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Answer **all** questions in the spaces provided.

1 The fluorine isotope $^{18}_{9}F$ can be produced in the process represented by

$$X + {}^{1}_{1}p \longrightarrow {}^{18}_{9}F + {}^{1}_{0}n$$

in which nucleus X combines with a fast moving proton to form the nucleus $^{18}_{9}F$ with the ejection of a neutron.

(a) (i) Determine the number of protons and neutrons in nucleus X.

..... protons

..... neutrons

(ii) Only one isotope of X produces this reaction.
Explain what is meant by *isotope*.

.....

.....

(3 marks)

(b) (i) Determine the $\frac{\text{charge}}{\text{mass}}$ ratio for the $^{18}_{9}F$ nucleus, in $C\,kg^{-1}$.

.....

.....

.....

(ii) Show that the $\frac{\text{charge}}{\text{mass}}$ ratio for the $^{18}_{9}F$ nucleus is larger than that of nucleus X.

.....

.....

.....

.....

(3 marks)

6

2 When a metal plate is illuminated with electromagnetic radiation of wavelength 1.5×10^{-7} m, the maximum kinetic energy of the emitted photoelectrons is 1.2×10^{-19} J.

(a) State what is meant by the *work function* of the metal.

.....

.....

.....

(2 marks)

(b) (i) Show that the work function of the metal is 1.2×10^{-18} J.

.....

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.....

(ii) Calculate the threshold frequency for the metal.

.....

.....

.....

(4 marks)

(c) The wavelength of the incident electromagnetic radiation remains at 1.50×10^{-7} m but its intensity is doubled.
State and explain what changes occur, if any, to the maximum kinetic energy of each photoelectron and to the number emitted per second.

You may be awarded additional marks for the quality of written communication in your answer.

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(4 marks)

10

Turn over for the next question

3 (a) A muon can decay via the weak interaction

$$\mu^- \rightarrow e^- + X + \nu_\mu$$

(i) Name a mediating particle of the weak interaction.

.....

(ii) Identify particle X.

.....

.....

.....

.....

(3 marks)

(b) An electron-neutrino may interact with a neutron as represented in the following equation.

$$\nu_e + n \rightarrow e^- + p$$

Draw a Feynman diagram to represent this interaction.

(3 marks)

(c) In a head-on collision between a proton and an antiproton the following reaction was observed.

$$p + \bar{p} \rightarrow 4\pi^+ + 4\pi^-$$

(i) What name is given to the type of process in which a particle and its antiparticle interact?

.....

(ii) Immediately following the process named in part (c)(i), what was formed before the $4\pi^+$ and $4\pi^-$ were created?

.....

.....

(3 marks)

(d) Determine the quark structure of an antiproton, $\bar{p}$.

.....

.....

(1 mark)

10

Turn over for the next question

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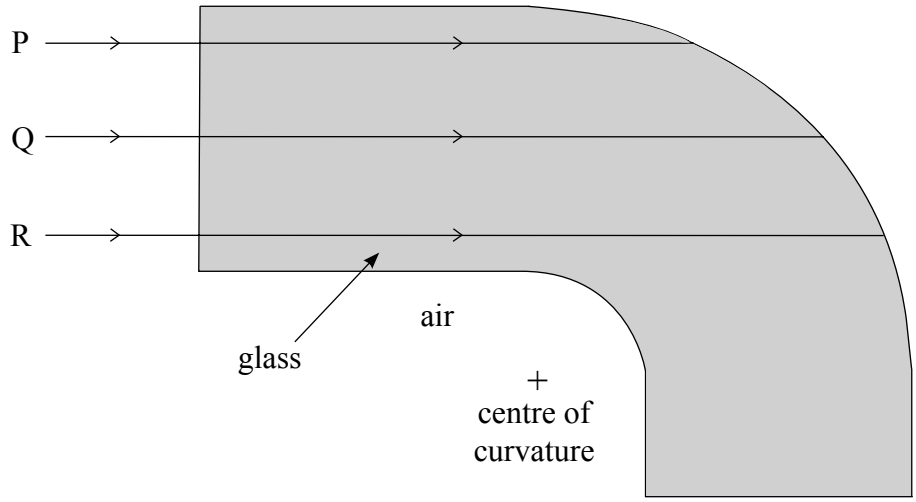
4 **Figure 1** shows a glass optical fibre bent through 90° and surrounded by air. Three light rays PQR, initially travelling parallel to the axis of the fibre, are incident normally on the flat end of the fibre. They then strike the internal surface of the fibre at the glass-air boundary. Ray Q is incident at the critical angle.

Figure 1



(a) (i) Explain what is meant by *critical angle*.

.....

.....

(ii) Calculate the critical angle for a boundary between the glass and air.
refractive index of the glass = 1.54

.....

.....

.....

(4 marks)

(b) Draw, using a ruler, on **Figure 1** the path taken by rays P, Q and R on striking the internal surface.

(3 marks)

(c) (i) Describe what would happen to ray Q if the glass shown in **Figure 1** had been surrounded during manufacture with a glass cladding of lower refractive index.

You may be awarded additional marks to those shown in the brackets for the quality of written communication in your answer.

.....

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.....

(ii) State **one** reason why a glass cladding is normally used.

.....

.....

.....

(iii) Calculate the critical angle for a boundary between the glass core and the glass cladding.

refractive index of the glass used for the cladding = 1.46

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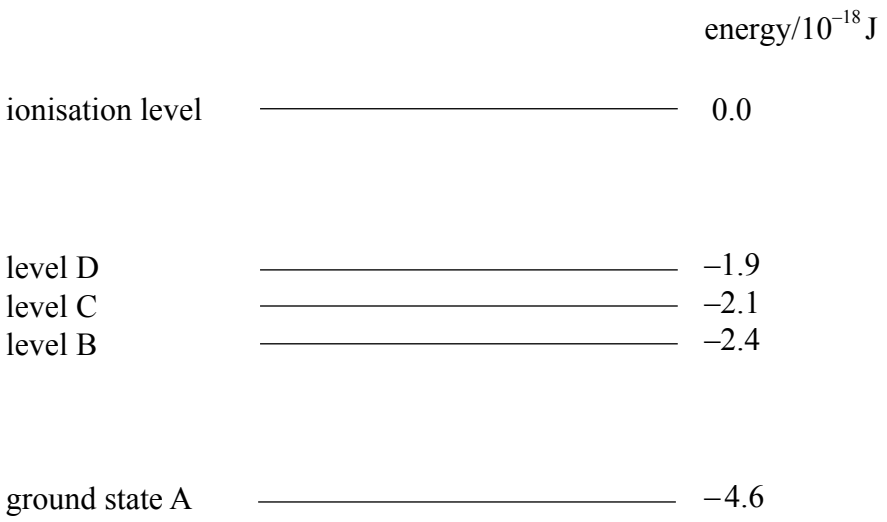
(6 marks)

13

Turn over for the next question

5 The diagram shows five electron energy levels of an isolated atom.
The ground state and the ionisation level are included.



(a) (i) Explain what is meant by *ionisation*.

.....

.....

(ii) Ionisation may be caused by electron impact.
Explain how else might an atom be ionised.

.....

.....

(iii) Calculate the ground state energy in eV.

.....

.....

.....

(3 marks)

(b) (i) An electron with kinetic energy 2.6×10^{-18} J collides inelastically with an electron in the ground state.
State which energy levels may be occupied following this collision.

.....

(ii) A photon of energy 2.6×10^{-18} J is incident on an electron in the ground state.
State and explain what would happen.

.....

.....

.....

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(3 marks)

(c) After a separate excitation process, level D is occupied.
Calculate the longest possible wavelength of electromagnetic radiation emitted as the atom de-excites.

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.....

.....

.....

(3 marks)

9

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

LEAVE MARGIN BLANK

Answer **all** questions.

1 (a) One of the assumptions of the kinetic theory of gases is that gas molecules move with random motion. State **two** other assumptions of the kinetic theory of gases.

.....

.....

.....

.....

.....

(2 marks)

(b) Explain why the average velocity of the gas molecules in a container is zero.

.....

.....

.....

.....

.....

(2 marks)

(c) The pressure a gas exerts on the walls of a container depends on the *mean square speed* of the molecules. Explain what is meant by mean square speed.

.....

.....

.....

.....

(2 marks)

LEAVE MARGIN BLANK

(d) Explain why the mean square speeds of the gas molecules of two different gases at the same temperature are **not** the same.

.....

.....

.....

.....

.....

(2 marks)

8

Turn over for the next question

2 (a) State the principle of moments for a body in equilibrium.

.....

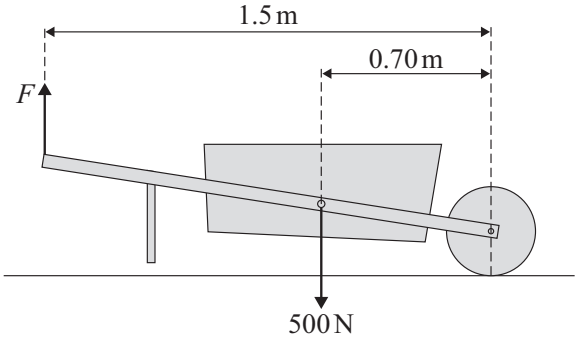
.....

.....

(2 marks)

(b) **Figure 1** shows a vertical force, *F*, being applied to raise a wheelbarrow which has a total weight of 500 N.

Figure 1



(i) On **Figure 1** draw an arrow to represent the position and direction of the force, *R*, exerted by the ground on the wheel.

(ii) Calculate the minimum value of the vertical force, *F*, needed to raise the legs of the wheelbarrow off the ground.

.....

.....

.....

(iii) Calculate the magnitude of *R* when the legs of the wheelbarrow have just left the ground.

.....

.....

.....

(5 marks)

7

LEAVE MARGIN BLANK

3 A steady stream of water strikes a wall horizontally without rebounding and, as a result, exerts a force on the vertical wall.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer to Question 3(a).

(a) With reference to Newton's Laws of motion,

(i) state and explain why the momentum of the water changes as it strikes the wall,

.....

.....

.....

(ii) explain why the water exerts a constant force on the wall.

.....

.....

.....

(5 marks)

(b) Water arrives at the wall at a rate of $18\,\text{kg}\,\text{s}^{-1}$. It strikes the wall horizontally, at a speed of $7.2\,\text{m}\,\text{s}^{-1}$ without rebounding. Calculate

(i) the change in momentum of the water in **one** second,

.....

.....

.....

(ii) the force exerted by the water on the wall.

.....

(3 marks)

(c) State and explain the effect on the magnitude of the force if the water rebounds after striking the wall.

.....

.....

.....

(2 marks)

LEAVE MARGIN BLANK

4 A dart is thrown horizontally at a speed of $8.0\,m\,s^{-1}$ towards the centre of a dartboard that is 2.0 m away. At the same instant that the dart is released, the support holding the dartboard fails and the dartboard falls freely, vertically downwards. The dart hits the dartboard in the centre before they both reach the ground.

(a) State and explain the motion of the dart and the dartboard, while the dart is in flight.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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(4 marks)

(b) Calculate

(i) the time taken for the dart to hit the dartboard,

.....

.....

(ii) the vertical component of the dart's velocity just before it strikes the dartboard,

.....

.....

(iii) the magnitude and direction of the resultant velocity of the dart as it strikes the dartboard.

.....

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.....

(5 marks)

9

5 An aircraft accelerates horizontally from rest and takes off when its speed is $82\,m\,s^{-1}$. The mass of the aircraft is 5.6×10^4 kg and its engines provide a constant thrust of 1.9×10^5 N.

(a) Calculate

(i) the initial acceleration of the aircraft,

.....

