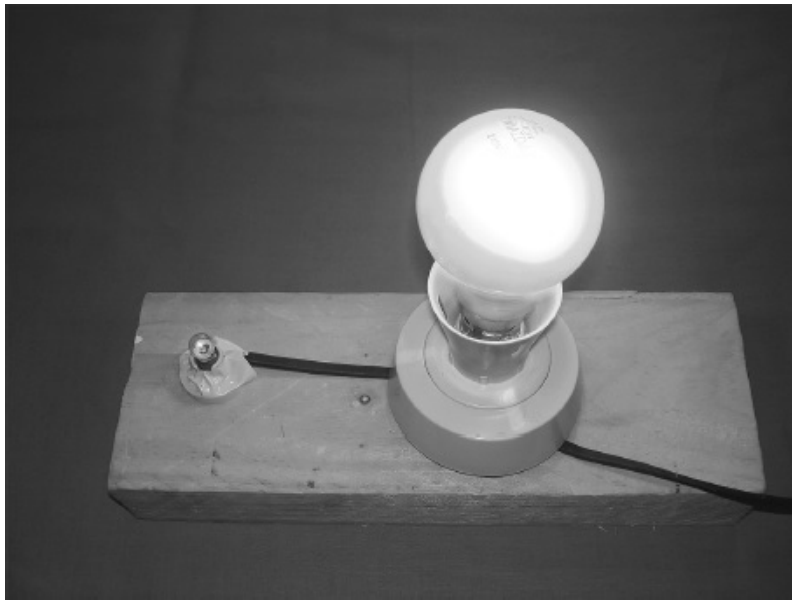
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Resistance = .....

**(Total for question = 4 marks)**

Q17. The photograph shows a piece of apparatus in which a mains light bulb and a torch bulb are both connected to the mains.



Students were surprised to see both bulbs shining normally when the apparatus was switched on.

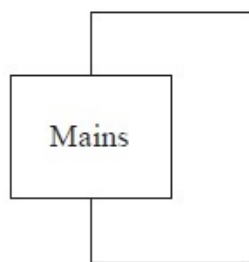
It is impossible to tell from looking at the apparatus whether the bulbs are connected in series or in parallel.

To test this, the apparatus was switched off and the mains bulb was removed. When it was switched on again the torch bulb did not light up. When this was repeated, removing the torch bulb, the mains bulb did not light up.

When the circuit was tried again with both bulbs, they still operated normally.

(a) Complete the circuit diagram to show how the bulbs are connected and explain why they must be connected in this way and not the alternative.

(3)



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(b) The mains bulb is marked 40 W, 230 V.

(i) Show that the current in the mains bulb is about 0.2 A when it is operating normally.

(2)

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(ii) Calculate the resistance of the mains bulb when it is operating normally.

(2)

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Resistance = .....

(iii) The torch bulb is marked 2.5 V, 0.20 A.

Calculate the resistance of the torch bulb when it is operating normally.

(2)

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Resistance = .....

(c) Explain, with reference to both current and potential difference, why it is possible to operate both bulbs at the same time from the same power supply.

(2)

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(d) Earlier in the question you were asked to calculate the resistances of the bulbs when operating normally.

Explain the effect on the resistances of the bulbs if they are operated at a much smaller current so that neither bulb lights up.

(4)

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**(Total for Question = 15 marks)**

Q18. Explain why an ammeter

- must be placed in series to measure current through a component
- must have a very low resistance.

(3)

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**(Total for Question = 3 marks)**

Q19.

A student is taking measurements in order to determine the resistance of a component in a circuit. He connects a voltmeter in parallel with the component and an ammeter in series with the component.

Explain why the voltmeter should have a very high resistance.

**(2)**

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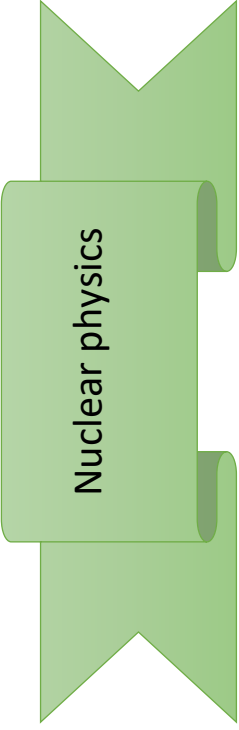
**(Total for question = 2 marks)**

**Mark Scheme**

Q1.

# Week 11





Nuclear physics

## Nuclear physics

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 6.4.4 a                 | Can you demonstrate Einstein's mass–energy equation, $\Delta E = \Delta mc^2$ ?                                     | <input type="checkbox"/> |
| 6.4.4 b                 | Can you understand how energy is released or absorbed in simple nuclear reactions?                                  | <input type="checkbox"/> |
| 6.4.4 c                 | Can you describe the creation and annihilation of particle–antiparticle pairs?                                      | <input type="checkbox"/> |
| 6.4.4 d                 | Can you define mass defect; binding energy; and binding energy per nucleon?   | <input type="checkbox"/> |
| 6.4.4 e                 | Can you explain the binding energy per nucleon against nucleon number curve; and energy changes in reactions?       | <input type="checkbox"/> |
| 6.4.4 f                 | Can you calculate the binding energy of nuclei using $\Delta E = \Delta mc^2$ , and calculate the masses of nuclei? | <input type="checkbox"/> |
| 6.4.4 g                 | Can you define induced nuclear fission and chain reaction?  | <input type="checkbox"/> |
| 6.4.4 h                 | Can you describe the basic structure of a fission reactor (components: fuel rods, control rods and moderator)?      | <input type="checkbox"/> |
| 6.4.4 i                 | Can you explain the environmental impact of nuclear waste?  | <input type="checkbox"/> |
| 6.4.4 j                 | Can you define nuclear fusion, fusion reactions and temperature?  | <input type="checkbox"/> |
| 6.4.4 k                 | Can you demonstrate balancing nuclear transformation equations?   | <input type="checkbox"/> |

