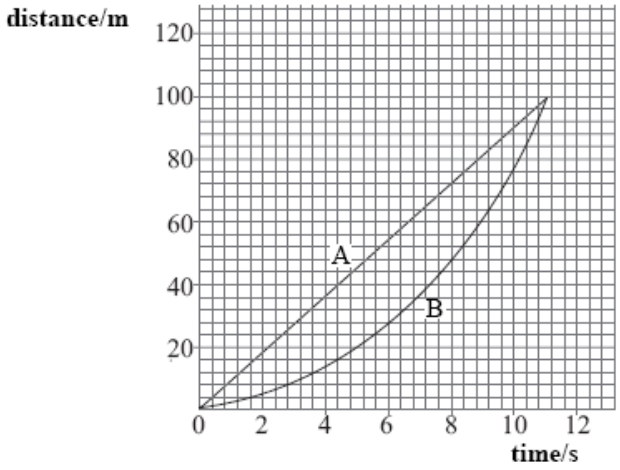
1 The distance-time graphs for two runners, A and B, in a 100 m race are shown.



(a) Explain how the graph shows that athlete B accelerates throughout the race.

.....

.....

(1 mark)

(b) Estimate the maximum distance between the athletes.

.....

(1 mark)

(c) Calculate the speed of athlete A during the race.

.....

(1 mark)

(d) The acceleration of athlete B is uniform for the duration of the race.

(i) State what is meant by uniform acceleration.

.....

(ii) Calculate the acceleration of athlete B.

.....

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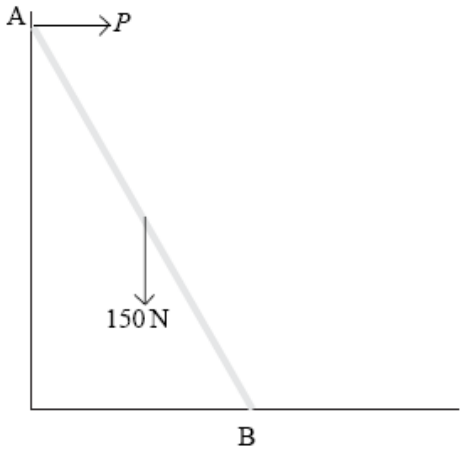
(3 marks)

2 **Figure 1** shows two of the forces acting on a uniform ladder resting against a smooth vertical wall.

Figure 1



The ladder is 6.0 m long and has a weight of 150 N. The horizontal force, P, exerted on the ladder by the wall is 43 N. Force Q (not shown) is the force the ground exerts on the ladder at B.

(a) Explain why the force, Q must have

(i) a vertical component,

.....

.....

(ii) a horizontal component.

.....

.....

(2 marks)

(b) Draw an arrow on the diagram to represent the force Q.

(1 mark)

(c) State the

(i) horizontal component of Q, ...

(ii) vertical component of Q. .....

(2 marks)

(d) State and explain the effect on force *Q* if a person stands on the bottom of the ladder and the direction of P is unchanged.

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

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(3 marks)

5 An athlete performs an experiment to measure the power developed as he runs up a flight of stairs. The athlete makes the assumption that the work done in climbing the stairs is equal to the gain in potential energy.

(i) State the measurements that would be needed to find the power developed by the athlete.

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(ii) Show how the measurements would be used to calculate the power developed as the athlete runs up the stairs.

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(iii) Explain why the power calculated by the athlete is likely to be less than the power actually developed.

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(8 marks)

6 (a) State the principle of moments.

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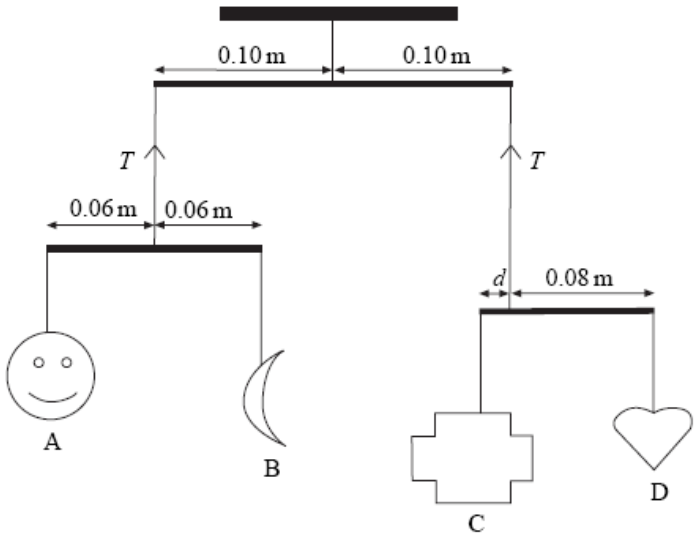
(2 marks)

Figure 2 shows a child's mobile in equilibrium.

Figure 2



A piece of cotton thread is attached to the rod supporting objects A and B and another piece of cotton thread supports the rod holding objects C and D. The tension in the cotton threads is T and all the rods are horizontal.

(b) (i) Complete the following table assuming the weights of the rods are negligible.

weight of object A /N	**weight of object B /N**	**weight of object C /N**	**weight of object D /N**
0.40			0.10

(ii) Calculate the distance, d.

.....

.....

(iii) Calculate the magnitude of T.

.....

(5 marks)

(c) Object A becomes detached and falls to the ground. State and explain the initial effect on

(i) the rod holding objects A and B,

.....

.....

(ii) the rod holding objects C and D,

.....

.....

(iii) the rod closest to the top of the mobile.

.....

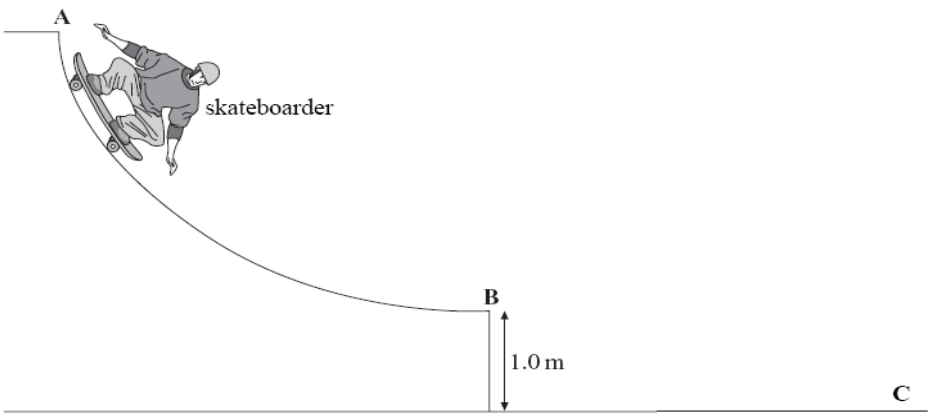
.....

(3 marks)

Jun 06 P2

2 **Figure 1** shows a skateboarder descending a ramp.

Figure 1



The skateboarder starts from rest at the top of the ramp at **A** and leaves the ramp at **B** horizontally with a velocity v.

(a) State the energy changes that take place as the skateboarder moves from **A** to **B**.

.....

.....

(2 marks)

(b) In going from **A** to **B** the skateboarder's centre of gravity descends a vertical height of 1.5 m. Calculate the horizontal velocity, v, stating an assumption that you make.

.....

.....

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.....