.....

(ii) the minimum length of runway required, assuming the acceleration is constant.

.....

.....

.....

(3 marks)

(b) In practice, the acceleration is unlikely to be constant. State a reason for this and explain what effect this will have on the minimum length of runway required.

.....

.....

.....

.....

(2 marks)

(c) After taking off, the aircraft climbs at an angle of 22° to the ground. The thrust from the engines remains at 1.9×10^5 N. Calculate

(i) the horizontal component of the thrust,

.....

.....

(ii) the vertical component of the thrust.

.....

.....

(2 marks)

7

LEAVE MARGIN BLANK

6 A car of mass 1200 kg is travelling at 12 m s^{-1}. When the brakes are applied the car comes uniformly to rest in 6.0 s.

(a) Calculate the kinetic energy lost by the car.

.....

.....

(2 marks)

(b) Approximately 70% of the kinetic energy of the car is converted into thermal energy in the brakes of the car when coming to rest. The total mass of the brake components is 28 kg and their average specific heat capacity is 540 J kg^{-1} K^{-1}.

(i) Estimate the temperature rise of the brake components.

.....

.....

.....

(ii) State and explain where some of the remaining energy is likely to have been dissipated.

.....

.....

.....

.....

(5 marks)

7

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

Practice 3

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The table shows some physical quantities. Which row correctly identifies scalar and vector quantities?

		Scalar	Vector
☒	**A**	distance	acceleration
☒	**B**	time	speed
☒	**C**	velocity	force
☒	**D**	work	power

(Total for Question 1 = 1 mark)

2 A cyclist travelling at a speed of 4.2 m s^{-1} accelerates at 1.1 m s^{-2}. In a time of 7.4 s the distance travelled is

☒ **A** 30 m

☒ **B** 35 m

☒ **C** 61 m

☒ **D** 91 m

(Total for Question 2 = 1 mark)

3 Which of these units is the same as the newton?

☒ **A** kg m s^{-1}

☒ **B** kg m s^{-2}

☒ **C** kg m^2 s^{-2}

☒ **D** kg m^2 s^{-3}

(Total for Question 3 = 1 mark)

4 A student is asked to determine the output of a motor as it lifts an object. He measures the height through which the object is raised, the time taken and the weight of the object.

To find the power he must calculate

☒ **A** height × weight × time

☒ **B** $\frac{\text{height} \times \text{weight}}{\text{time}}$

☒ **C** $\frac{\text{time} \times \text{weight}}{\text{height}}$

☒ **D** $\frac{\text{weight}}{\text{height} \times \text{time}}$

(Total for Question 4 = 1 mark)

5 A football is kicked at a speed of 12 m s^{-1} at an angle of 35° to the horizontal. The horizontal component of its velocity, in m s^{-1}, is given by

☒ **A** 12 cos 35°

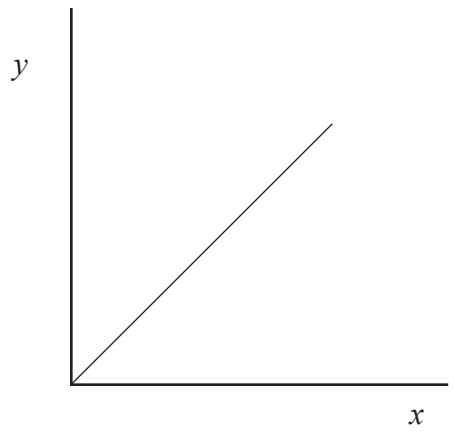
☒ **B** 12 sin 35°

☒ **C** $\frac{12}{\cos 35°}$

☒ **D** $\frac{12}{\sin 35°}$

(Total for Question 5 = 1 mark)

6 The diagram shows a graph plotted using the results from an experiment in which a metal wire was stretched.



The gradient of the graph equals the Young modulus of the metal.

Which row gives the correct labels for the axis?

		y	*x*
☒	**A**	extension	force
☒	**B**	force	extension
☒	**C**	strain	stress
☒	**D**	stress	strain

(Total for Question 6 = 1 mark)

7 A pigeon of mass 0.45 kg is flying with kinetic energy 58 J.
Its speed is

☒ **A** 8.0 m s^{-1}

☒ **B** 11 m s^{-1}

☒ **C** 16 m s^{-1}

☒ **D** 22 m s^{-1}

(Total for Question 7 = 1 mark)

8 A ball bearing is dropped through a liquid and its terminal velocity measured.
The experiment is repeated at a different temperature.

Which row could correctly describe this second experiment?

		Temperature	Viscosity	Terminal velocity
☒	**A**	lower	greater	faster
☒	**B**	lower	greater	slower
☒	**C**	higher	greater	slower
☒	**D**	higher	smaller	slower

(Total for Question 8 = 1 mark)

9 Velocity can be found from the

☒ **A** area under a displacement-time graph

☒ **B** area under a force-time graph

☒ **C** gradient of a displacement-time graph

☒ **D** gradient of an acceleration-time graph

(Total for Question 9 = 1 mark)

10 A freely falling object on Earth has a speed of 5.0 m s^{-1}.

After falling a further 20 m its speed is

☒ **A** 15 m s^{-1}

☒ **B** 20 m s^{-1}

☒ **C** 25 m s^{-1}

☒ **D** 45 m s^{-1}

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The Saturn V rocket used in NASA's space programme had a mass of 3.04×10^6 kg.
It took off vertically with a thrust force of 3.40×10^7 N.

(a) Show that the resultant force on the rocket is about 4×10^6 N.

(3)

.....

.....

.....

(b) Calculate the initial acceleration.

(2)

.....

.....

Initial acceleration = ...

(c) After 150 s the rocket reached a speed of 2390 m s^{-1}.

Calculate its average acceleration.

(2)

.....

.....

.....

Average acceleration = ...

(d) Suggest why the initial acceleration and average acceleration are different.

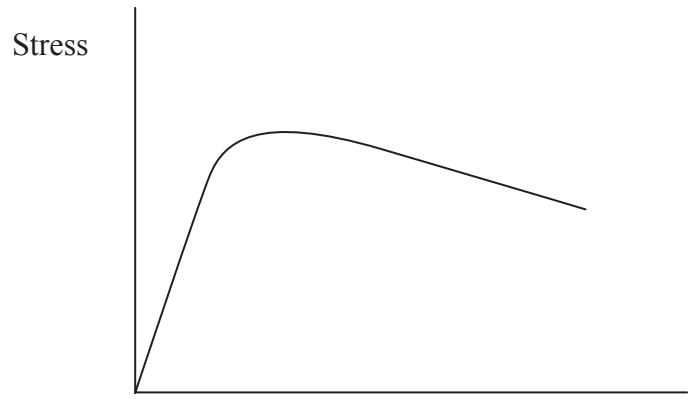
(1)

.....

.....

(Total for Question 11 = 8 marks)

12 The graph shows how stress varies with strain for a given material.



(a) Explain what is meant by each of the following terms

(3)

limit of proportionality (L)

.....

.....

tensile strength

.....

.....

yield point (Y)

.....

.....

(b) Using crosses and the letters shown above, mark the 'limit of proportionality' (L) and the 'yield point' (Y) on the graph.

(2)

(Total for Question 12 = 5 marks)

13 When a ball moves through air, the airflow is laminar around the front of the ball and turbulent behind it.

(a) State what is meant by

(2)

laminar flow

.....

.....

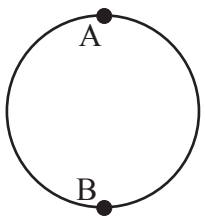
turbulent flow

.....

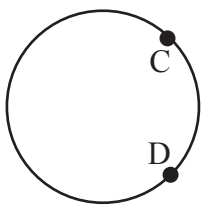
.....

(b) The diagram shows a ball for which the airflow becomes turbulent beyond points A and B. Add to the diagram to show the airflow around the ball. The ball is moving to the left.

(2)



(c) It is suggested that 'dimples' on a golf ball decrease the area over which there is turbulent flow so it is only produced beyond points C and D.



Explain how decreasing the area over which there is turbulent flow would increase the range of a golf ball.

(2)

.....

.....

.....

(Total for Question 13 = 6 marks)

14 (a) What is meant by Newton's first law of motion?

(2)

.....

.....

(b) Newton's third law identifies pairs of forces.

(i) State **two** ways in which the forces in a pair are identical.

(2)

.....

.....

(ii) State **two** ways in which the forces in a pair differ.

(2)

.....

.....

(iii) One of the forces acting on a car can be described as follows:

'The Earth exerts a downward gravitational force of 12 000 N on the car'.

Describe its Newton's third law pair force.

(2)

.....

.....

(Total for Question 14 = 8 marks)

*** 15** You are asked to determine the acceleration of free fall at the surface of the Earth, g, using a free fall method in the laboratory.

(a) Describe the apparatus you would use, the measurements you would take and explain how you would use them to determine g.

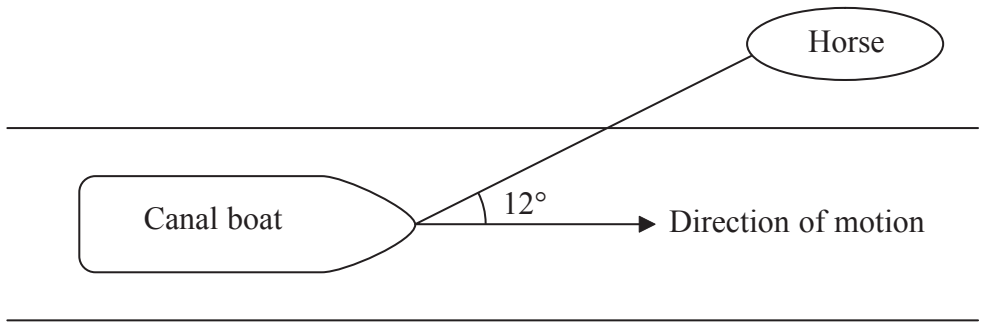
(6)

(b) Give **one** precaution you would take to ensure the accuracy of your measurements.

(1)

(Total for Question 15 = 7 marks)

16



A horse is pulling a canal boat using a rope at 12° to the direction of motion of the boat. The tension in the rope is 1150 N.

(a) The canal boat is moving at a steady speed. Calculate the resistive force opposing the boat's forward motion.

(2)

.....

.....

Force = ...

(b) Calculate the work done on the boat by the horse when the canal boat is towed 500 m along the canal.

(2)

.....

.....

Work = ...

(c) Explain why using a longer rope could allow the horse to do the same work while producing a lower tension in the rope.

(2)

.....

.....

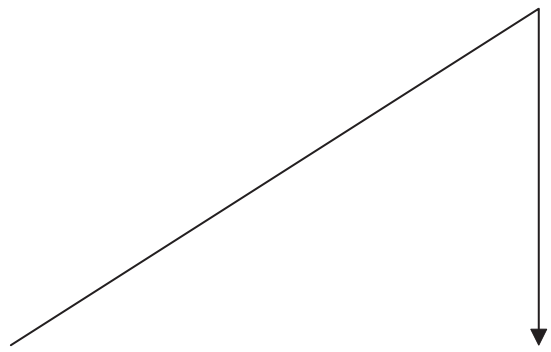
.....

(Total for Question 16 = 6 marks)

***17** In the fifteenth century, an explanation of projectile motion went as follows:

When you throw an object you give it a force called impetus. It moves in a straight line until the impetus is used up. Then the object falls vertically to the ground.

The diagram shows the path described.



(a) Correct the diagram to show the path followed by a projectile according to modern observations. Assume it has the same initial direction.

(1)

(b) Explain why a projectile follows the path you have drawn. Your answer should include reference to horizontal velocity.