## Medical imaging

| Specification reference | Checklist questions  |                          |
|-------------------------|--|--------------------------|
| 6.5.1 a                 | Can you describe the basic structure of an X-ray tube (components: heater (cathode), anode, target metal and high-voltage supply)? | <input type="checkbox"/> |
| 6.5.1 b                 | Can you describe the production of X-ray photons from an X-ray tube?   | <input type="checkbox"/> |
| 6.5.1 c                 | Can you define these X-ray attenuation mechanisms: simple scatter, photoelectric effect, Compton effect, and pair production?      | <input type="checkbox"/> |
| 6.5.1 d                 | Can you explain the attenuation of X-rays?   | <input type="checkbox"/> |
| 6.5.1 d                 | Can you demonstrate that $I = I_0 e^{-\mu x}$ ?  | <input type="checkbox"/> |
| 6.5.1 e                 | Can you describe X-ray imaging with contrast media?  | <input type="checkbox"/> |
| 6.5.1 f                 | Can you describe computerised axial tomography (CAT) scanning and the necessary components?  | <input type="checkbox"/> |
| 6.5.1 g                 | Can you explain the advantages of a CAT scan over an X-ray image?  | <input type="checkbox"/> |
| 6.5.2 a                 | Can you describe the medical tracers technetium-99m and fluorine-18?   | <input type="checkbox"/> |
| 6.5.2 b                 | Can you describe the gamma camera and its components, and the formation of gamma camera images?                                    | <input type="checkbox"/> |
| 6.5.2 c                 | Can you explain diagnosis using the gamma camera?  | <input type="checkbox"/> |
| 6.5.2 d                 | Can you define positron emission tomography (PET)?   | <input type="checkbox"/> |
| 6.5.2 e                 | Can you explain diagnosis using PET scanning?  | <input type="checkbox"/> |
| 6.5.3 a                 | Can you explain ultrasound frequency?  | <input type="checkbox"/> |

| Specification reference | Checklist questions   |                          |
|-------------------------|---|--------------------------|
| 6.5.3 b                 | Can you define the piezoelectric effect?  | <input type="checkbox"/> |
| 6.5.3 b                 | Can you define ultrasound transducers?  | <input type="checkbox"/> |
| 6.5.3 c                 | Can you describe ultrasound A-scans and B-scans?  | <input type="checkbox"/> |
| 6.5.3 d                 | Can you calculate the acoustic impedance of a medium, $Z = \rho c$ ?                                    | <input type="checkbox"/> |
| 6.5.3 e                 | Can you explain the reflection of ultrasound at a boundary?   | <input type="checkbox"/> |
| 6.5.3 e                 | Can you demonstrate that $\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ ?                      | <input type="checkbox"/> |
| 6.5.3 f                 | Can you describe impedance (acoustic) matching?   | <input type="checkbox"/> |
| 6.5.3 f                 | Can you explain the use of gel in ultrasound scanning?  | <input type="checkbox"/> |
| 6.5.3 g                 | Can you describe the Doppler effect in ultrasound?  | <input type="checkbox"/> |
| 6.5.3 g                 | Can you calculate the speed of blood $v$ in the body: $\frac{\Delta f}{f} = \frac{2v \cos \theta}{c}$ ? | <input type="checkbox"/> |

Particle physics

|  |  |
|--|--|
| What type of particles were used in Rutherford's scattering experiment?  | Alpha particles  |
| What power of 10 is the diameter of a nucleus?   | $10^{-14}\text{m}$   |
| What power of 10 is the diameter of an atom?   | $10^{-10}\text{m}$   |
| What material was used as a target in Rutherford's scattering experiment?  | Gold foil, a few atoms thick   |
| What was measured in Rutherford's scattering experiment?   | The angle of deflection of the alpha particles.  |
| What happened to most of the alpha particles in Rutherford's scattering experiment?  | They passed straight through the foil (with very little scattering).   |
| What proportion of alpha particles were scattered in Rutherford's scattering experiment?   | Around 1 in 2000   |
| What proportion of alpha particles were deflected by more than $90^\circ$ in Rutherford's scattering experiment?                 | Around 1 in 10,000   |
| What was concluded due to most of the alpha particles passing straight through the gold foil Rutherford's scattering experiment? | Most of the atom is empty space with most of the mass concentrated in a small nucleus.                       |
| What was concluded due to some alpha particles being scattered in Rutherford's scattering experiment?                            | The nucleus is positively charged.   |
| How did Rutherford estimate the maximum radius of the nucleus?   | He equated the KE of the alpha particle to the electric potential energy at closest approach to the nucleus. |
| What is a nucleon?   | A proton or neutron.   |
| What is an isotope?  | A nucleus of an element with the same number of protons but a different number of neutrons.                  |
| What is an atomic mass unit?   | One twelfth of the mass of a neutral carbon 12 atom.   |
| How has the radius of the nucleus been measured?   | By the diffraction of fast moving electrons.   |
| What is R in $R = r_0A^{(1/3)}$ ?  | The radius of the nucleus.   |
| What is $r_0$ in $R = r_0A^{(1/3)}$ roughly equivalent to?   | The radius of a proton.  |
| What is A in $R = r_0A^{(1/3)}$ ?  | Nucleon number.  |
| What force holds protons and neutrons together in the nucleus?   | The strong nuclear force.  |
| What is the maximum range of the strong nuclear force?   | $\sim 3\text{fm}$  |
| Below what distance is the strong nuclear force repulsive?   | 0.5fm  |
| Which group of particles are subject to the weak nuclear force but not the strong nuclear force?                                 | Leptons  |
| What is the quark composition of a meson?  | A quark and an antiquark.  |
| Which force do Hadrons decay by?   | The weak nuclear force.  |