(3 marks)

(c) Explain why the acceleration decreases as the skateboarder moves from **A** to **B**.

.....

.....

.....

.....

(2 marks)

(d) After leaving the ramp at **B** the skateboarder lands on the ground at **C** 0.42 s later.

Calculate for the skateboarder

(i) the horizontal distance travelled between **B** and **C**,

.....

.....

(ii) the vertical component of the velocity immediately before impact at **C**,

.....

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.....

(iii) the magnitude of the resultant velocity immediately before impact at **C**.

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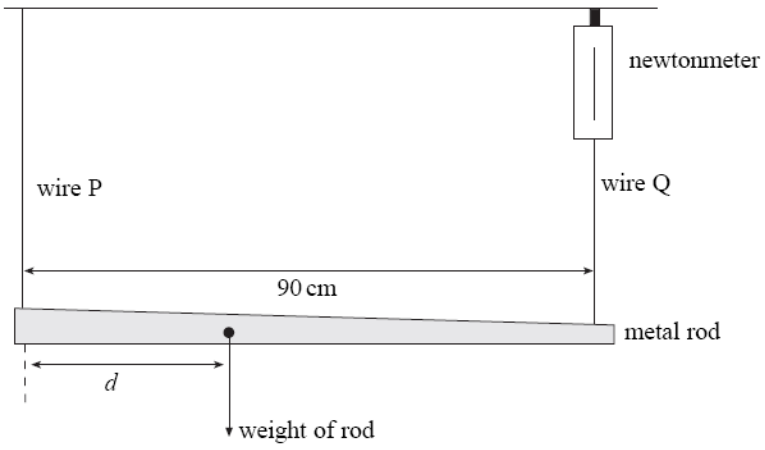
(5 marks)

3 **Figure 2** shows an apparatus used to locate the centre of gravity of a non-uniform metal rod.

Figure 2



The rod is supported horizontally by two wires, P and Q and is in equilibrium.

(a) State **two** conditions that must be satisfied for the rod to be in equilibrium.

.....

.....

.....

.....

(2 marks)

(b) Wire Q is attached to a newtonmeter so that the force the wire exerts on the rod can be measured. The reading on the newtonmeter is 2.0 N and the weight of the rod is 5.0 N. Calculate

(i) the force that wire P exerts on the rod,

.....

(ii) the distance *d*.

.....

.....

.....

(3 marks)

Jun 05 P2

3 (a) Explain why a raindrop falling vertically through still air reaches a constant velocity.

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

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(4 marks)

(b) A raindrop falls at a constant vertical velocity of $1.8\,m\,s^{-1}$ in still air. The mass of the raindrop is 7.2×10^{-9} kg.

Calculate

(i) the kinetic energy of the raindrop,

.....

.....

(ii) the work done on the raindrop as it falls through a vertical distance of 4.5 m.

.....

.....

(4 marks)

(c) The raindrop in part (b) now falls through air in which a horizontal wind is blowing. If the velocity of the wind is $1.4\,m\,s^{-1}$, use a scale diagram or calculation to determine the magnitude and direction of the resultant velocity of the raindrop.

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(3 marks)

1 The aeroplane shown in **Figure 1** is travelling horizontally at $95\,m\,s^{-1}$. It has to drop a crate of emergency supplies.
The air resistance acting on the crate may be neglected.

Figure 1

(a) (i) The crate is released from the aircraft at point **P** and lands at point **Q**. Sketch the path followed by the crate between **P** and **Q** as seen from the ground.

(ii) Explain why the horizontal component of the crate's velocity remains constant while it is moving through the air.

.....

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.....

(3 marks)

(b) (i) To avoid damage to the crate, the maximum vertical component of the crate's velocity on landing should be $32\,m\,s^{-1}$. Show that the maximum height from which the crate can be dropped is approximately 52 m.

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(ii) Calculate the time taken for the crate to reach the ground if the crate is dropped from a height of 52 m.

.....

.....

(iii) If **R** is a point on the ground directly below **P**, calculate the horizontal distance **QR**.

.....

.....

(6 marks)

(c) In practice air resistance is **not** negligible. State and explain the effect this has on the maximum height from which the crate can be dropped.

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.....

(2 marks)

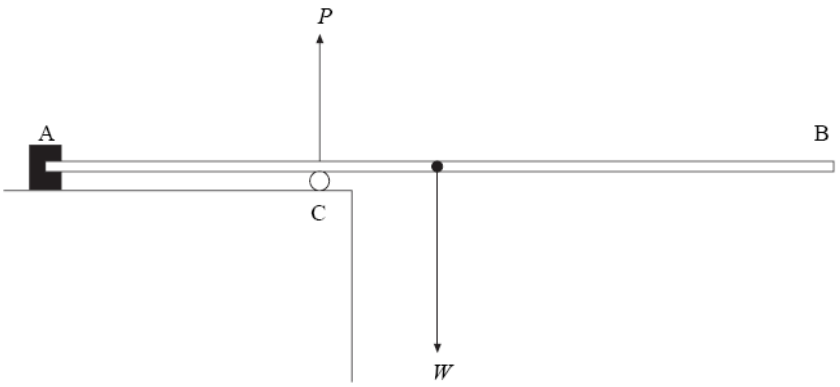
3 (a) Define the moment of a force.

.....

.....

(2 marks)

(b) The diagram shows a uniform diving board of weight, W, that is fixed at A. The diving board is supported by a cylinder at C, that exerts an upward force, P, on the board.



(i) By considering moments about A, explain why the force P must be greater than the weight of the board, W.

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(ii) State and explain what would be the effect on the force P of a girl walking along the board from A to B.

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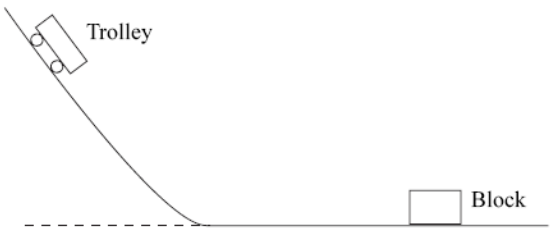
(4 marks)

2 The diagram represents an experiment that can be used to investigate stopping distances for a moving trolley.



The trolley is placed on the raised section of the track. When released it moves down the track and then travels along the horizontal section before colliding with the block. The trolley and block join and move together after the collision. The distance they move is measured.

(a) State the main energy changes taking place

(i) as the trolley descends,

.....

(ii) after the collision, as the trolley and block move together.

.....

(2 marks)

(b) Describe how the speed of the trolley, just before it collides with the block may be measured experimentally.

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

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(3 marks)

(c) State and explain how the speed of the trolley, prior to impact could be varied.

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(2 marks)

3 An apple and a leaf fall from a tree at the same instant. Both apple and leaf start at the same height above the ground but the apple hits the ground first.

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

Use Newton's laws of motion to explain why

(i) the leaf accelerates at first then reaches a terminal velocity,

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.....

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(ii) the apple hits the ground first.

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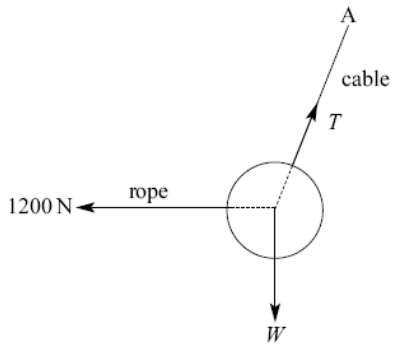
(5 marks)

4 The diagram shows a 250 kg iron ball being used on a demolition site. The ball is suspended from a cable at point A, and is pulled into the position shown by a rope that is kept horizontal. The tension in the rope is 1200 N.