(3)

(c) When a toy balloon is hit quickly up at an angle, it appears to follow a path similar to the one described by the fifteenth century explanation.

Explain why the balloon follows this path.

(3)

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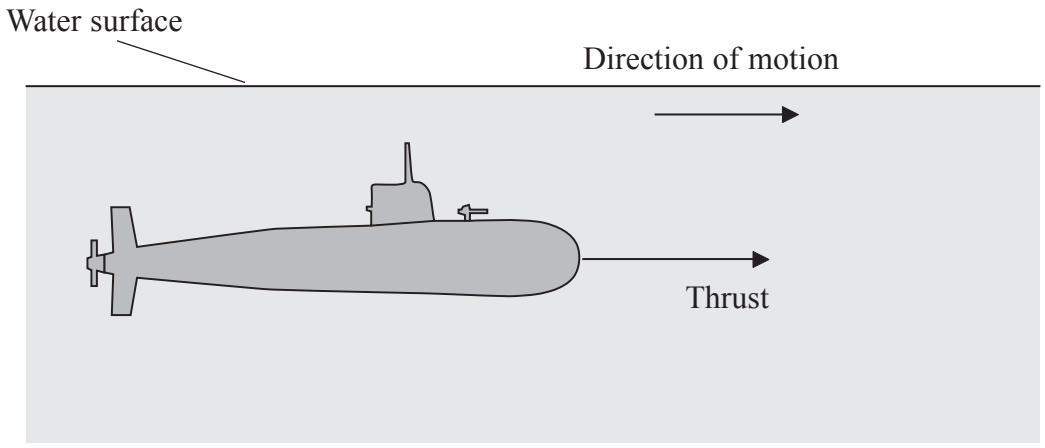
(Total for Question 17 = 7 marks)

***18** The diagram shows a submarine and one of the forces acting on it. The submarine moves at a constant depth and speed in the direction shown.



(a) Add labelled arrows to show the other **three** forces on the submarine.

(2)

(b) State **two** equations that show the relationship between the forces acting on the submarine.

(2)

(c) The submarine has a volume of 7100 m^3.
Show that the weight of the submarine is about 7×10^7 N.

Density of sea water = 1030 kg m^{-3}

(2)

(d) The submarine can control its depth by changing its weight. This is done by adjusting the amount of water held in ballast tanks.

As the submarine dives to greater depths the increased pressure of the surrounding water produces a compressive strain.

(i) Explain what is meant by compressive strain.

(1)

.....

.....

.....

(ii) This decreases the volume of the submarine. Explain the action that should be taken to maintain a constant depth as the volume of the submarine is decreased.

(2)

.....

.....

.....

(iii) The submarine is made from steel. Suggest why a material, such as fibreglass, which has a much smaller Young modulus than steel would be unsuitable at greater depths.

(2)

.....

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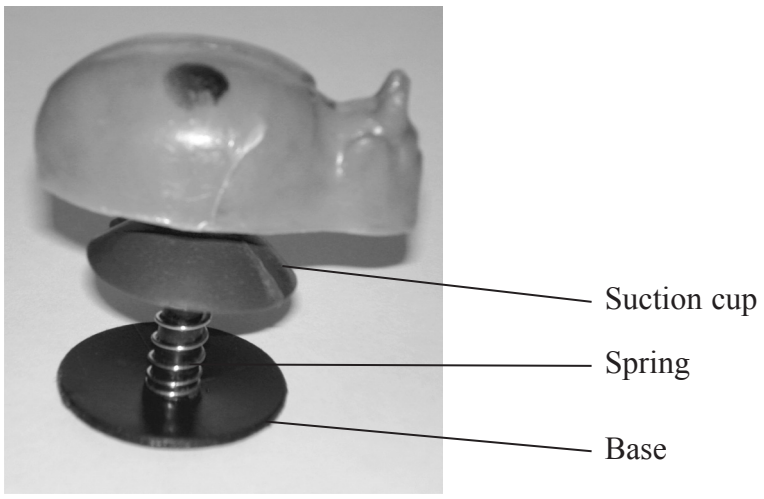
.....

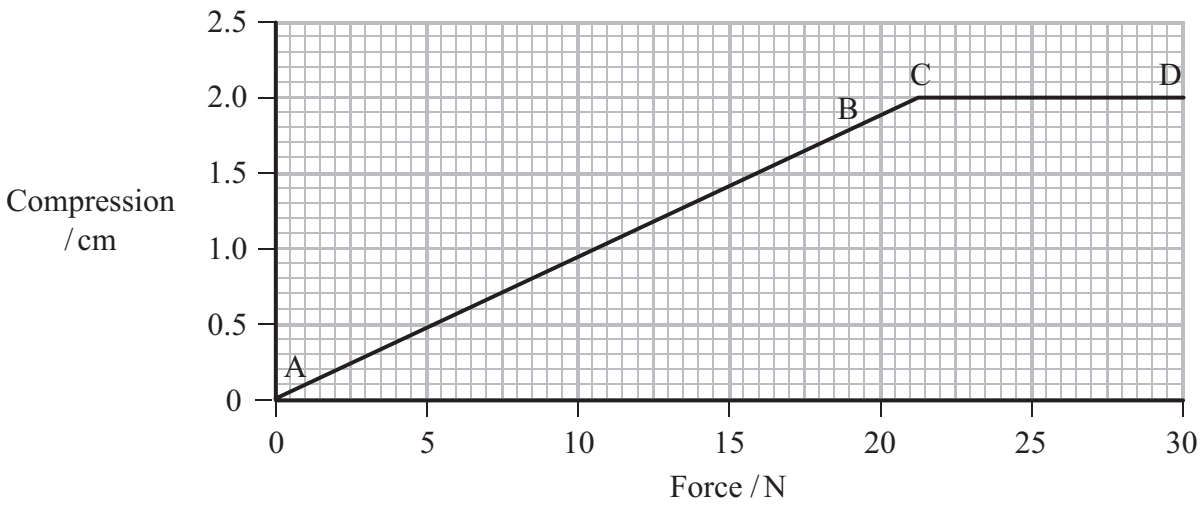
(Total for Question 18 = 11 marks)

19 The picture shows a jumping toy on which a student carries out some experiments.



The top of the toy is pushed down, compressing the spring. The suction cup adheres to the base and holds the toy down. After a short time, the suction cup leaves the base, causing the toy to jump.

A compression–force graph is obtained for the spring in the toy.



(a) (i) Explain the shape of section AB of the graph.

(1)

.....

.....

(ii) Explain why section CD of the graph is horizontal.

(1)

.....

.....

.....

(b) Show that the stiffness of the spring is about 1000 N m^{-1}.

(2)

.....

.....

.....

(c) As the suction cup is about to leave the base the compression of the spring is 0.018 m.

(i) Calculate the energy stored in the spring at this stage.

(2)

.....

.....

.....

Energy stored = ...

(ii) Calculate the maximum possible height reached by the toy.

Mass of toy = 7.3×10^{-3} kg

(2)

.....

.....

.....

Height = ...

(iii) State an assumption made in your calculation.

(1)

.....

.....

(d) The student uses a camera to video the movement of the toy in front of a metre rule. The video is then used to find the maximum height reached by the toy.

(i) Explain the advantage of using the video camera over making observations just by eye.

(2)

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.....

.....

.....

.....

(ii) The student repeats this procedure several times and records the following data:

0.45 m, 0.44 m, 0.36 m, 0.46 m, 0.45 m.

mean maximum height = 0.45 m

Why is the student justified in using 0.45 m as the mean?

(1)

.....

.....

(Total for Question 19 = 12 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A child's toy is operated by a small motor. The potential difference across the motor is 6.0 V and the current in it is 0.20 A. The energy used by the motor in 120 s is

☒ **A** 2.40 J

☒ **B** 60.0 J

☒ **C** 144 J

☒ **D** 3600 J

(Total for Question 1 = 1 mark)

2 Which one of the following does **not** apply to sound waves?

☒ **A** They transmit energy.

☒ **B** They travel faster in a vacuum.

☒ **C** They result from vibrations.

☒ **D** They are longitudinal waves.

(Total for Question 2 = 1 mark)

3 Two coherent sources emit waves of wavelength λ in phase. At a point where the two waves meet they have a phase difference of 90° ($\frac{\pi}{2}$ radians). Which of the following could be the path difference at this point?

☒ **A** 2λ

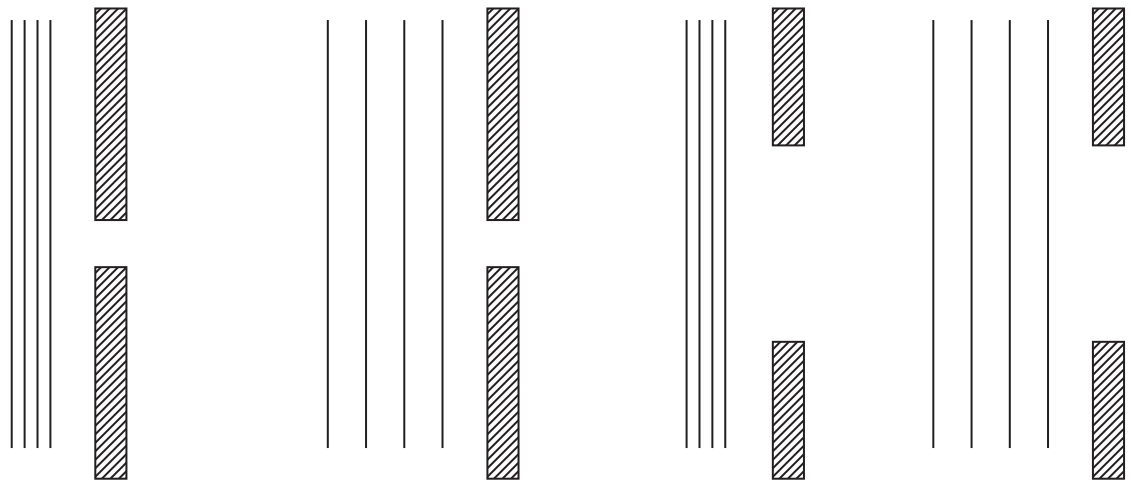
☒ **B** λ

☒ **C** $\frac{\lambda}{2}$

☒ **D** $\frac{\lambda}{4}$

(Total for Question 3 = 1 mark)

4 The four diagrams show waves of different wavelengths approaching slits of different widths.



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

In which diagram will the diffraction be the greatest?