|   |  |
|---|--|
| What is the quark composition of a Baryon   | Three quarks   |
| What is a neutrino?   | A lepton with no charge and a tiny mass.                         |
| Why doesn't a neutrino experience the electromagnetic force?                                | They have no charge..  |
| What is the quark composition of a neutron?   | up down down (udd)   |
| What is the quark composition of a proton?  | up up down (uud)   |
| What is the quark composition of an anti-baryon?  | Three antiquarks   |
| Name the two types of hadron.   | baryons and mesons   |
| What force hold quarks together in hadrons?   | The strong nuclear force.  |
| What is the family of particles that are subject to both the strong and weak nuclear force? | Hadrons  |
| What type of particle are nucleons?   | Baryons  |
| How does a proton compare to an antiproton?   | The have the same mass but opposite charge.                      |
| How does an electron compare to a positron?   | The have the same mass but opposite charge.                      |
| What is the antiparticle of the electron?   | Positron.  |
| What type of particle are there millions of passing through your body every second?         | Neutrinos  |
| Describe beta minus decay.  | A neutron in an unstable nucleus decays into a proton            |
| Describe beta plus decay.   | A proton in an unstable nucleus decays into a neutron            |
| What quark transformation occurs during beta minus decay?                                   | A down quark (in a neutron) turns into an up quark (in a proton) |
| What quark transformation occurs during beta plus decay                                     | An up quark (in a proton) turns into a down quark (in a neutron) |

## X-rays and CAT scans

|  |   |
|--|---|
| What provides the energy of the X-rays in an X-ray tube?   | The kinetic energy of the accelerated electrons.                    |
| What is an X-ray?  | A photon produced by the deceleration of a fast moving electron     |
| What is the typical p.d. of an X-ray tube for medical imaging?   | 30-100kV  |
| What causes the emission of electrons from the cathode in an X-ray tube?                                   | It is heated to produce thermionic emission.                        |
| What name is given to the anode in an X-ray tube?  | The target metal.   |
| What is an essential property for the target metal in an X-ray tube?                                       | High melting point.   |
| What causes the production of X-rays in an X-ray tube?   | The deceleration of electrons when they hit the target metal/anode. |
| In an X-ray tube what happens to most of the kinetic energy lost by the electrons when they hit the anode? | It is transferred to thermal energy of the anode.                   |

|  |  |
|--|--|
| What measures can be taken to prevent an anode melting in an X-ray tube?   | It is cooled by oil or rotated   |
| What feature of X-ray tubes protects the radiographer?                     | Lead lining.   |
| What determines the maximum frequency of X-rays produced in an X-ray tube? | The maximum kinetic energy of a single electron.   |
| When is the equation $\lambda = hc/eV$ used?                               | To find the minimum wavelengths of X-ray produced (by an X-ray tube)                               |
| What is V in the equation $\lambda = hc/eV$ ?                              | The accelerating potential difference.   |
| Describe the beam used by CAT scanners.                                    | A thin (1-10mm) fan.   |
| What happens to the position of the X-ray tube during a CAT scan?          | It rotates around the patient.   |
| What are the key advantages of CAT scans over conventional X-rays?         | They produce a 3D image and can distinguish between tissues with similar attenuation coefficients. |
| What are the disadvantages of CAT scans compared to conventional X-rays?   | The radiation dose is greater and they are more expensive and take more time.                      |
| How does a CAT scan produce a 3D image?                                    | A series of slices are imaged and processed via a computer to produce a 3D image.                  |

## X-ray attenuation

|   |   |
|---|---|
| What is X-ray attenuation?  | The decrease in intensity as X-rays pass through matter.  |
| What are the four mechanisms of X-ray attenuation?  | Simple scatter Photoelectric Effect Compton Scattering Pair Production  |
| What occurs during simple scatter of X-rays?  | The X-ray interacts with an electron in an atom and changes direction but not energy.   |
| Which method of attenuation is most significant with X-rays with energy in the range 1-20keV? | Simple scatter  |
| What occurs during the photoelectric effect attenuation of X-rays?                            | The X-ray is absorbed by an electron in an atom which gains the energy of the photon and leaves the atom.                               |
| Which method of attenuation is significant with X-rays with energies up to 100keV?            | Photoelectric effect  |
| Which method of attenuation is most significant to medical X-ray imaging?                     | The photoelectric effect.   |
| What occurs during Compton scattering attenuation of X-rays?                                  | The X-ray interacts with an electron in the atom causing the electron to be ejected and the photon to be scattered with reduced energy. |
| Which method of attenuation is significant with X-rays with energy in the range 0.5-5MeV?     | Compton scattering.   |
| What occurs during pair production with X-rays?   | An X-ray interacts with the nucleus of an atom converting the energy of the photon to an electron and a positron.                       |
| Which method of attenuation occurs with X-rays with energies 1.02MeV?                         | Pair production   |
| What is I in the equation $I = I_0 e^{-\mu x}$ ?  | Transmitted intensity   |
| What is $I_0$ in the equation $I = I_0 e^{-\mu x}$ ?  | Intensity before absorption   |
| What is $\mu$ in the equation $I = I_0 e^{-\mu x}$ ?  | Attenuation/absorption coefficient.   |
| What is x in the equation $I = I_0 e^{-\mu x}$ ?  | Thickness of the absorbing substance  |
| What are the SI units of attenuation coefficient?   | $m^{-1}$  |