(a) In the position shown the ball is in equilibrium.

(i) What balances the force of the rope on the ball?

.....

(ii) What balances the weight of the ball?

.....

(2 marks)

(b) Determine

(i) the magnitude of the vertical component of the tension in the cable,

.....

.....

(ii) the magnitude of the horizontal component of the tension in the cable,

.....

.....

(iii) the magnitude of the tension in the cable,

.....

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(iv) the angle the cable makes to the vertical.

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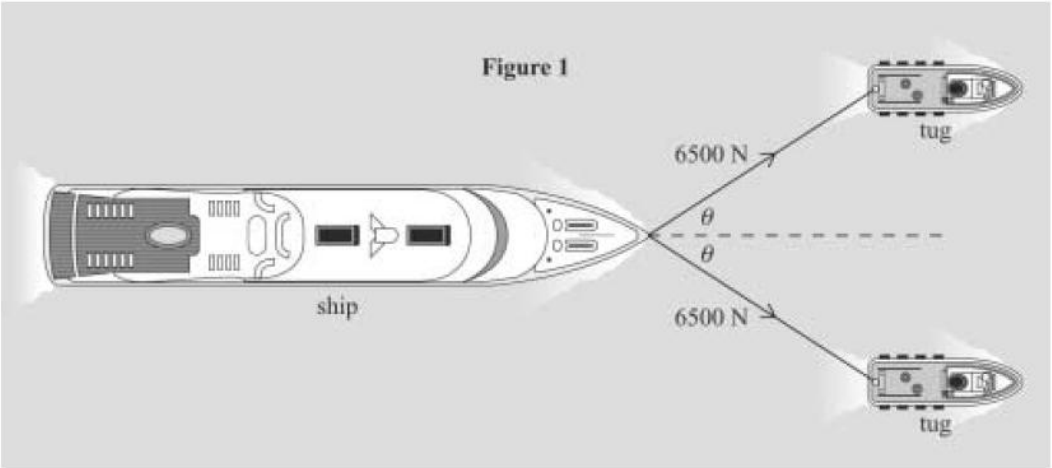
(6 marks)

3 **Figure 1** shows a ship being pulled along by cables attached to two tugs.



(a) The tension in each cable is 6500 N and the ship is moving at a constant speed of $1.5\,m\,s^{-1}$. When θ is equal to 35°, calculate

(i) the resultant force exerted on the ship by the cables,

.....

.....

.....

(ii) the work done by the tension in the cables in one minute.

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(4 marks)

(b) Explain why the work done on the ship does not result in a gain in its kinetic energy.

.....

.....

(2 marks)

(c) State and explain the initial effect on the ship if the angle θ is reduced while the tension in the cables remains constant.

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

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(3 marks)

1 A car accelerates from rest to a speed of 26 m s^{-1}. The table shows how the speed of the car varies over the first 30 seconds of motion.

time/ s	0	5.0	10.0	15.0	20.0	25.0	30.0
speed/ m s^{-1}	0	16.5	22.5	24.5	25.5	26.0	26.0

(a) Draw a graph of speed against time on the grid provided.

(3 marks)

(b) Calculate the average acceleration of the car over the first 25 s.

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(2 marks)

(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

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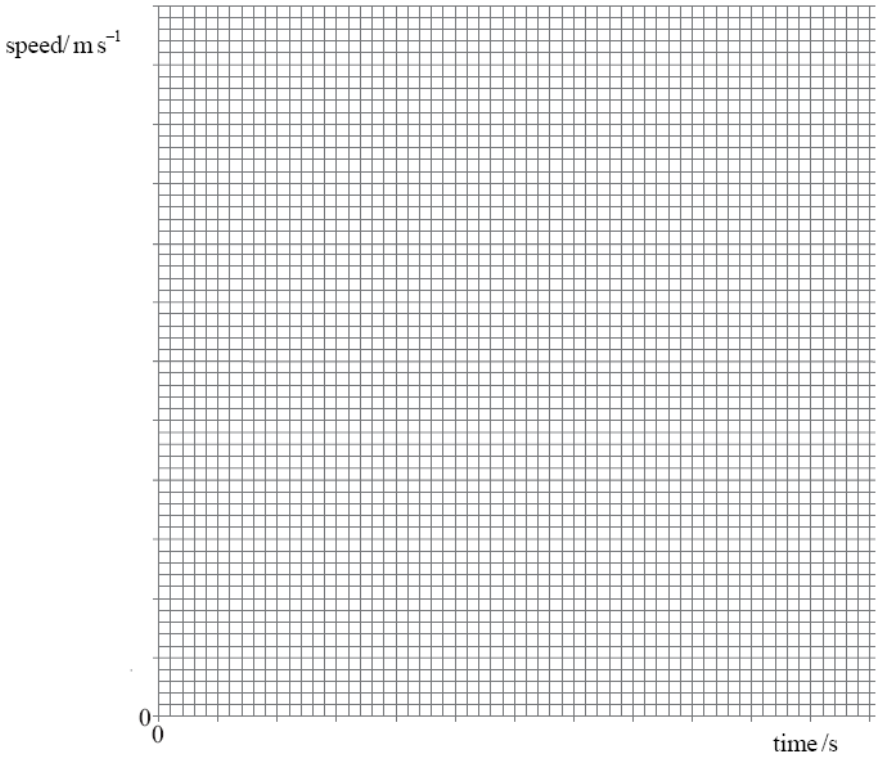
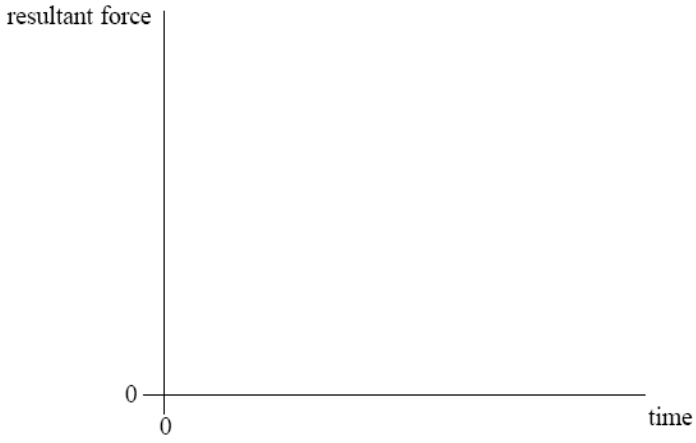
(2 marks)

Graph for (a)



(d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.



(2 marks)

(e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

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(2 marks)

5 (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, ...

.....

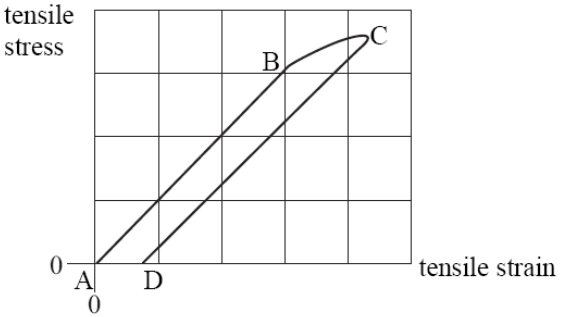
tensile strain. .....