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

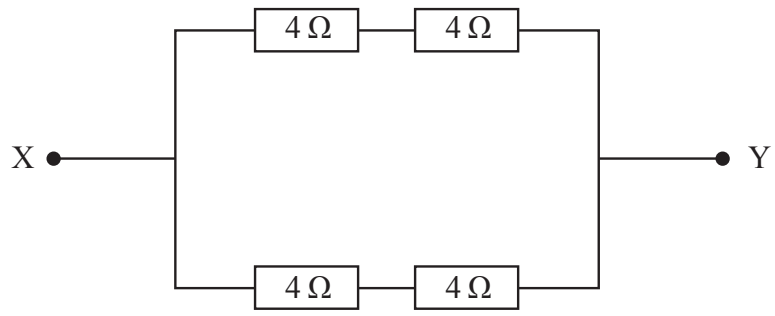
(Total for Question 4 = 1 mark)

5 The heating element for an electric fire is made from a wire of resistance R. It is replaced with a wire of the same material which has the same length but is twice the diameter. The resistance of this second wire is

- ☒ **A** $\frac{1}{4}R$
- ☒ **B** $\frac{1}{2}R$
- ☒ **C** $2R$
- ☒ **D** $4R$

(Total for Question 5 = 1 mark)

6 The diagram shows a resistor network.



The total resistance between points X and Y is

☒ **A** 0.25 Ω

☒ **B** 1.0 Ω

☒ **C** 4.0 Ω

☒ **D** 16 Ω

(Total for Question 6 = 1 mark)

7 The speed of sound in steel is 6000 m s^{-1}. The wavelength of an ultrasound wave of frequency 50 kHz travelling through a steel girder is

☒ **A** 0.0083 m

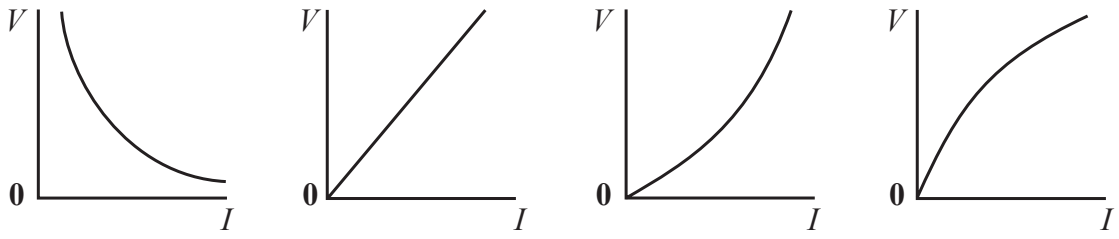
☒ **B** 0.12 m

☒ **C** 8.3 m

☒ **D** 120 m

(Total for Question 7 = 1 mark)

8 Which one of the following graphs correctly shows the relationship between potential difference (V) and current (I) for a filament lamp?



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

☒ **A**

☒ **B**

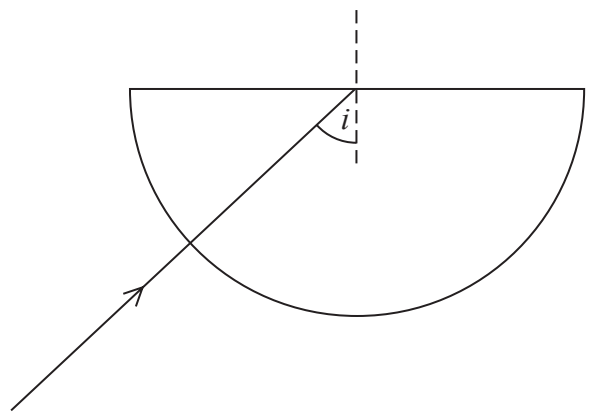
☒ **C**

☒ **D**

(Total for Question 8 = 1 mark)

9 Light travels into a semicircular glass block as shown in the diagram. The ray of light reaches the straight edge of the block at an angle of incidence i.

The critical angle for glass is c.



Which one of the following statements is true for light at the straight edge?

☒ **A** When i is bigger than c then no light is reflected.

☒ **B** When i is bigger than c then no light is transmitted.

☒ **C** When i is smaller than c then no light is reflected.

☒ **D** When i is smaller than c then no light is transmitted.

(Total for Question 9 = 1 mark)

10 When a fire engine moves away from an observer, the pitch of the siren heard by the observer decreases. This is because

- ☒ **A** the wavelength of the sound wave decreases
- ☒ **B** the speed of the fire engine increases
- ☒ **C** the frequency of the siren decreases
- ☒ **D** the distance travelled by each wavefront increases

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Explain, in terms of energy, the difference between potential difference (p.d.) and electromotive force (e.m.f.).

(2)

.....

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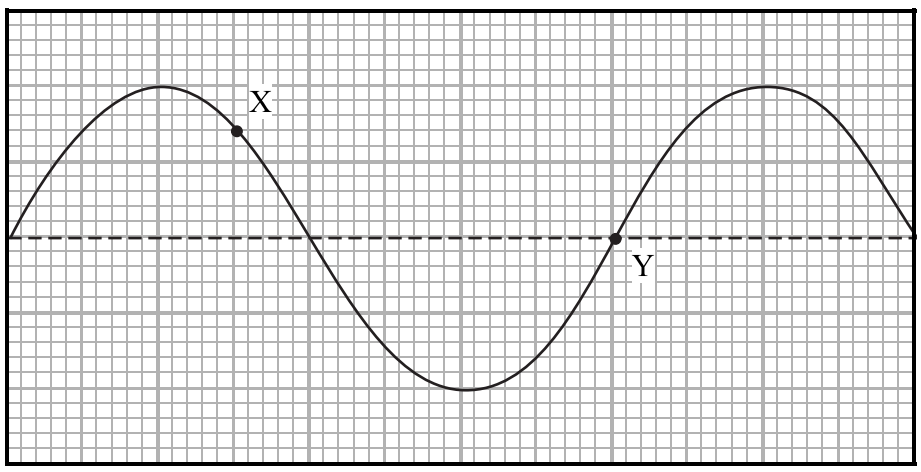
.....

(Total for Question 11 = 2 marks)

12 The diagram shows the shape of a wave on the surface of a tank of water at one instant of time. The wave is travelling to the right.



On the diagram

(a) mark a point on the water surface whose motion is exactly 180° out of phase with the motion at X. Label this point A,

(1)

(b) draw an arrow at point Y to show the direction in which the water at Y is moving at the instant shown,

(1)

(c) mark a point on the water surface that is at rest at the instant shown. Label this point B.

(1)

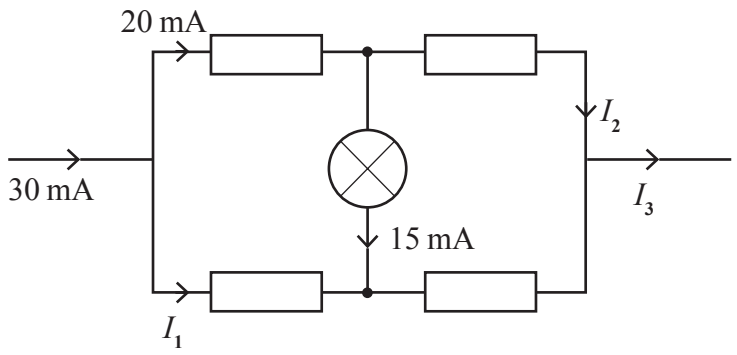
(Total for Question 12 = 3 marks)

13 (a) What is the coulomb in base units?

(1)

.....

(b) The diagram shows part of an electrical circuit.



Determine the magnitudes of the currents I_1, I_2 and I_3.

(3)

I_1 = ...

I_2 = ...

I_3 = ...

(Total for Question 13 = 4 marks)

*1

15

***14** A student looks at the sunlight reflected off a puddle of water. She puts a polarising (Polaroid) filter in front of her eye. As she rotates the filter the puddle appears darker then lighter.

Explain this observation.

(3)

(Total for Question 14 = 3 marks)

15 The current I in a length of aluminium of cross-sectional area A is given by the formula

$$I = nevA$$

where e is the charge on an electron.

(a) State the meanings of n and v.

(2)

n:

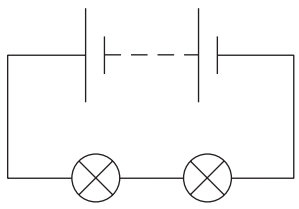
v:

(b) Show that the units on the left hand side of the equation are consistent with those on the right hand side.

(3)

(Total for Question 15 = 5 marks)

16 (a) Two lamps A and B are connected in series with a battery.



Lamp B glows more brightly than lamp A. Complete each of the sentences by choosing one of the phrases in the box.

(3)

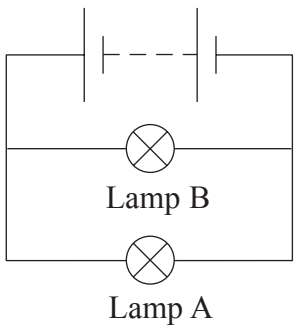
equal to	**greater than**	**less than**

The current in lamp A is ..... the current in lamp B.

The p.d. across lamp A is ..... the p.d. across lamp B.

The resistance of lamp A is ..... the resistance of lamp B.

(b) The same bulbs are now connected in parallel with the battery.



State which bulb will be brighter and explain your answer.

(3)

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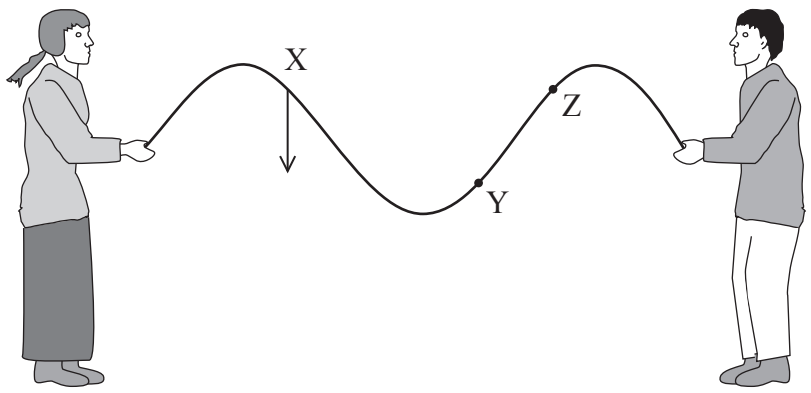
(Total for Question 16 = 6 marks)

17

17 Two students demonstrate standing waves to the rest of the class using a rope.

The diagram shows the appearance of the standing wave on the rope at one instant.
Each part of the rope is at its maximum displacement.



(a) (i) Mark the position of **one** node on the diagram. Label this point N.

(1)

(ii) The arrow at point X shows the direction in which the point X is about to move. Add arrows to the diagram to show the directions in which points Y and Z are about to move.

(2)

(b) The frequency of the vibration shown in the diagram is 1.5 Hz. When a rope is vibrating with its fundamental frequency there is one antinode. Calculate the fundamental frequency of this wave.

(2)

.....

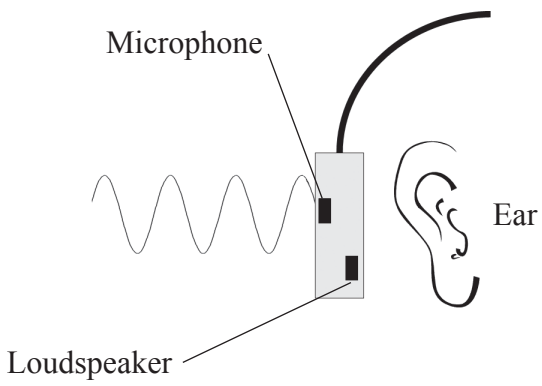
.....

Frequency = ...

(Total for Question 17 = 5 marks)

18 Noise cancelling headphones were first invented to cancel the noise in aeroplane and helicopter cockpits. They work using the principle of superposition of waves.

Sound waves enter and pass through the headphone and are detected by a microphone. An electronic circuit sends a signal to the loudspeaker so that it produces an 'opposite wave'.



(a) Compare the properties of the two sound waves necessary to produce complete cancellation of the two waves that reach the ear.

(3)

(b) In practice the incoming sound is reduced in volume rather than cancelled completely.

Noise-cancelling headphones work well when the noise is from a jet engine. They are not very effective at cancelling speech or music. Explain why.

(3)

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(Total for Question 18 = 6 marks)

***19** (a) A 60 W filament light bulb is used as a ceiling light. The bulb is 2.5 m above the floor and is 5.0% efficient at converting electrical energy into visible light.

Calculate the visible light intensity (radiation flux) on the floor directly below the bulb.

Assume that at a distance r from the source the energy is spread over a total area $4\pi r^2$.

(3)

.....

.....

.....

Visible light intensity = ...

(b) Increasingly a different type of light bulb is being used. It is a coiled fluorescent bulb. A 10 W bulb of this type could replace the 60 W filament bulb and give the same visible light intensity on the floor.