|   |   |
|---|---|
| What is a contrast medium in X-rays?                                    | A material with a high attenuation coefficient used to image soft tissue. |
| What contrast medium is typically to examine blood flow?                | Iodine  |
| What contrast medium is typically used to imagine the digestive system? | Barium sulfate  |
| How are X-rays used for cancer therapy?                                 | A linear accelerator produces high energy X-rays that destroy cells.      |

## Imaging with Gamma Radiation

|  |   |
|--|---|
| Which radionuclide is used for imaging with a gamma camera?                        | Technitium-99m  |
| Which radionuclide is used in PET scanning?  | Fluorine-18   |
| Why are gamma emitting sources useful for imaging inside the body?                 | They are the least ionising and can penetrate through a patient to be detected externally.  |
| Why are short half-lives necessary for the radioisotopes used for medical imaging? | To ensure a large activity from a small amount and to minimise radiation dose after the procedure.  |
| What is a medical tracer?  | A compound containing a radioisotope that is put into the patients body.  |
| What is the function of a collimator in a gamma camera?                            | To absorb any photons not travelling along the axis of the tubes so the source location of gamma radiation can be identified.                                 |
| How is a collimator in a gamma camera constructed?                                 | It is a honeycomb of long, thin lead tubes.   |
| What is the function of a scintillator in a gamma camera?                          | It produces many photons of visible light when a gamma photon interacts with it.  |
| What is the function of the photomultiplier tubes in a gamma camera?               | They convert visible light photons to an electrical pulse.  |
| What is the function of the computer in a gamma camera?                            | It processes the signals from the photomultipliers to locate where the gamma ray originated to produce an image showing the concentrations of medical tracer. |
| What type of radiation is detected in a PET scan?                                  | Gamma   |
| What type of radiation is emitted by Fluorine-18 nucleus in a PET scan?            | Beta plus/positron  |
| What process produces gamma photons in a PET scan?                                 | Electron and positron annihilation.   |
| How is the the source of the gamma photons located in a PET scan?                  | By the time delay between the arrival of diametrically opposite gamma photons.  |
| What is the typical time delay between the arrival of gamma photons in PET scan?   | Nanoseconds   |
| Why is medical imaging using gamma emitting tracers useful?                        | It can measure the function of organs in the body rather than just the structure.   |
| What are the disadvantages of a PET scan?  | They are expensive and require facilities to prepare tracers local to the scanner.  |

## Ultrasound Scans

|  |  |
|--|--|
| What is X-ray attenuation?                         | The decrease in intensity as X-rays pass through matter.               |
| What are the four mechanisms of X-ray attenuation? | Simple scatter Photoelectric Effect Compton Scattering Pair Production |

|   |   |
|---|---|
| What occurs during simple scatter of X-rays?  | The X-ray interacts with an electron in an atom and changes direction but not energy.   |
| Which method of attenuation is most significant with X-rays with energy in the range 1-20keV? | Simple scatter  |
| What occurs during the photoelectric effect attenuation of X-rays?                            | The X-ray is absorbed by an electron in an atom which gains the energy of the photon and leaves the atom.                               |
| Which method of attenuation is significant with X-rays with energies up to 100keV?            | Photoelectric effect  |
| Which method of attenuation is most significant to medical X-ray imaging?                     | The photoelectric effect.   |
| What occurs during Compton scattering attenuation of X-rays?                                  | The X-ray interacts with an electron in the atom causing the electron to be ejected and the photon to be scattered with reduced energy. |
| Which method of attenuation is significant with X-rays with energy in the range 0.5-5MeV?     | Compton scattering.   |
| What occurs during pair production with X-rays?   | An X-ray interacts with the nucleus of an atom converting the energy of the photon to an electron and a positron.                       |
| Which method of attenuation occurs with X-rays with energies 1.02MeV?                         | Pair production   |
| What is I in the equation $I = I_0 e^{-\mu x}$ ?  | Transmitted intensity   |
| What is $I_0$ in the equation $I = I_0 e^{-\mu x}$ ?  | Intensity before absorption   |
| What is $\mu$ in the equation $I = I_0 e^{-\mu x}$ ?  | Attenuation/absorption coefficient.   |
| What is x in the equation $I = I_0 e^{-\mu x}$ ?  | Thickness of the absorbing substance  |
| What are the SI units of attenuation coefficient?   | $m^{-1}$  |
| What is a contrast medium in X-rays?  | A material with a high attenuation coefficient used to image soft tissue.   |
| What contrast medium is typically used to examine blood flow?                                 | Iodine  |
| What contrast medium is typically used to image the digestive system?                         | Barium sulfate  |
| How are X-rays used for cancer therapy?   | A linear accelerator produces high energy X-rays that destroy cells.  |