.....

(2 marks)

(b) A long, thin metal wire is suspended from a fixed support and hangs vertically. Masses are suspended from its lower end.

As the load on the lower end is increased from zero to a certain value, and then decreased again to zero, the variation of the resulting tensile strain with the applied tensile stress is shown in the graph.



(i) Describe the behaviour of the wire during this process. Refer to the points A, B, C and D in your answer.
You may be awarded marks for the quality of written communication in your answer.

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(ii) State, with a reason, whether the material of the wire is ductile or brittle.

.....

.....

(iii) What does AD represent?

.....

(iv) State how the Young modulus for the material may be obtained from the graph.

.....

(v) State how the energy per unit volume stored in the wire during the loading process may be estimated from the graph.

.....

(9 marks)

(c) The wire described in part (b) has an unstretched length of 3.0 m and cross-sectional area 2.8×10^{-7} m^2. At a certain stage between the points A and B on the graph, the wire supports a load of 75 N. Calculate the extension produced in the wire by this load.

the Young modulus for the material of the wire = 2.1×10^{11} Pa

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(2 marks)

Jun 05 P3

5 (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

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(2 marks)

(b) A length of steel wire and a length of brass wire are joined together. This combination is suspended from a fixed support and a force of 80 N is applied at the bottom end, as shown in **Figure 5**.

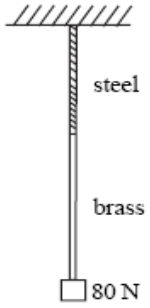

Figure 5

Each wire has a cross-sectional area of $2.4 \times 10^{-6}\,m^2$.

length of the steel wire = 0.80 m
length of the brass wire = 1.40 m
the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) Calculate the total extension produced when the force of 80 N is applied.

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(ii) Show that the mass of the combination wire = 4.4×10^{-2} kg.

density of steel = $7.9 \times 10^{3}\,kg\,m^{-3}$
density of brass = $8.5 \times 10^{3}\,kg\,m^{-3}$

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(7 marks)

(c) A single brass wire has the same mass and the same cross-sectional area as the combination wire described in part (b). Calculate its length.

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(2 marks)

5 (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

.....

.....

(ii) Explain what is meant by the elastic limit of the wire.

.....

.....

(iii) Define the Young modulus of a material and state the unit in which it is measured.

.....

.....

(5 marks)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.
A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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(6 marks)

6 (a) (i) Describe an experiment a student would carry out to determine the Young modulus of the material of a long uniform wire of known cross-sectional area. You may draw a diagram of the apparatus, if necessary.

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

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(ii) Explain how the value of the Young modulus could be determined from the measurements made using a suitable graph.

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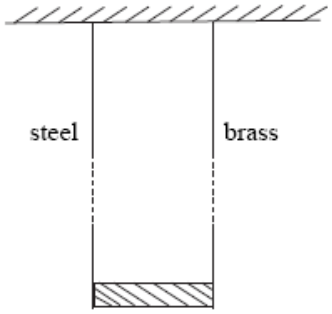
(8 marks)

(b) A uniform heavy metal bar is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown in **Figure 12**. One of the wires is brass and the other steel. Each wire has the same original length and both extend by the same amount, thus making the metal bar horizontal.

Figure 12



the Young modulus for brass = 1.0×10^{11} Pa
the Young modulus for steel = 2.0×10^{11} Pa

(i) Explain why the brass wire has the greater cross-sectional area.

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(ii) The unstretched length of each wire is 2.5 m and the extension produced is 4.8×10^{-3} m. If the cross-sectional area of the steel wire is 1.6×10^{-7} m^2, calculate the tension in the steel wire.

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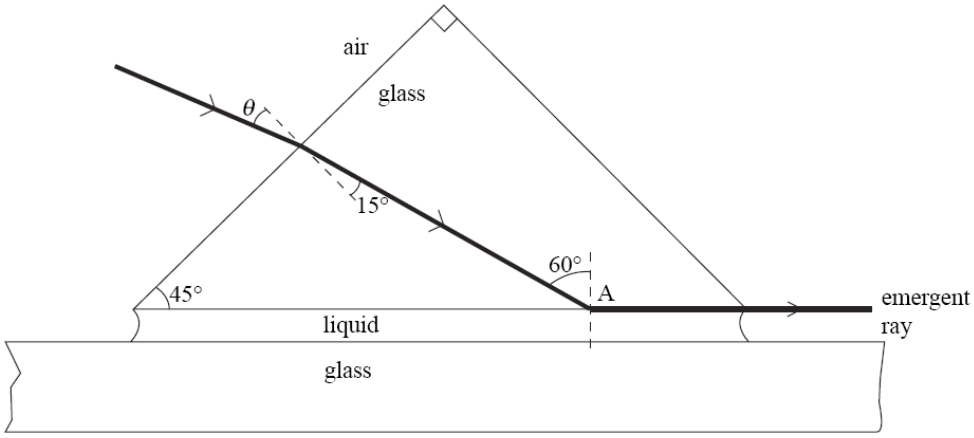
(4 marks)

6 The diagram, which is not to scale, shows the cross-section of a 45° right angled glass prism supported by a film of liquid on a glass table. A ray of monochromatic light is incident on the prism at an angle of incidence θ and emerges along the glass – liquid boundary as shown.

refractive index of glass = 1.5



(a) Calculate the speed of light in the glass.

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.....

.....

(2 marks)

(b) Determine

(i) the angle of incidence, θ,

.....

.....

.....

(ii) the refractive index of the liquid.

.....

.....

.....

.....

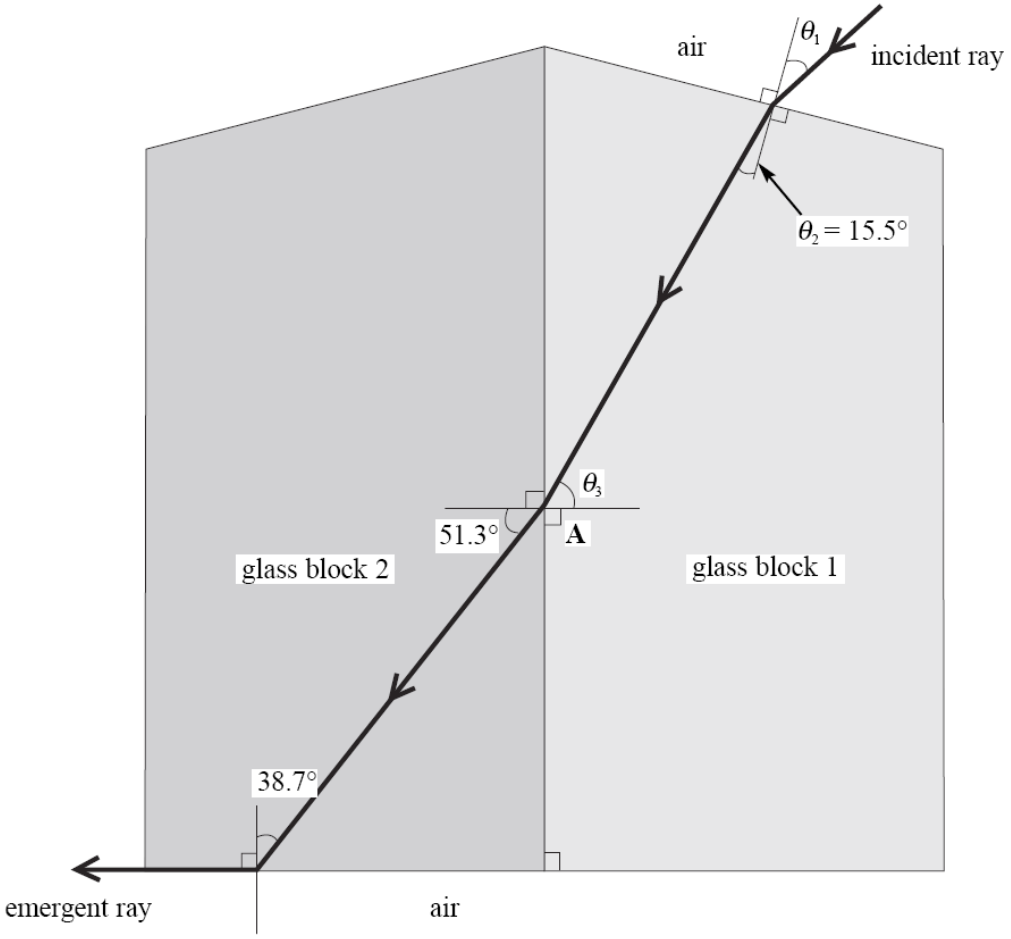
(5 marks)