Approximately 25% of national power production is used for lighting.

Discuss why some countries have announced that filament bulbs will be banned in the next few years.

(3)

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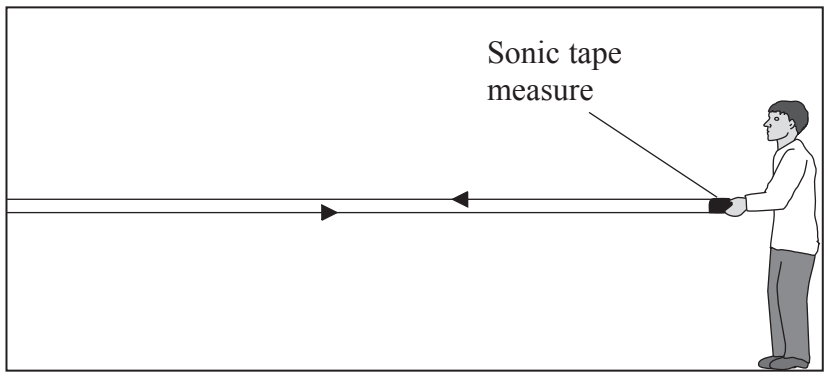
(Total for Question 19 = 6 marks)

20

20 A sonic tape measure uses ultrasound to measure distances in buildings. It sends out pulses of ultrasound towards a distant wall and records the time interval between a pulse being sent and its return.



(a) For one particular measurement the time interval was 25 ms.

Calculate the distance from the sonic tape measure to the wall.

Speed of sound = 330 m s^{-1}

(3)

Distance = ...

(b) Why is the ultrasound transmitted in pulses?

(1)

(Total for Question 20 = 4 marks)

21 An electronics student is using light emitting diodes (LEDs) to make a traffic light model. He uses red, orange and green LEDs. The table gives information about these LEDs. They are identified as 1, 2 and 3.

LED	Frequency / 10^{14} Hz	Wavelength / 10^{-9} m	Colour
1	5.66	530	
2	5.00	600	
3	4.41	680	

(a) Complete the table by filling in the colour of light emitted by each LED.

(1)

(b) Calculate the energy of the lowest energy photon emitted by this traffic light model.

(3)

.....

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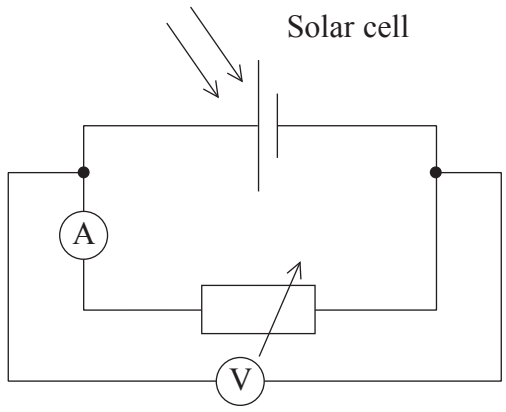
Energy = ...

(Total for Question 21 = 4 marks)

22 A solar cell generates an e.m.f. when certain wavelengths of light are incident on it.
A student connects a solar cell in the following circuit.

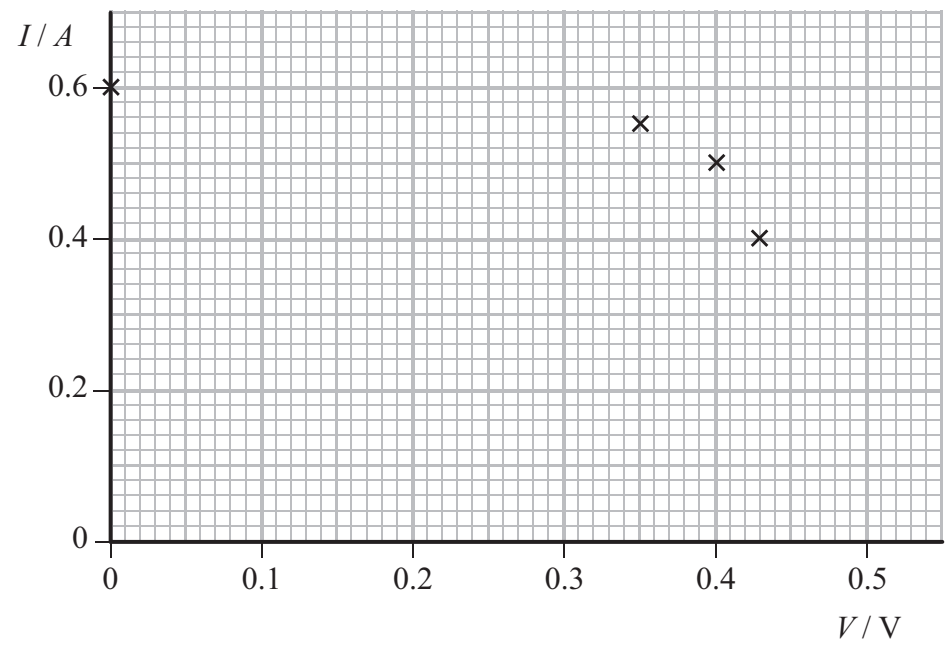


The student keeps the intensity and wavelength of the incident light constant and adjusts the variable resistor to obtain the following set of results.

Current I / A	Terminal potential difference V / V
0.60	0.00
0.55	0.35
0.50	0.40
0.40	0.43
0.30	0.46
0.20	0.48
0.10	0.50
0.00	0.52

(a) On the grid opposite, plot these results and draw the line of best fit through all the points. The first four points have been plotted.

(3)



(b) (i) Calculate the power output of the solar cell when the current in the cell is 0.40 A.

(2)

.....

.....

Power = ...

(ii) Explain why the e.m.f. of this cell is 0.52 V.

(2)

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(iii) Calculate the internal resistance of the cell when the potential difference across the cell is 0.40 V.

(3)

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Internal resistance = ...

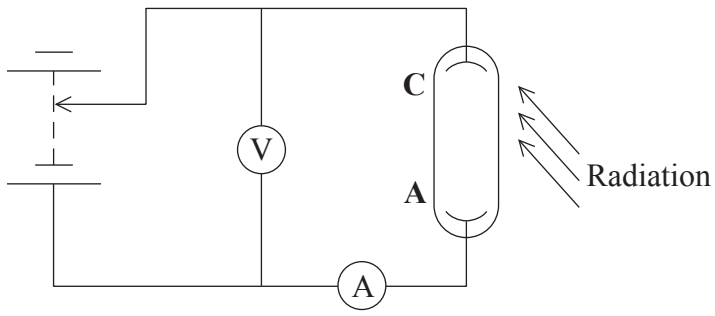
(c) The e.m.f. of this particular cell is independent of the light intensity.
The current increases as the light intensity increases.

Add to the grid above a line showing a set of results that might be obtained if the intensity of the incident light was increased.

(2)

(Total for Question 22 = 12 marks)

23 The diagram shows the apparatus for an experiment on the photoelectric effect.



(a) A light is shone onto the cathode **C** and a potential difference is applied between the cathode and the anode **A** of the photocell. A sensitive ammeter is used to detect any current that flows.

The light is replaced by one of the same intensity, but a different photon energy. The results are shown in the table below.

	Photon energy/eV	**Intensity of light/W m^{-2}**	**Work function/eV**	**Ammeter reading/A**
First light	1.8	1.0	2.3	0.0
Second light	3.8	1.0	2.3	5.0×10^{-12}

Explain why the first ammeter reading is zero.

(2)

.....

.....

.....

.....

(b) The experiment is repeated using the same two photon energies but the intensities of the sources are increased. Add the new ammeter readings to the table below.

(2)

	Photon energy/eV	**Intensity of light/W m^{-2}**	**Work function/eV**	**Ammeter reading/A**
First light	1.8	4.0	2.3	
Second light	3.8	4.0	2.3	

(c) (i) The cathode metal is lithium.

Express the work function of lithium in joules.

Work function of lithium = 2.3 eV

(2)

.....

.....

Work function = ... J

(ii) Ultraviolet radiation with photon energy of 4.8×10^{-18} J is shone onto the lithium cathode.

Calculate the maximum speed of the photoelectrons that are emitted.

(4)

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.....

.....

Maximum speed = ...

(Total for Question 23 = 10 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

Answer **all** the questions.

1 **(a)** Draw a line from each unit on the left-hand side to the correct equivalent unit on the right-hand side.

joule (J)	kg m s^{-2}
watt (W)	N m
newton (N)	J s^{-1}

[2]

(b) This question is about estimating the pressure exerted by a person wearing shoes standing on a floor, see Fig. 1.1.

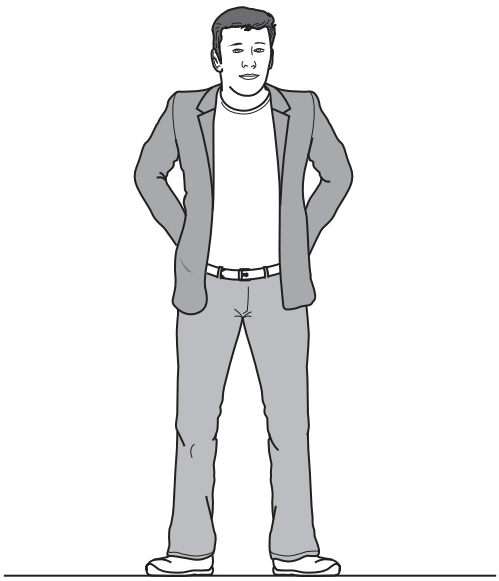

Fig. 1.1

(i) Estimate the weight in newtons of a person.

weight = ... N **[1]**

(ii) Estimate the total area of contact in square metres between the shoes of this person and the floor.

area = ... m^2 **[1]**

(iii) Hence estimate the pressure in pascals exerted by this person standing on the floor.

pressure = ... Pa **[1]**

[Total: 5]

2 Fig. 2.1 shows two masses **A** and **B** tied to the ends of a length of string. The string passes over a pulley. The mass **A** is held at rest on the floor.

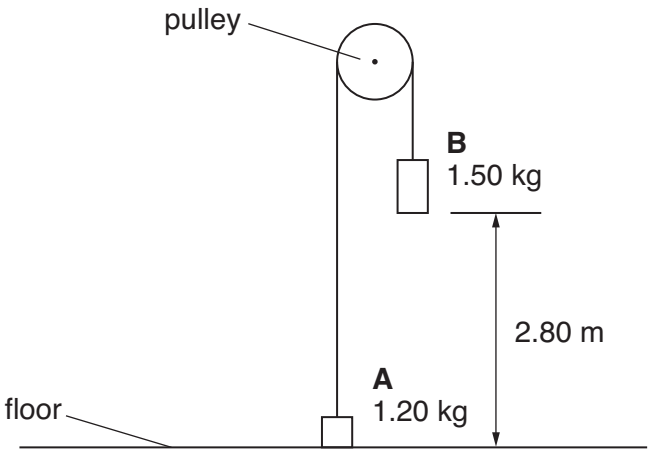

Fig. 2.1

The mass **A** is 1.20 kg and the mass **B** is 1.50 kg.

(a) Calculate the weight of mass **B**.

weight = ... N **[1]**

(b) Mass **B** is initially at rest at a height of 2.80 m above the floor. Mass **A** is then released. Mass **B** has a constant downward acceleration of 1.09 m s^{-2}. Assume that air resistance and the friction between the pulley and the string are negligible.

(i) In terms of forces, explain why the acceleration of the mass **B** is less than the acceleration of free fall *g*.

.....