## Reflection of Ultrasound

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|---|--|
| What determines the acoustic impedance of a substance?                                    | The density and the speed of sound in the substance.   |
| What are the units of acoustic impedance?   | $kgm^{-2}s^{-1}$   |
| What is the intensity reflection coefficient for ultrasound?                              | The ratio (reflected intensity of ultrasound ÷ incident intensity of ultrasound)                                       |
| What factor determines the reflection intensity coefficient for ultrasound at a boundary? | The difference between the acoustic impedances of the two substances.  |
| Why does a coupling gel need to be used when performing an ultrasound?                    | Air pockets between the transducer and skin cause reflection of nearly all of the ultrasound at the skin-air boundary. |
| What is an ultrasound coupling gel?   | A substance applied to the skin and transducer with an impedance similar to skin.                                      |
| What is impedance/acoustic matching?  | When two substances have similar acoustic impedances so negligible reflection of ultrasound occurs.                    |
| What causes ultrasound to undergo doppler shift?  | Reflection from moving blood cells.  |
| What is doppler ultrasound used for?  | Measuring the speed (and volume) of blood flow.  |

|   |   |
|---|---|
| What is measured in doppler ultrasound to determine the velocity of the blood?              | The observed change in frequency of the reflected ultrasound pulse.                                   |
| How is blood flow viewed during a doppler ultrasound?                                       | The signal is processed by computer and displayed as a colour coded image on a screen.                |
| Why does the transducer have to be placed away from the normal during a doppler ultrasound? | To ensure there is a component of the blood flow's velocity in the direction of the ultrasound pulse. |
| What is $\Delta f$ in the equation? $\Delta f = (2fv\cos\theta)/c$                          | Change in the observed frequency of the reflected ultrasound.   |
| What is $v$ in the equation? $\Delta f = (2fv\cos\theta)/c$                                 | Blood flow speed.   |
| What is $\theta$ in the equation? $\Delta f = (2fv\cos\theta)/c$                            | The angle between the transducer axis and the blood flow.   |
| What is $c$ in the equation? $\Delta f = (2fv\cos\theta)/c$                                 | The speed of ultrasound in blood.   |

A – There are three types of radiation that can be emitted from the nucleus. Describe the three types of radiation, how they are produced, how ionising they are, what they can be absorbed by.

B – Fission and fusion both cause a release of energy from the nucleus. What occurs in each of these processes and why is energy released? Sketch the binding energy per nucleon against nucleon number curve to support your answer.

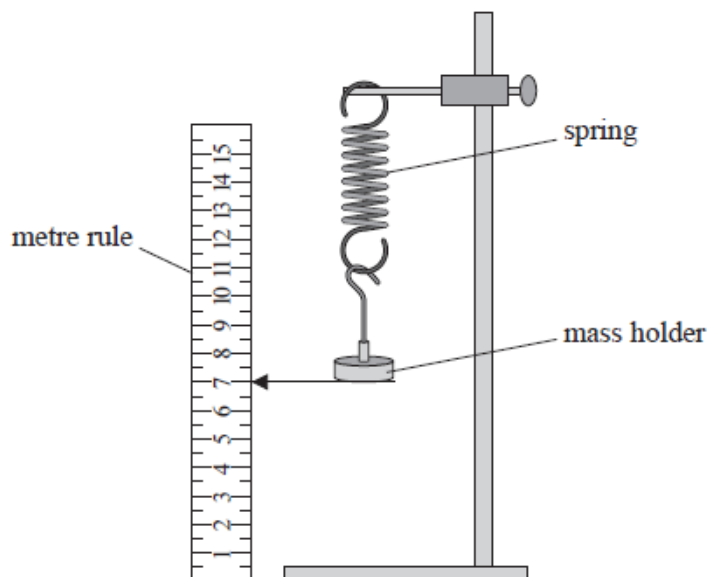
C – Neutron induced fission is used in nuclear power generation as a chain reaction can be created and maintained. Why does a chain reaction occur in this type of fission? What are the key features of a fission power station and how are they used to maintain a stable nuclear reaction and extract energy from that reaction?

D – Fusion is a promising power source but is very difficult to achieve. Why is this and what are the advantages of fusion over fission?

## Questions

Q1.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.



The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

| Mass added / g | Extension / cm | Stretching force / N |
|----------------|----------------|----------------------|
| 50             | 1.9            | 0.49                 |
| 70             | 3              | 0.69                 |
| 90             | 3.5            | 0.9                  |
| 110            | 4.5            | 1.08                 |
| 130            | 5.3            | 1.28                 |
| 150            | 5.8            | 1.47                 |

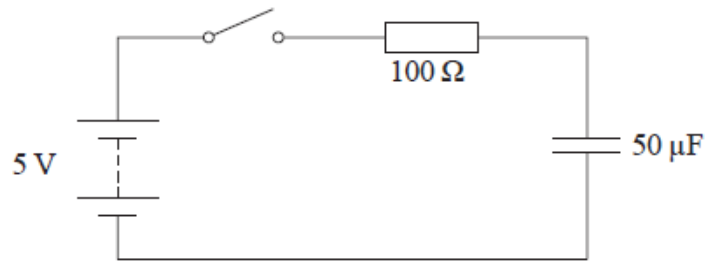
\* Identical bar magnets are suspended from identical springs, with the North pole of each magnet inside a coil of wire as shown. The two coils are connected together with conducting leads.