(c) The liquid is now changed to one with a lower refractive index. Draw a possible path for the ray beyond the point A and into the air. *(2 marks)*

5 **Figure 1** shows a ray of light passing from air into glass at the top face of glass block 1 and emerging along the bottom face of glass block 2.

refractive index of the glass in block 1 = 1.45

Figure 1



(a) Calculate

(i) the incident angle θ_1,

.....

.....

.....

(ii) the refractive index of the glass in block 2,

.....

.....

(iii) the angle θ_3 by considering the refraction at point **A**.

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(7 marks)

(b) In which of the two blocks of glass will the speed of light be greater?

.....

Explain your reasoning.

.....

.....

.....

(2 marks)

(c) Using a ruler, draw the path of a ray partially reflected at **A** on **Figure 1**. Continue the ray to show it emerging into the air. No calculations are expected.

(2 marks)

6 **Figure 1** shows a pool of water of depth 1.0 m which has a lamp set into the bottom corner as shown. The angle θ_c marked on the diagram is the critical angle for a water-air boundary.
refractive index of water = 1.33

Figure 1

(a) Calculate

(i) the speed of light in water,

.....

.....

(ii) the critical angle θ_c.

.....

.....

.....

(3 marks)

(b) On **Figure 1** draw the continuation of the paths taken by the three rays shown. No further calculations are required. *(3 marks)*

(c) A layer of oil is poured over the surface of the water. Without calculation explain how the critical angle for the water-oil boundary differs from the critical angle, θ_c, for the water-air boundary.

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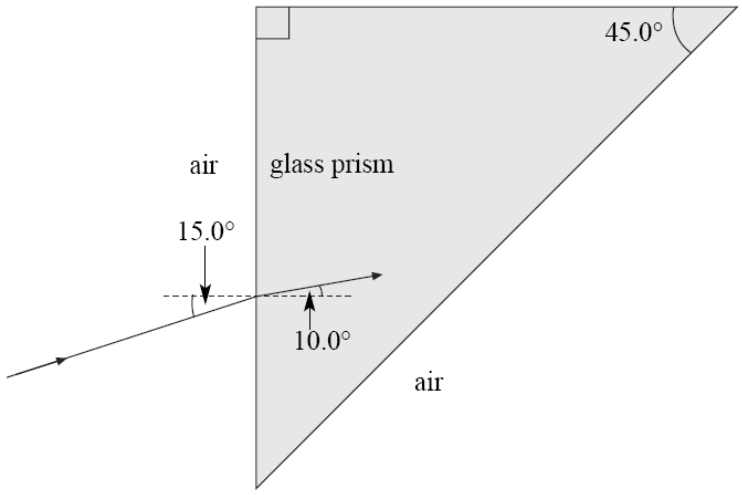
(2 marks)

3 A ray of light passes from air into a glass prism as shown in **Figure 1**.

Figure 1



(a) Confirm, by calculation, that the refractive index of the glass from which the prism was made is 1.49.

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(1 mark)

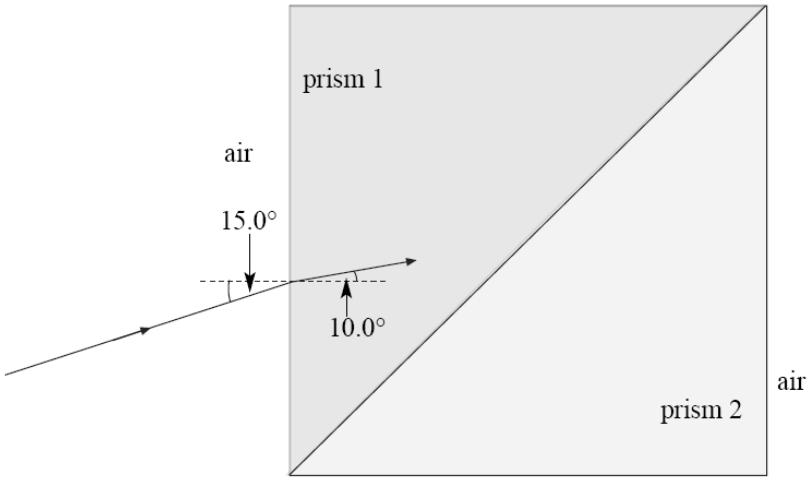
(b) On **Figure 1**, draw the continuation of the path of the ray of light until it emerges back into the air. Write on **Figure 1** the values of the angles between the ray and any normals you have drawn.

the critical angle from glass to air is less than 45°

(2 marks)

(c) A second prism, prism 2, made from transparent material of refractive index 1.37 is placed firmly against the original prism, prism 1, to form a cube as shown in **Figure 2**.

Figure 2



(i) The ray strikes the boundary between the prisms. Calculate the angle of refraction of the ray in prism 2.

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(ii) Calculate the speed of light in prism 2.

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.....

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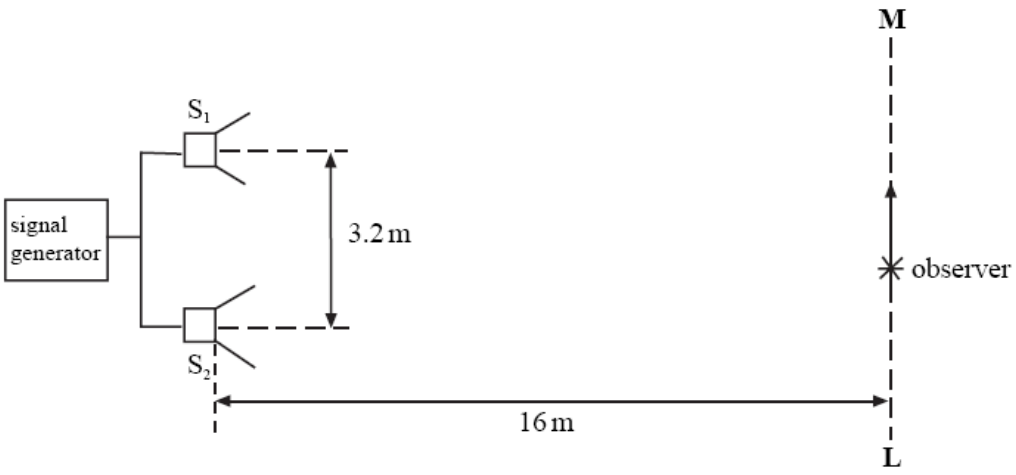
(iii) Draw a path the ray could follow to emerge from prism 2 into the air.