..... **[1]**

(ii) Calculate the time taken for the mass **B** to fall 1.40 m.

time = ... s **[3]**

(iii) Calculate the velocity of mass **B** after falling 1.40 m.

velocity = ... $m\,s^{-1}$ **[2]**

(iv) Mass **B** hits the floor at a speed of 2.47 $m\,s^{-1}$. It **rebounds** with a speed of 1.50 $m\,s^{-1}$. The time of contact with the floor is 3.0×10^{-2} s. Calculate the magnitude of the average acceleration of mass **B** during its impact with the floor.

acceleration = ... $m\,s^{-2}$ **[2]**

[Total: 9]

3 A lift has a mass of 500 kg. It is designed to carry a maximum of 8 people of total mass 560 kg. The lift is supported by a steel cable of cross-sectional area $3.8 \times 10^{-4}\,m^2$. When the lift is at ground floor level the cable is at its maximum length of 140 m, as shown in Fig. 3.1. The mass per unit length of the cable is $3.0\,kg\,m^{-1}$.

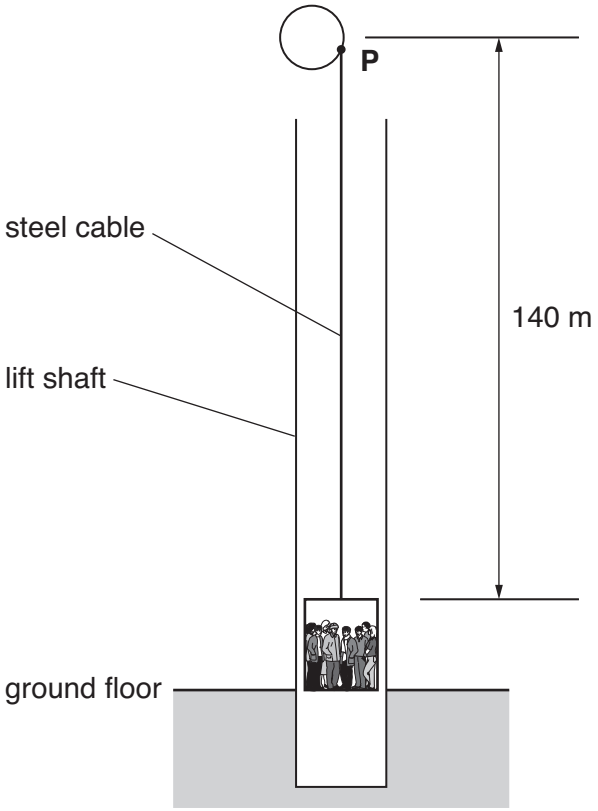

Fig. 3.1

(a) Show that the mass of the 140 m long steel cable is 420 kg.

[1]

(b) (i) The lift with its 8 passengers is stationary at the ground floor level. The initial upward acceleration of the lift and the cable is $1.8\,m\,s^{-2}$. Show that the **maximum** tension in the cable at point **P** is $1.7 \times 10^4\,N$.

[4]

(ii) Calculate the maximum stress in the cable.

stress = ... Pa **[2]**

[Total: 7]

4 **(a)** An electron in a particle accelerator experiences a constant force. According to one student, the acceleration of the electron should remain constant because the ratio of force to mass does not change. In reality, experiments show that the acceleration of the electron decreases as its velocity increases. Describe what can be deduced from such experiments about the nature of accelerated electrons.

.....

.....

.....

..... **[2]**

(b) Fig. 4.1 shows the velocity vector for a particle moving at an angle of 31° to the horizontal.

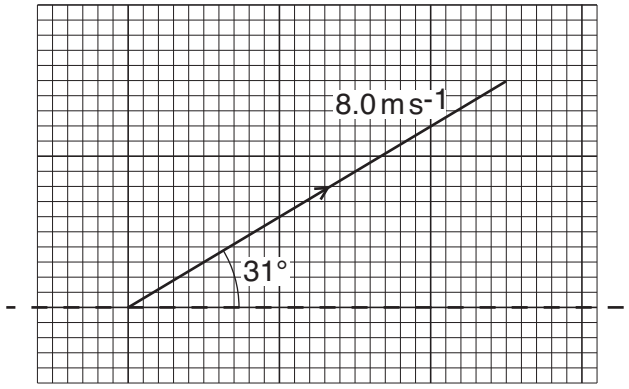

Fig. 4.1

(i) On Fig. 4.1, show the horizontal (*x*-direction) and vertical (*y*-direction) components of the velocity. **[2]**

(ii) Calculate the horizontal (*x*-direction) component of the velocity.

velocity = ... $m\,s^{-1}$ **[1]**

(c) Fig. 4.2 shows a ship **S** being pulled by two tug-boats.

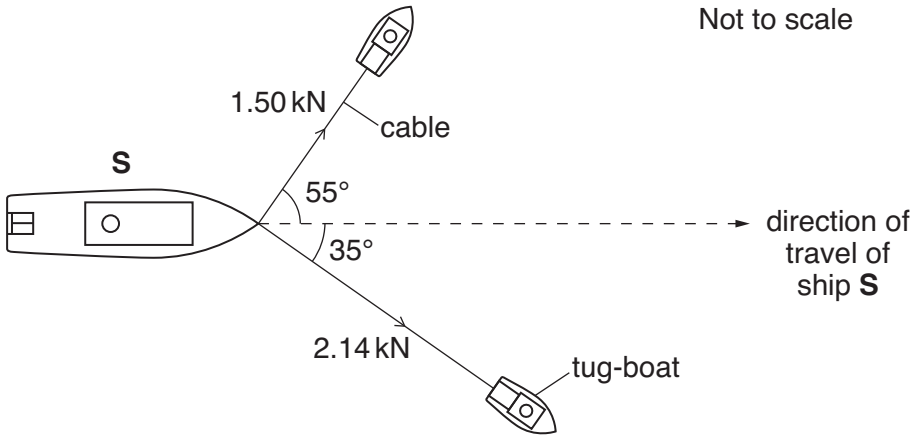

Fig. 4.2

The ship is travelling at a constant velocity. The tensions in the cables and the angles made by these cables to the direction in which the ship travels are shown in Fig. 4.2.

(i) Draw a vector triangle and determine the resultant force provided by the two cables.

resultant force = ... kN **[3]**

(ii) State the value of the drag force acting on the ship **S**. Explain your answer.

.....

.....

..... **[2]**

[Total: 10]

5 **(a)** State the principle of conservation of energy.

.....

..... **[1]**

(b) Describe one example where elastic potential energy is stored.

..... **[1]**

(c) Fig. 5.1 shows a simple pendulum with a metal ball attached to the end of a string.

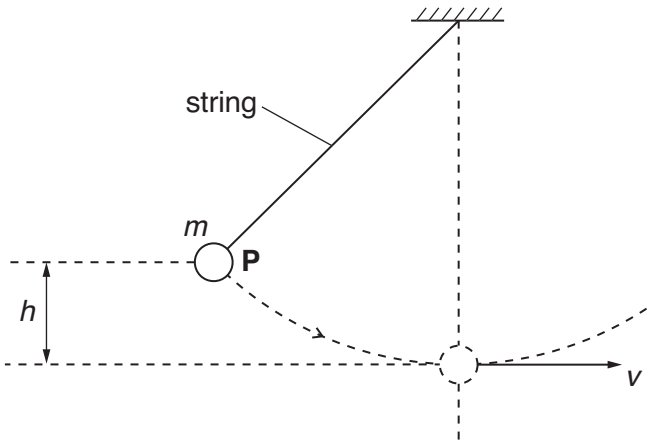

Fig. 5.1

When the ball is released from **P**, it describes a circular path. The ball has a maximum speed v at the bottom of its swing. The vertical distance between **P** and bottom of the swing is h. The mass of the ball is m.

(i) Write the equations for the change in gravitational potential energy, E_p, of the ball as it drops through the height h and for the kinetic energy, E_k, of the ball at the bottom of its swing when travelling at speed v.

E_p =

E_k = **[1]**

(ii) Use the principle of conservation of energy to derive an equation for the speed v. Assume that there are no energy losses due to air resistance.

[2]

(d) Some countries in the world have frequent thunderstorms. A group of scientists plan to use the energy from the falling rain to generate electricity. A typical thunderstorm deposits rain to a depth of 1.2×10^{-2} m over a surface area of 2.0×10^{7} m^2 during a time of 900 s. The rain falls from an average height of 2.5×10^{3} m. The density of rainwater is 1.0×10^{3} kg m^{-3}. About 30% of the gravitational potential energy of the rain can be converted into electrical energy at the ground.

(i) Show that the total mass of water deposited in 900 s is 2.4×10^{8} kg.

[2]

(ii) Hence show that the average electrical power available from this thunderstorm is about 2 GW.

[3]

(iii) Suggest one problem with this scheme of energy production.

.....

..... **[1]**

[Total: 11]

6 The force against length graph for a spring is shown in Fig. 6.1.

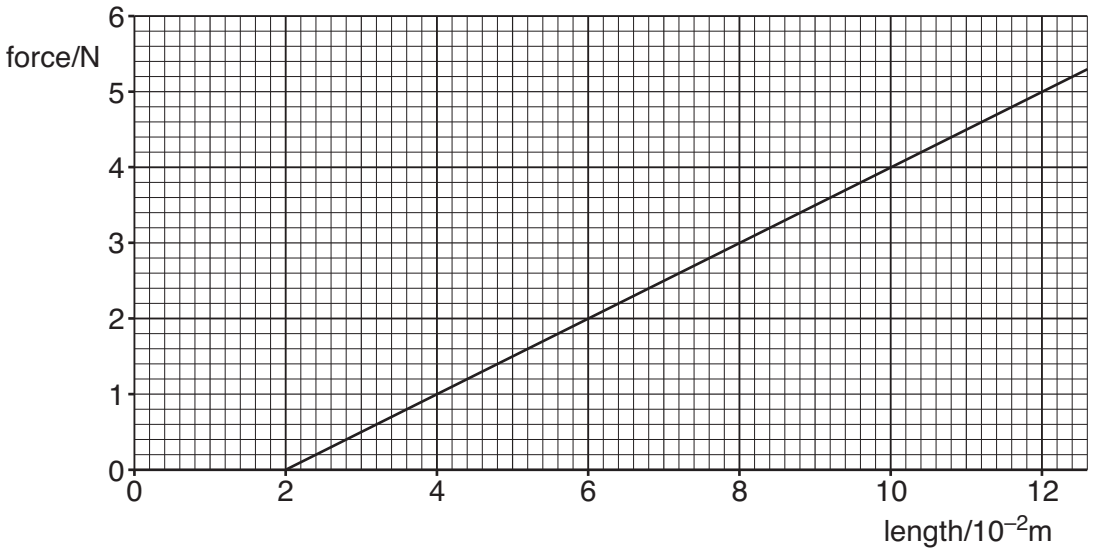

Fig. 6.1

(a) Explain why the graph does not pass through the origin.

.....

..... **[1]**

(b) State what feature of the graph shows that the spring obeys Hooke's law.

.....

..... **[1]**

(c) The gradient of the graph is equal to the force constant *k* of the spring. Determine the force constant of the spring.

force constant = ... N m^{-1} **[2]**

(d) Calculate the work done on the spring when its length is increased from 2.0×10^{-2} m to 8.0×10^{-2} m.

work done = ... J **[2]**

(e) One end of the spring is fixed and a mass is hung vertically from the other end. The mass is pulled down and then released. The mass oscillates up and down. Fig. 6.2 shows the displacement *s* against time *t* graph for the mass.