**(Total for question = 6 marks)**

Q2.

A circuit consists of a battery of e.m.f. 5 V and negligible internal resistance, a switch, a 100  $\Omega$  resistor and an uncharged 50  $\mu\text{F}$  capacitor.



Describe what happens to the potential difference across the resistor and the potential difference across the capacitor after the switch is closed.

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**(Total for question = 4 marks)**

Q3.

A capacitor of capacitance  $C$  is charged to a potential difference  $V$  by a power supply.

The energy stored on the charged capacitor is  $W$ .

What would be the energy stored if the potential difference were  $2V$ ?

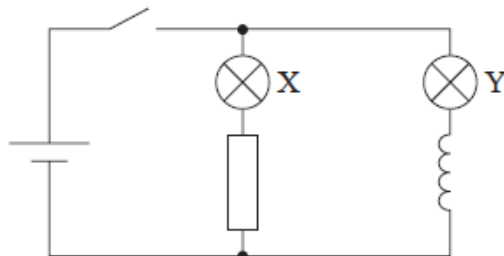
(1)

- A  $\frac{W}{4}$
- B  $\frac{W}{2}$
- C  $2W$
- D  $4W$

(Total for question = 1 mark)

Q4.

A circuit is set up as shown in the diagram. Lamps X and Y are identical. The coil has a soft iron core. The resistor and the coil have the same resistance.



The switch is closed and lamp X lights instantly.

Which statement best describes lamp Y after the switch is closed?

(1)

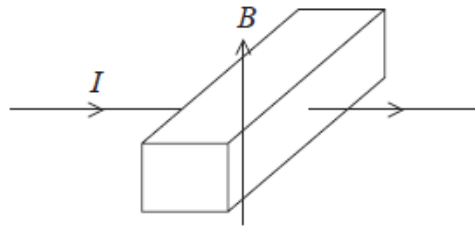
- A Lights after a delay with a final brightness less than X
- B Lights after a delay with a final brightness the same as X
- C Lights instantly with less brightness than X
- D Lights instantly with the same brightness as X

(Total for question = 1 mark)

Q5.

Some liquids conduct electricity. This property can be used to pump these liquids through pipes.

A short section of a rectangular pipe containing a liquid is shown in the diagram. The pipe is placed in a magnetic field of flux density  $B$  and a current  $I$  is passed through the liquid as shown.



Add an arrow to the diagram above to show the direction in which the liquid will move.

(1)

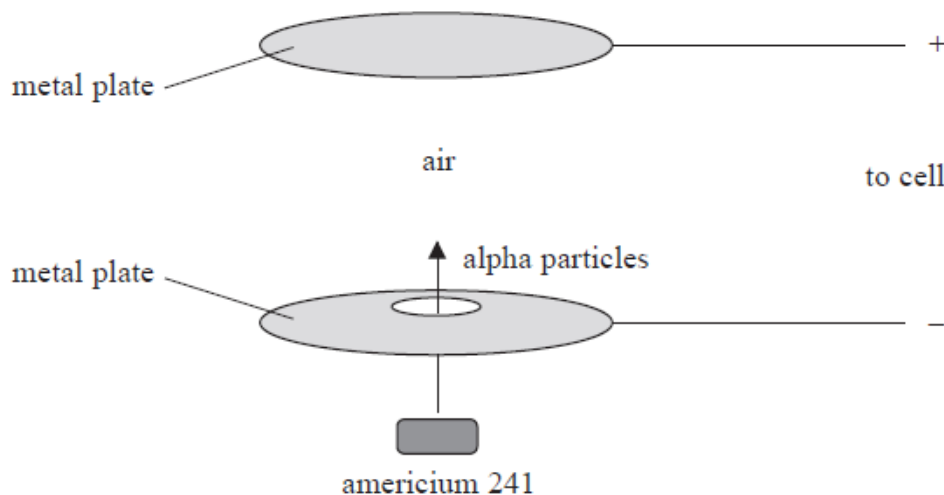
**(Total for question = 1 mark)**

Q6.

Some types of smoke detector contain a radioactive isotope of americium,  $^{241}\text{Am}$ . The nuclei of  $^{241}\text{Am}$  decay by emitting an alpha particle.

The diagram shows part of a smoke detector.

The detectors use a small amount of  $^{241}\text{Am}$  to make the air between two metal plates conduct charge.



(a) (i) Explain why a stream of alpha particles will cause charge to flow between the metal plates.

(2)

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(ii) Suggest how smoke particles entering the space between the plates will cause the current to decrease.

(1)

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(b) (i) The decay of  $^{241}\text{Am}$  is said to be random and spontaneous. State what is meant by random and spontaneous.

(2)

Random

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Spontaneous

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(ii) Complete the equation for the decay of  $^{241}\text{Am}$ .

(2)



**(Total for question = 7 marks)**

When alpha particles are directed at a thin gold foil it is found that most of the alpha particles go straight through undeflected. However a very small number are scattered through angles greater than  $90^\circ$ .