(7 marks)

1 (a) Two identical loudspeakers, S_1 and S_2, are connected to the same signal generator so that each produces a sound wave of frequency 850 Hz. They are arranged in the open air, as shown in **Figure 1**, with their centres 3.2 m apart. An observer who walks along the line **LM**, 16 m away from the loudspeakers, notices that there are minima of sound every 2.0 m.

Figure 1



Calculate

(i) the wavelength of the sound waves,

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(ii) the speed of sound in the air.

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(2 marks)

(b) You may be awarded additional marks to those shown in brackets for the quality of written communication in your answers.

(i) The sound waves from the loudspeakers in part (a) produce interference effects. Light waves from two separate small monochromatic light sources of the same frequency do not produce observable interference effects. Explain why the loudspeakers are able to produce interference effects but the light sources do not.

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(ii) Describe and explain how interference effects may be produced from a single monochromatic light source using appropriate additional equipment.

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(5 marks)

2 (a) When a parallel beam of monochromatic light is incident normally on a diffraction grating, light leaving the grating has maxima of intensity in particular directions. Explain the parts played by *diffraction* and *interference* in the production of these maxima.

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(3 marks)

(b) Light consisting of two wavelengths, the shorter of which is 420 nm, is incident normally on a grating. At a diffraction angle of 44°, the third order maximum produced by light of one wavelength coincides exactly with the second order maximum produced by light of the other wavelength.

(i) Show that the other wavelength is 630 nm.

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(ii) Calculate the number of lines per metre on the grating.

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(iii) Determine the highest order maximum that can be observed with the 420 nm wavelength.

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(5 marks)

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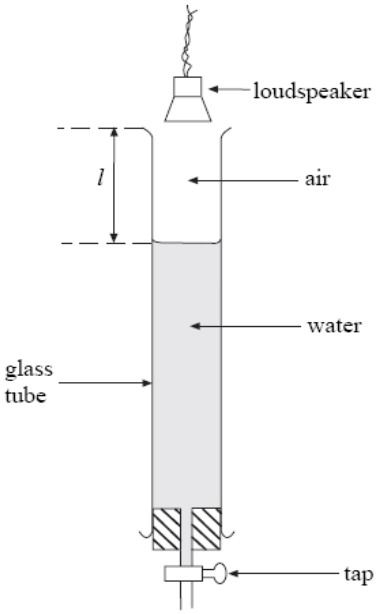

Figure 1

A small loudspeaker emitting sound of constant frequency is positioned a short distance above a long glass tube containing water. When water is allowed to run slowly out of the tube, the intensity of the sound heard increases whenever the length l (shown in **Figure 1**) takes certain values.

(a) Explain these observations by reference to the physical principles involved.

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

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(4 marks)

(b) With the loudspeaker emitting sound of frequency 480 Hz, the effect described in part (a) is noticed first when l = 168 mm. It next occurs when l = 523 mm.

Use both values of l to calculate

(i) the wavelength of the sound waves in the air column,

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(ii) the speed of these sound waves.

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(4 marks)

1 A battery of emf 24 V and negligible internal resistance is connected to a resistor network as shown in the circuit diagram in **Figure 1**.

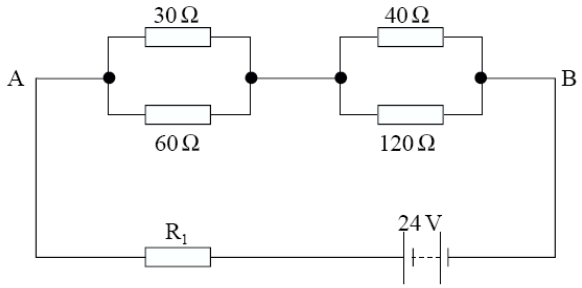

Figure 1

(a) Show that the resistance of the single equivalent resistor that could replace the four resistors between the points A and B is 50 Ω.

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(4 marks)

(b) If R_1 is 50 Ω, calculate

(i) the current in R_1,

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(ii) the current in the 60 Ω resistor.

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(4 marks)

2 (a) In the circuit shown in **Figure 2**, the battery has an emf of 12 V and negligible internal resistance.

PQ is a potential divider, S being the position of the sliding contact. In the position shown, the resistance between P and S is 180 Ω and the resistance between S and Q is 60 Ω.

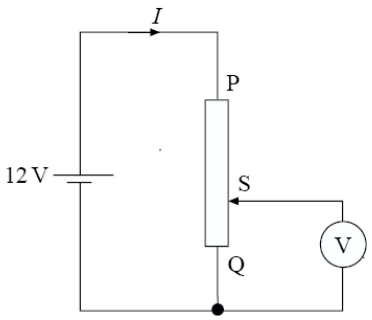

Figure 2

(i) Calculate the current, *I*, in the circuit, assuming that there is no current through the voltmeter V.

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(ii) What property of the voltmeter allows us to assume that no current flows through it?

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(iii) What is the reading on the voltmeter?

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(4 marks)

(b) The circuit in **Figure 2** is modified as shown in **Figure 3**, by exchanging the voltmeter for a load R, whose resistance is about the same as the resistance of section SQ of the potential divider.

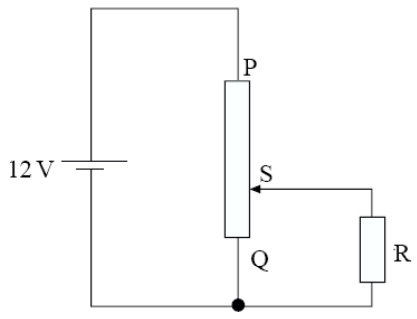

Figure 3

Explain, without calculation, why the current through the battery increases in value from that in part (a).

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

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(2 marks)

3 (a) The circuit shown in **Figure 4** may be used to determine the internal resistance of a battery. An oscilloscope is connected across the battery as shown. **Figure 5** represents the screen of the oscilloscope.

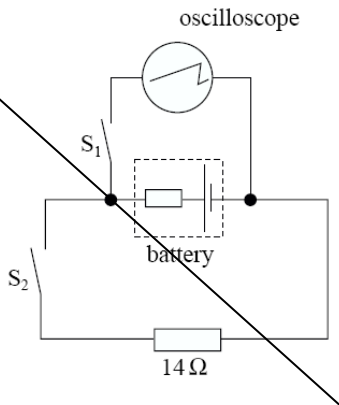

Figure 4

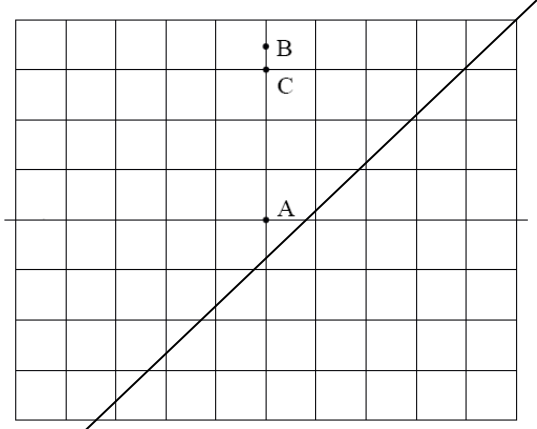

Figure 5

The time base of the oscilloscope is switched off throughout the experiment.
Initially the switches S_1 and S_2 are both open. Under these conditions the spot on the oscilloscope screen is at A.