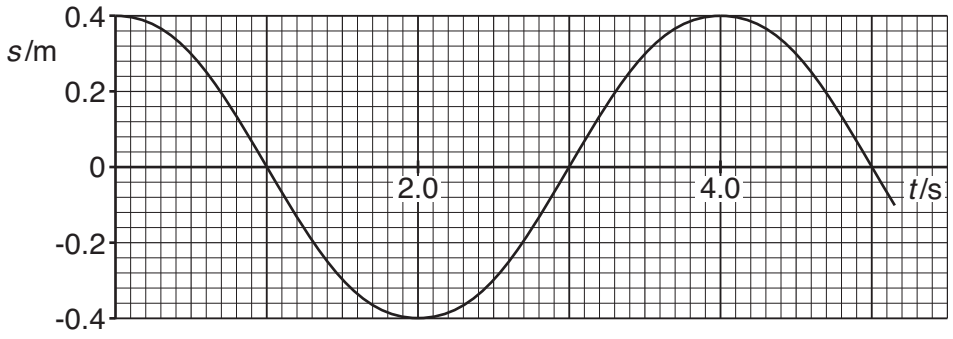

Fig. 6.2

Explain how you can use Fig. 6.2 to determine the **maximum** speed of the mass. You are not expected to do the calculations.

.....

.....

.....

..... **[2]**

[Total: 8]

7 **(a)** Fig. 7.1 shows a length of tape under tension.

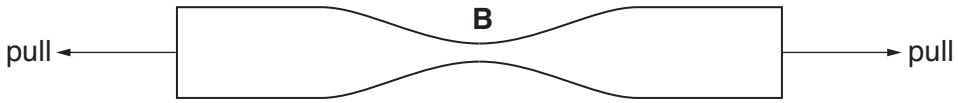

Fig. 7.1

(i) Explain why the tape is most likely to break at point **B**.

.....

..... **[1]**

(ii) Explain what is meant by the statement:

'the tape has gone beyond its elastic limit'.

.....

.....

..... **[1]**

(b) Fig. 7.2 shows one possible method for determining the Young modulus of a metal in the form of a wire.

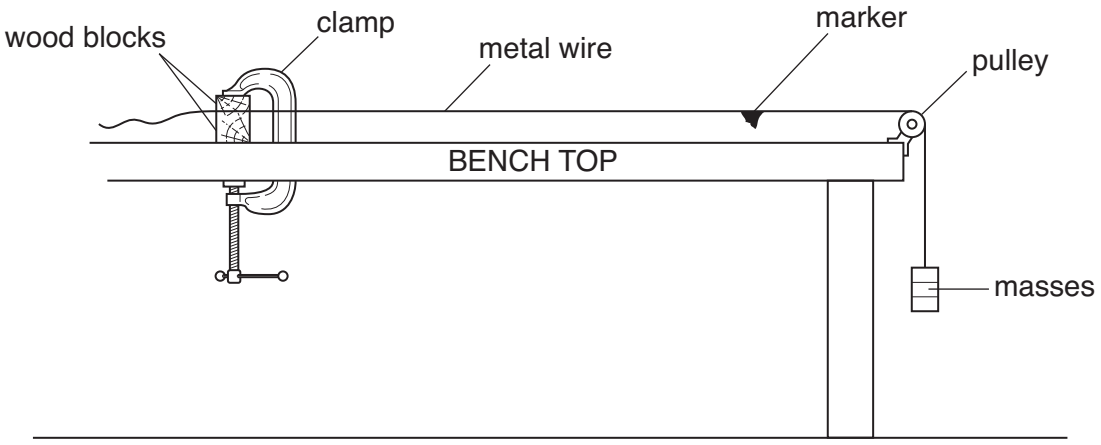

Fig. 7.2

Describe how you can use this apparatus to determine the Young modulus of the metal. The sections below should be helpful when writing your answers.

The **measurements** to be taken:

In your answer, you should use appropriate technical terms, spelled correctly.

.....

.....

.....

.....

.....

.....

The **equipment** used to take the measurements:

In your answer, you should use appropriate technical terms, spelled correctly.

.....

.....

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.....

.....

How you would **determine** Young modulus from your measurements:

.....

.....

.....

.....

.....

.....

[8]

[Total: 10]

END OF QUESTION PAPER

Answer **all** the questions.

1 **(a)** A 12V 36W lamp is lit to normal brightness using a 12V car battery of negligible internal resistance. The lamp is switched on for one hour (3600 s). For the time of 1 hour, calculate

(i) the energy supplied by the battery

energy = ……..J **[2]**

(ii) the charge passing through the lamp

charge = …….unit…….**[3]**

(iii) the total number of electrons passing through the lamp.

number of electrons = …… **[2]**

(b) The wires connecting the 36W lamp to the 12V battery are made of copper. They have a cross-sectional area of 1.1×10^{-7} m^2. The current in the wire is 3.0 A. The number *n* of free electrons per m^3 for copper is 8.0×10^{28} m^{-3}.

(i) Describe what is meant by the term *mean drift velocity* of the electrons in the wire.

.....

.....

..... **[2]**

(ii) Calculate the mean drift velocity v of the electrons in this wire.

v = ...m s^{-1} **[3]**

[Total: 12]

2 **(a)** Define the *resistivity* ρ of a metal wire.

.....

.....

..... **[2]**

(b) In the UK the National Grid is used to transmit electric power. Each pylon supports 24 cables. See Fig. 2.1. Each cable consists of 38 strands of aluminium. See Fig. 2.2.

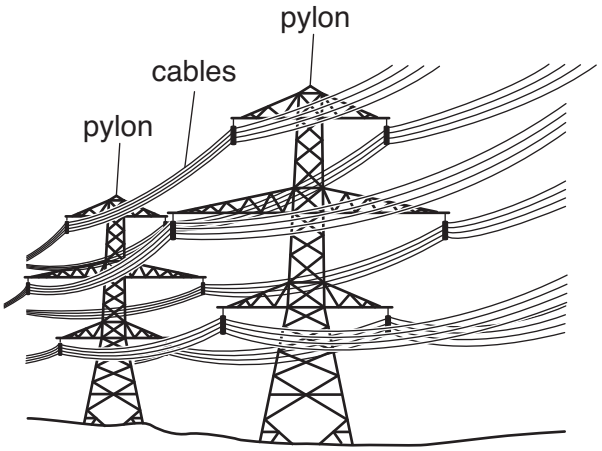

Fig. 2.1

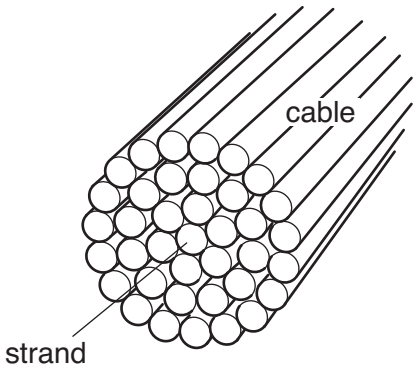

Fig. 2.2

(i) The resistance per km of a cable is 0.052 Ω km^{-1}. Explain why the resistance per km of a single strand is approximately 2.0 Ω km^{-1}.

.....

.....

..... **[2]**

(ii) The resistivity of aluminium is 2.6 x 10^{-8} Ω m. Calculate the cross-sectional area A of a single strand of the cable.

A = ……..m^2 **[2]**

(c) The input voltage to each cable in Fig. 2.1 is 400 kV. The cable carries a current of 440 A. Calculate

(i) the input power to one cable

input power = ……W **[2]**

(ii) the number of cables required to transmit the power from a 2000 MW power station

number of cables = ……**[1]**

(iii) the power lost as heat per km of cable

lost power = ……**[3]**

(iv) the percentage of the input power that is available at a distance of 100 km from the power station.

percentage of power =……% **[2]**

[Total: 14]

3 Fig. 3.1 shows a circuit containing a battery of e.m.f. 12V, two resistors, a light-dependent resistor (LDR), an ammeter and a switch **S**. The battery has negligible internal resistance.

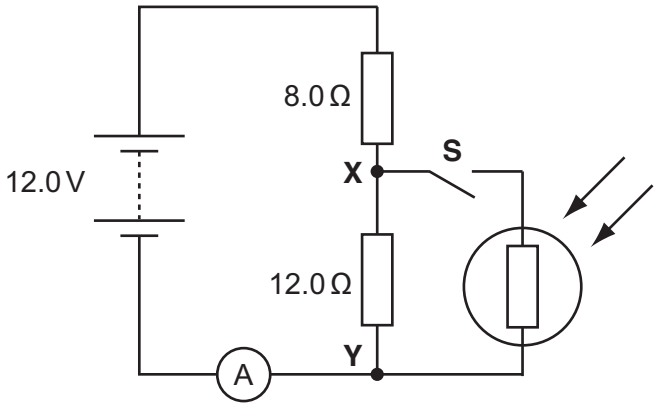

Fig. 3.1

(a) When the switch **S** is open, show that the potential difference between the points **X** and **Y** is 7.2V.

[2]

(b) The switch **S** is now closed. Describe and explain the change to each of the following when the intensity of light falling on the LDR is increased:

(i) the ammeter reading

.....

.....

..... **[2]**

(ii) the potential difference across **XY**.

.....

.....

..... **[2]**

[Total: 6]

4 **(a)** Fig. 4.1 shows the I-V characteristic of a light-emitting diode (LED).

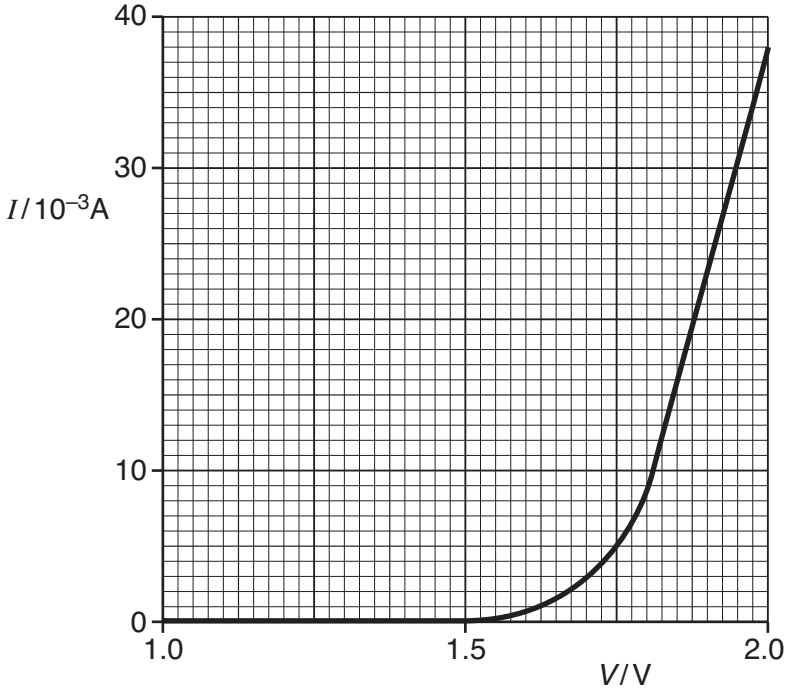

Fig. 4.1

(i) Describe the significant features of the graph in terms of current, voltage and resistance.

In your answer you should make clear how the features of the graph are related to the action of an LED.

.....

.....

.....

.....

.....

.....

.....

..... **[5]**

(ii) Calculate the resistance of the LED

1 at 1.2V

resistance = ... Ω **[1]**

2 at 1.9V.

resistance = ... Ω **[2]**

(b) In order to carry out an investigation to determine the *I-V* characteristic of an LED a student connects the circuit shown in Fig. 4.2.