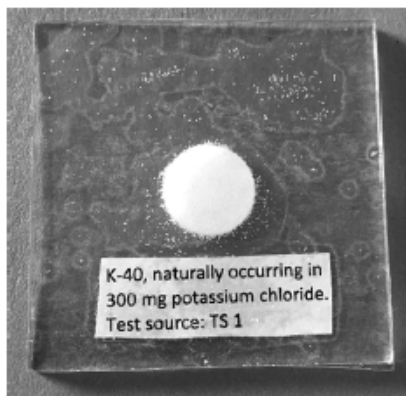
Which of the following is **not** a valid conclusion?

- A** The atom is mainly empty space.
- B** The nucleus must be positively charged.
- C** The nucleus must contain most of the mass of the atom.
- D** There is a large charge concentration in the centre of the atom.

**(Total for question = 1 mark)**

Q8.

A school science department keeps a sample of potassium chloride to use as a test source for Geiger-Müller tubes.



Potassium contains 0.012% of the unstable isotope potassium-40.

The science department also has a sample of strontium-90. This undergoes beta decay with a half-life of 29 years.

State why the half-life of potassium-40 makes the potassium chloride a more suitable material than strontium-90 for the test.

**(1)**

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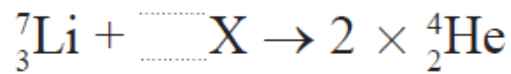
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(Total for question = 1 mark)

Q9.

(a) In 1939 Hans Bethe published a paper describing the fusion processes in stars.

In the proton-proton cycle, hydrogen is converted to helium in stages. The nuclear equation below represents one of the stages.



(i) Complete the equation and identify X.

(2)

X is .....

(ii) Calculate, in joules, the energy emitted in this stage of the cycle.

(3)

|         | Mass / MeV/c <sup>2</sup> |
|---------|---------------------------|
| Proton  | 938.3                     |
| Neutron | 939.6                     |
| Helium  | 3727.4                    |
| Lithium | 6533.8                    |

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Energy = ..... J

(b) In 1967 Bethe received a Nobel Prize in Physics for his work on understanding the fusion

processes in stars.

Explain why sustainable fusion has not yet been achieved for the generation of electrical power.

(4)

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Q10.

All living organisms contain  $^{12}\text{C}$  and radioactive  $^{14}\text{C}$ . The concentration of  $^{14}\text{C}$  in the organism is maintained whilst the organism is alive, but starts to fall once death has occurred.

(a) The count rate obtained from wood from an old Viking ship is  $14.7 \text{ min}^{-1}$  per gram of wood, after being corrected for background radiation. The corrected count rate from similar living wood is  $16.5 \text{ min}^{-1}$  per gram of wood

Calculate the age of the ship in years.

$^{14}\text{C}$ . has a half life of 5700 years.

(4)

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Age of ship = .....years

(b) The concentration of  $^{14}\text{C}$  in living organisms might have been greater in the past.

Explain how this would affect the age that you have calculated.

(2)

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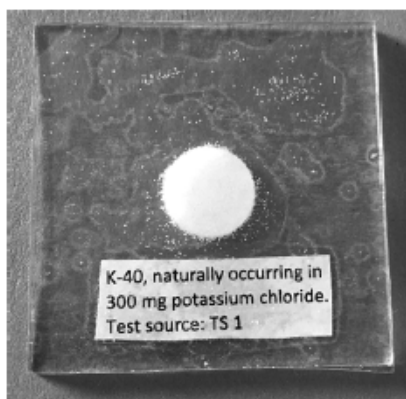
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**(Total for question = 6 marks)**

Q11.

A school science department keeps a sample of potassium chloride to use as a test source for Geiger-Müller tubes.

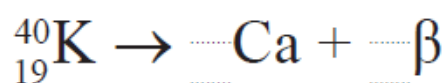


Potassium contains 0.012% of the unstable isotope potassium-40.

Potassium-40 undergoes  $\beta^-$  decay, producing a stable isotope of calcium.

Complete the nuclear equation for this decay.

(2)

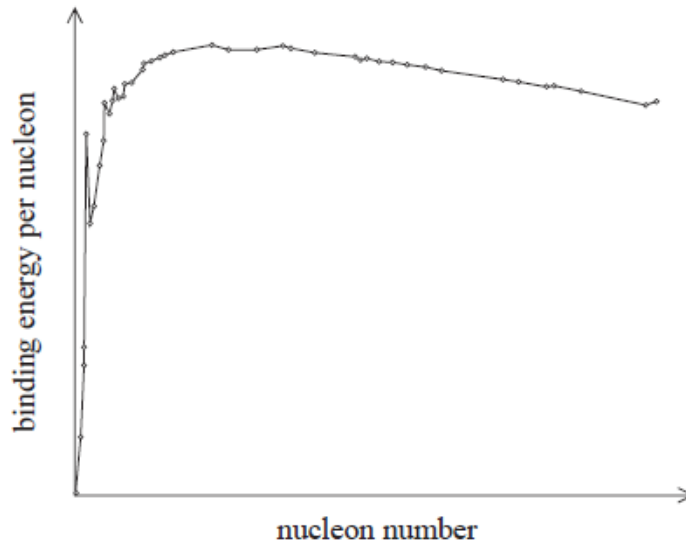


**(Total for question = 2 marks)**

Q12.

Nuclear fusion involves small nuclei joining to make larger nuclei. Nuclear fission involves large nuclei splitting to become smaller nuclei. Both of these processes release energy.

The graph shows how the binding energy per nucleon varies with nucleon number for a range of isotopes.



Use the binding energy per nucleon curve to explain how fusion and fission both release energy.