(i) Switch S_1 is now closed, with S_2 remaining open. The spot moves to B.
State what the deflection AB represents.

.....

(ii) Switch S_1 is kept closed and S_2 is also closed. The spot moves to C.
State what the deflection AC represents.

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(iii) The vertical sensitivity of the oscilloscope is 0.50 V div^{-1}. Calculate the current through the 14 Ω resistor with both switches closed.

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(iv) Hence, calculate the internal resistance of the battery.

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(6 marks)

(b) The oscilloscope is now connected to an alternating voltage source of rms value 3.5 V.

(i) Calculate the peak value of the alternating voltage.

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(ii) Draw on **Figure 6** what you would expect to see on the oscilloscope screen, if the time base is still switched off and the voltage sensitivity is altered to 2.0 V div^{-1}.

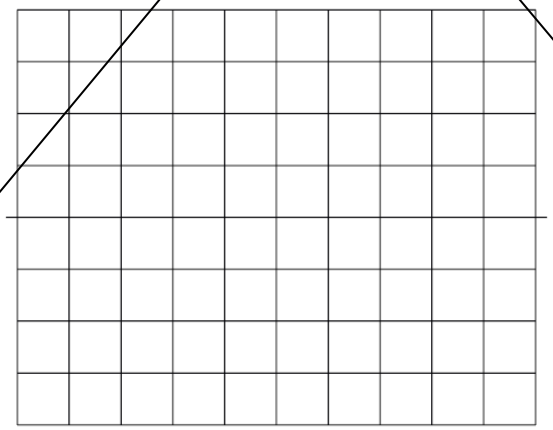

Figure 6

(3 marks)

5 (a) On the axes in **Figure 7** draw $I - V$ characteristics for **two** components, A and B, both of which obey Ohm's law. Component B has a lower resistance than component A.
Label your characteristics clearly as A and B.

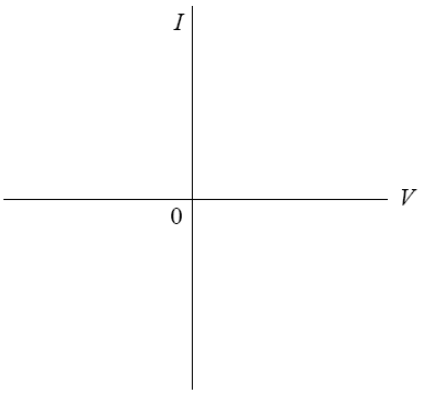

Figure 7

(2 marks)

(b) On the axes in **Figure 8** draw the $I - V$ characteristic for a silicon semiconductor diode, giving any relevant voltage values.

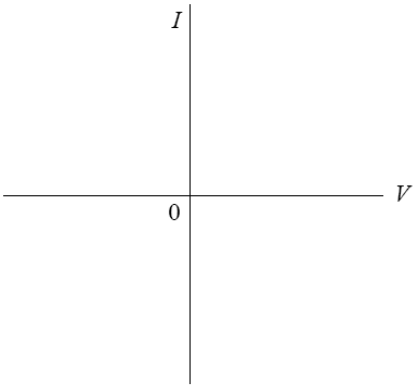

Figure 8

(3 marks)

(c) **Figure 9** shows the $I - V$ characteristic of a filament lamp. Explain the shape of this characteristic.

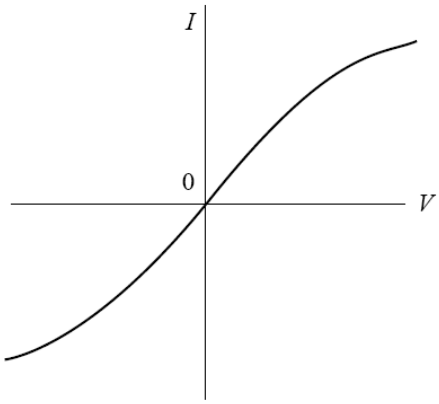

Figure 9

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(4 marks)

Jan 04 P3

1 (a) In the circuit in **Figure 1**, the battery, of emf 15 V and negligible internal resistance, is connected in series with two lamps and a resistor. The three components each have a resistance of 12 Ω.

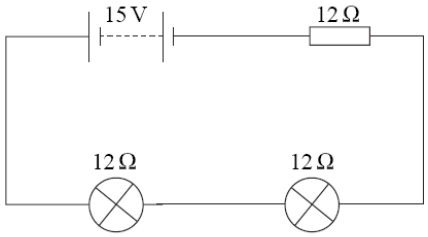

Figure 1

(i) What is the voltage across each lamp?

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(ii) Calculate the current through the lamps.

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(3 marks)

(b) The two lamps are now disconnected and reconnected in parallel as shown in **Figure 2**.

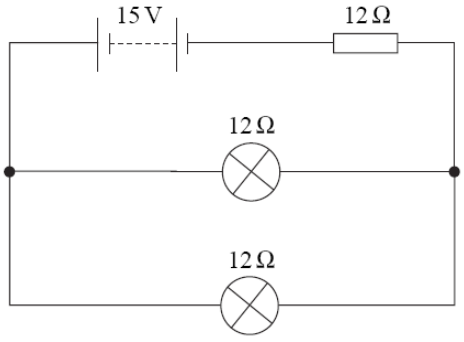

Figure 2

(i) Show that the current supplied by the battery is 0.83 A.

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(ii) Hence show that the current in each lamp is the same as the current in the lamps in the circuit in **Figure 1**.

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(3 marks)

(c) How does the brightness of the lamps in the circuit in **Figure 1** compare with the brightness of the lamps in the circuit in **Figure 2**?

Explain your answer.

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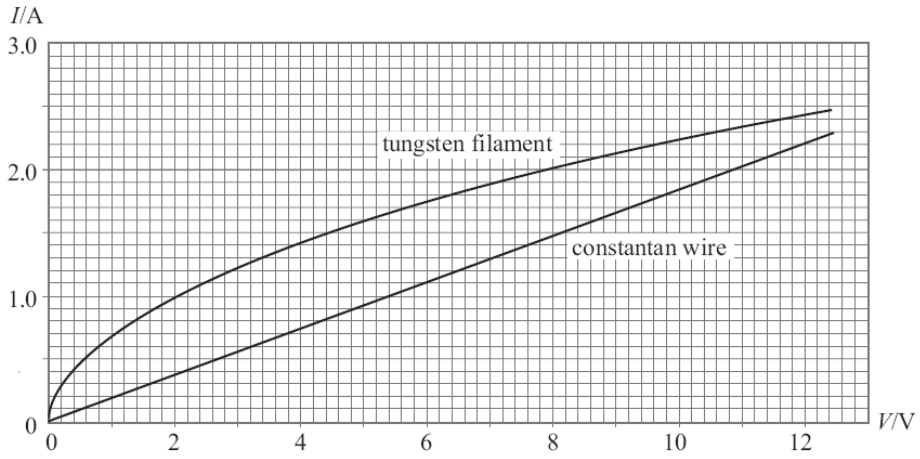
(2 marks)

2 The graph shows the *I* - *V* characteristics for two conductors, the tungsten filament of a lamp and a length of constantan wire.