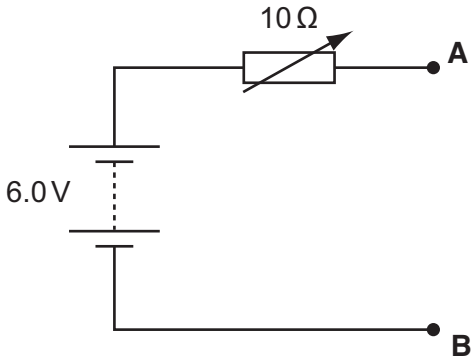

Fig. 4.2

On Fig. 4.2 add an LED with a 100 Ω resistor in series, an ammeter and a voltmeter to complete the circuit between terminals **A** and **B**. **[3]**

(c) When designing a circuit which includes an LED, it is normal practice to connect a resistor in series with the LED, in this case 100 Ω. Suggest and explain the purpose of this resistor.

.....

.....

..... **[2]**

(d) Another student uses the 10 Ω variable resistor as a potentiometer (potential divider) as shown in Fig. 4.3. The rest of the circuit is then completed between terminals **A** and **B** as for Fig. 4.2 in **(b)**.

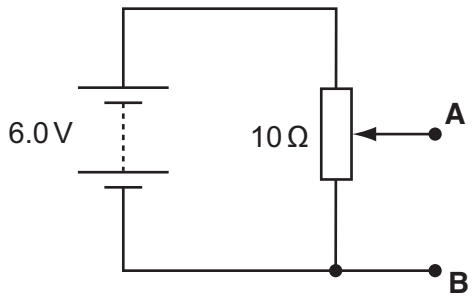

Fig. 4.3

Explain why the circuit of Fig. 4.3 is more suitable for obtaining the *I*-*V* characteristic of the LED than the circuit of Fig. 4.2.

.....

.....

.....

.....

..... **[3]**

[Total: 16]

5 **(a)** **(i)** Define the terms *wavelength, frequency* and *speed* used to describe a progressive wave.

wavelength, λ .....

.....

frequency, f.....

.....

speed, v.....

..... **[3]**

(ii) Hence derive the wave equation $v = f\lambda$ which relates these terms together.

[2]

(b) **(i)** Explain what is meant by *infra-red radiation*.

.....

.....

..... **[2]**

(ii) For infra-red radiation emitted at a frequency of 6.7×10^{13} Hz, calculate

1 its wavelength

wavelength = ... m **[2]**

2 its period of oscillation.

period = ... s **[2]**

(iii) Infra-red radiation is absorbed by molecular ions in a crystal causing them to vibrate at a frequency of 6.7×10^{13} Hz. The amplitude of oscillation of the ions is 8.0×10^{-12} m.

On the grid of Fig. 5.1 sketch a graph showing the variation with time of the displacement of an ion.

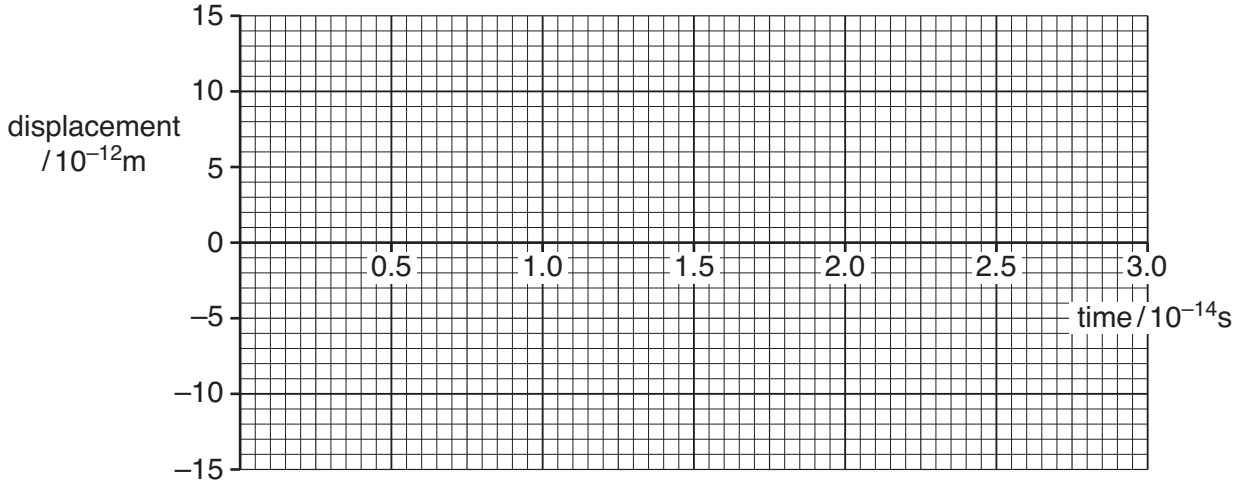

Fig. 5.1

[3]

[Total: 14]

6 **(a)** Interference of waves from two sources can only be observed when the waves are coherent.

Explain the meaning of

(i) *interference*

.....

.....

..... **[2]**

(ii) *coherence*.

.....

..... **[1]**

(b) Fig. 6.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of equal amplitude in phase and of wavelength 30 mm. A detector, moved along the line **PQ** at a distance of 5.0 m from **AB**, detects regions of high and low intensity forming an interference pattern.

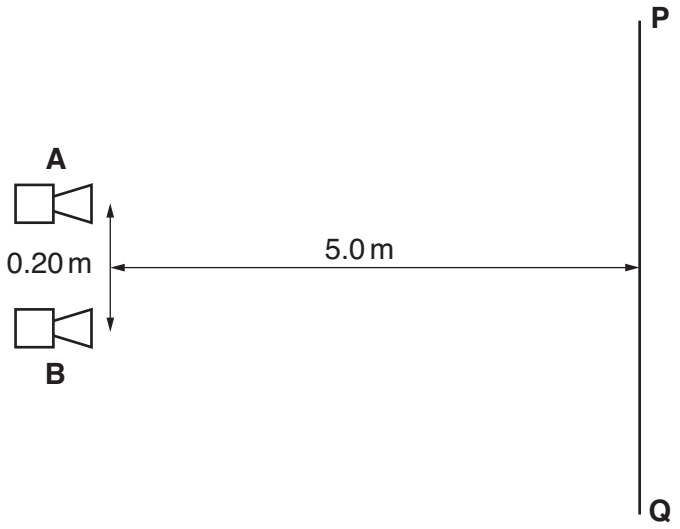

Fig. 6.1

(i) Use the ideas of path difference or phase difference to explain how the interference pattern is formed.

.....

.....

.....

.....

.....

..... **[3]**

(ii) Calculate the separation between one region of high intensity and the next along the line **PQ**.

separation = ... m **[2]**

(iii) State the effect, if any, on the position and intensity of the maxima when each of the following changes is made, separately, to the experiment.

1 The amplitude of the transmitted waves is doubled.

.....

.....

..... **[2]**

2 The separation between the transmitters is halved.

.....

.....

..... **[2]**

3 The phase of transmitter **A** is reversed so that there is now a phase difference of 180° between the waves from **A** and **B**.

.....

.....

..... **[2]**

[Total: 14]

7 **(a)** A helium-neon laser emits red light of wavelength 6.3×10^{-7} m.

(i) Show that the energy of a single photon is about 3×10^{-19} J.

[2]

(ii) The power of the laser beam is 1.0 mW. Show that about 3×10^{15} photons are emitted by the laser each second.

[1]

(iii) The photons of red light are emitted by the neon atoms in the gas inside the laser.

Explain what *energy levels* are and how they can be used to explain the emission of photons from atoms.

In your answer take care to make your explanation clear.

.....

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..... **[4]**

(iv) Another laser emits blue light. The power in its beam is also 1.0 mW.

Explain why the laser emitting blue light emits fewer photons per second compared with a laser of the same power emitting red light.

.....

.....

..... **[2]**

(b) A photodiode is a circuit component which can be used to convert a light signal into an electrical one. Fig. 7.1 shows an enlarged cross-section through a photodiode to illustrate how it is constructed. Light incident on the thin transparent conducting surface layer of the diode passes through it to be absorbed in the insulating layer. The energy of each photon is sufficient to release one electron in the insulating layer. The potential difference *V* applied across the insulating layer causes these electrons to move to one of the conducting layers.

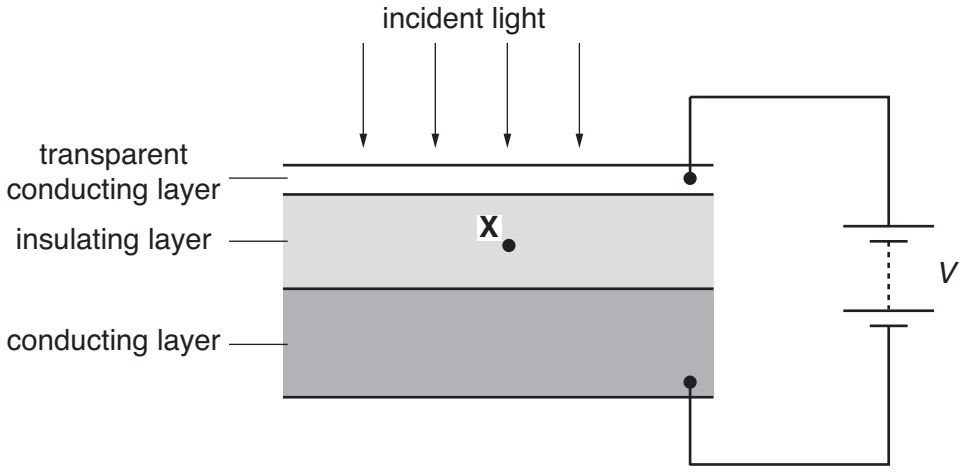

Fig. 7.1

(i) Draw an arrow on Fig. 7.1 to show the direction of motion of an electron released at point **X** in the centre of the insulating layer. **[1]**

(ii) The red light from the laser in **(a)** is incident on the photodiode. Experiments show that only 20% of the red light photons release electrons in the insulating layer and hence in the circuit of Fig. 7.1. Calculate the current through the photodiode.

current = …….. A **[3]**

(iii) Suggest one reason why the efficiency of the photodiode is less than 100%.

.....

..... **[1]**

[Total: 14]

8 In 1927 it was shown by experiment that electrons can produce a diffraction pattern.

(a) (i) Explain the meaning of the term *diffraction*.

.....

.....

..... **[1]**

(ii) State the condition necessary for electrons to produce observable diffraction when passing through matter, e.g. a thin sheet of graphite in an evacuated chamber.

.....

.....

.....

..... **[2]**

(b) Show that the speed of an electron with a de Broglie wavelength of 1.2×10^{-10} m is $6.0 \times 10^{6}\ \text{m s}^{-1}$.

[3]

(c) The electrons in **(b)** are accelerated to a speed of 6.0×10^6 m s^{-1} using an electron gun shown diagrammatically in Fig. 8.1.

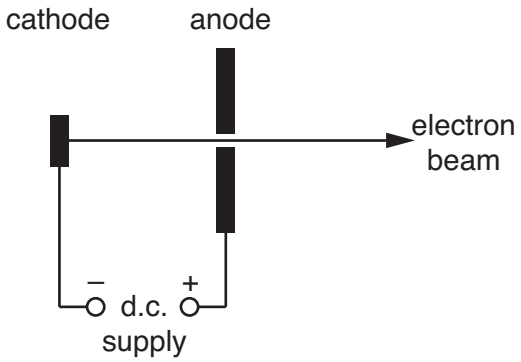

Fig. 8.1

(i) Calculate the potential difference V across the d.c. supply between the cathode and the anode.

V = ... V **[3]**

(ii) Suggest why, in an electron gun, the cathode is connected to the negative terminal of the supply rather than the positive terminal.

.....

.....

..... **[1]**

[Total: 10]

END OF QUESTION PAPER