(3)

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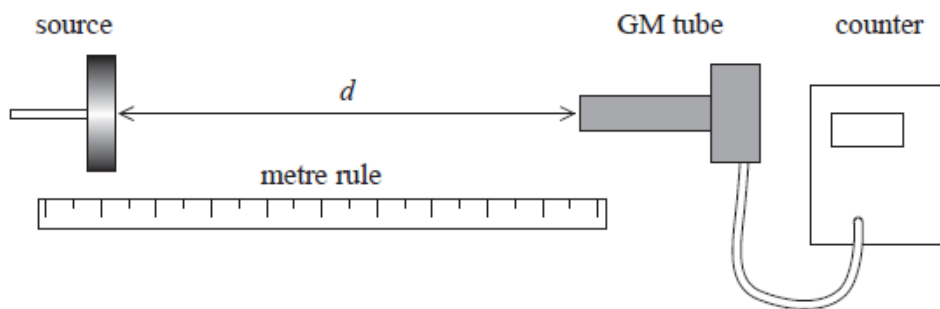
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**(Total for question = 3 marks)**

Q13.

A student investigated the way in which gamma radiation spreads out from a source.

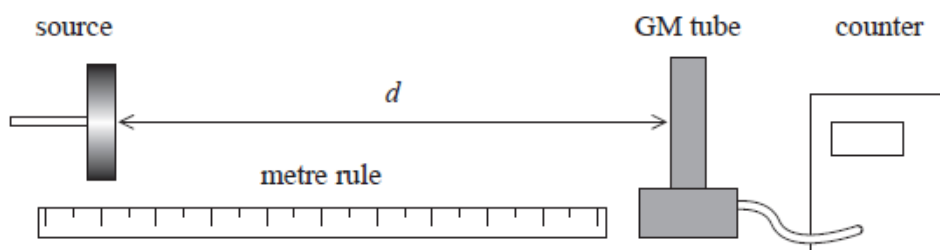
He placed a cobalt-60 source in a source holder and set up a Geiger-Müller (GM) tube a short distance  $d$  away. He connected the GM tube to a counter as shown.



**Figure 1**

The student recorded the count for 2 minutes.

His teacher turned the GM tube through  $90^\circ$  so that the side of the tube faced the source as shown below.



**Figure 2**

It is suggested that the investigation into the way in which gamma radiation spreads out from a source, using the apparatus as shown in **Figure 2**, could be carried out successfully using a radium-226 source.

Radium-226 emits  $\alpha$ ,  $\beta$  and  $\gamma$  radiation.

Justify this suggestion.

(2)

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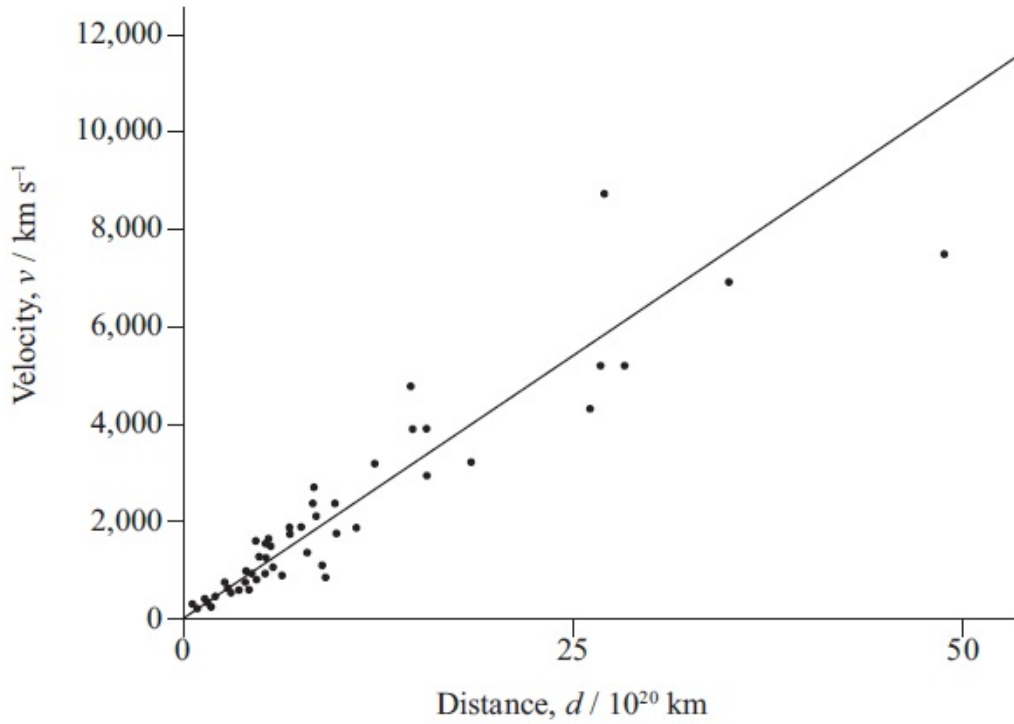
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**(Total for question = 2 marks)**

Q14.

The graph shows how the velocity varies with distance for a number of distant galaxies. All the galaxies are receding from Earth, and there appears to be a linear relationship between the velocity of recession and the distance to the galaxy.



(a) Use the graph to estimate an age for the Universe

(4)

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Age of the Universe = .....

\*(b) Describe how astronomers would have determined the velocity of each galaxy.

(5)

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\*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

(3)

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**(Total for question = 12 marks)**

**Mark Scheme**

Q1.