(a) State, with a reason, which conductor obeys Ohm's law across the full voltage range.

conductor: .....

reason: .....

(2 marks)

(b) (i) Calculate the resistance of the tungsten filament when $V = 1\,V$ and $V = 10\,V$.

$V = 1\,V$: .....

.....

$V = 10\,V$: .....

.....

(ii) Explain why the values of resistance, calculated in part (b)(i), differ from each other.

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

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(4 marks)

(c) Use the graph to determine the resistivity of constantan, given that the wire is 0.80 m long with a uniform cross-sectional area of $6.8 \times 10^{-8} m^2$.

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(3 marks)

(d) A student is required to obtain the $I - V$ characteristic for a filament lamp using a datalogger, so that the data can be fed into a computer to give a visual display of the characteristic.

Draw a labelled circuit diagram for such an experiment.
(An account of the experiment is not required).

(3 marks)

1 In the circuit shown in **Figure 1**, the battery, of emf 6.0 V, has negligible internal resistance.

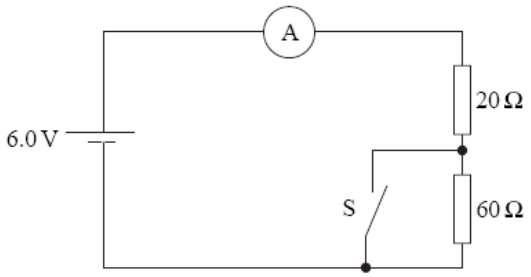

Figure 1

(a) Calculate the current through the ammeter when the switch S is

(i) open,

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(ii) closed.

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(3 marks)

(b) The switch S is now replaced with a voltmeter of infinite resistance.
Determine the reading on the voltmeter.

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(2 marks)

2 (a) The graph in **Figure 2** shows the $I - V$ characteristic for a semiconductor diode.

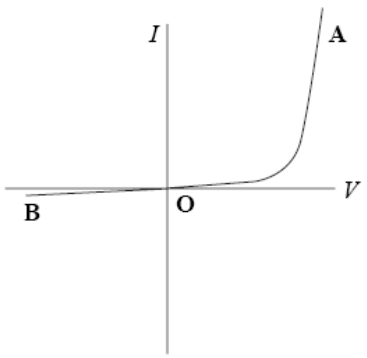

Figure 2

In order to produce this characteristic in the laboratory, a student is given suitable apparatus, including a data logger. The output of the data logger is connected to a computer to give a visual display.

(i) Draw a labelled circuit diagram of the apparatus that would be used to obtain the characteristic from **O** to **A** in **Figure 2**.

(ii) Describe how the apparatus would be used.

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

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(iii) What change would have to be made to the circuit in order to obtain the characteristic from **O** to **B** in **Figure 2**?

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(6 marks)

(b) On the axes in **Figure 3** draw the characteristic for a filament lamp.

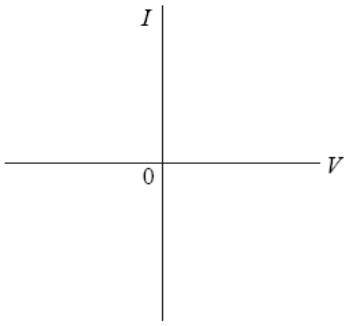

Figure 3

Explain why the $I - V$ characteristic has the shape you have drawn.

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

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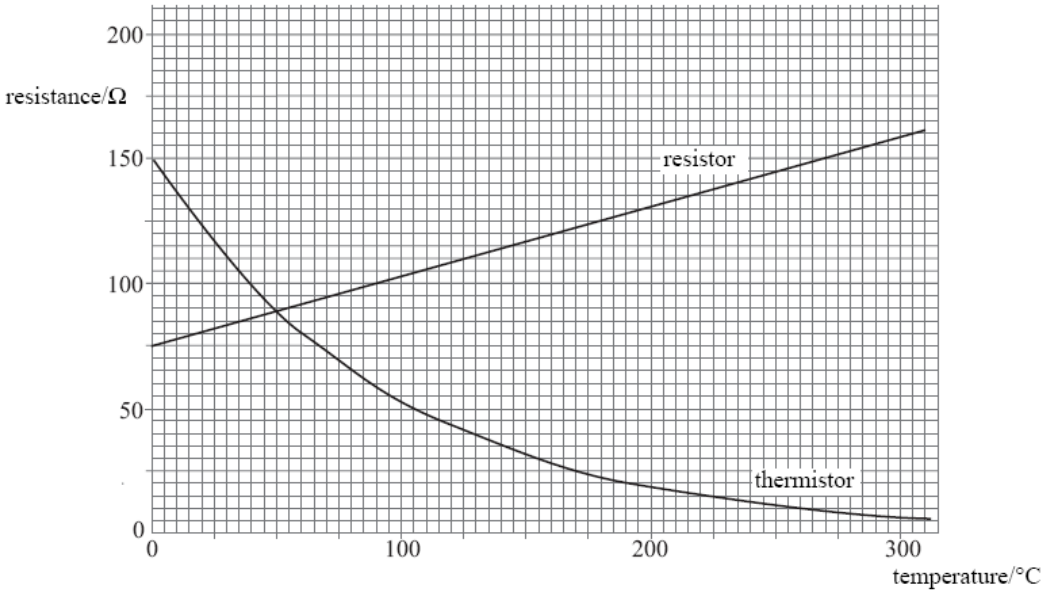
(5 marks)

3 The graph shows how the resistance, R_R, of a metal resistor and the resistance, R_{Th}, of a thermistor change with temperature.



(a) Give the values of the resistance R_R and R_{Th} at a temperature of 200°C.

R_R ..... R_{Th} .....

(1 mark)

(b) The resistor and thermistor are connected in series to a 12 V battery of negligible internal resistance, as shown in **Figure 4**.

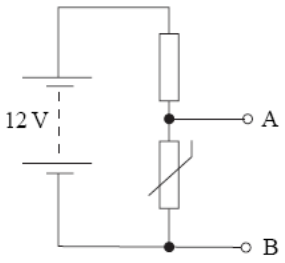


Figure 4

(i) Calculate the voltage across the terminals AB when both the resistor and thermistor are at 200 °C.

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(ii) Assuming that the temperature of the resistor always equals the temperature of the thermistor, deduce the temperature when the voltage across the resistor equals the voltage across the thermistor.

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(4 marks)

(c) A lamp and a switch are now connected across the terminals AB, as shown in **Figure 5**. The temperature of the thermistor does not change from that obtained in part (b)(ii).

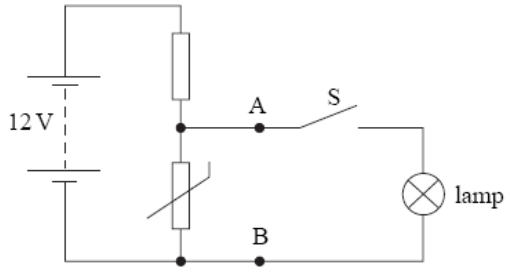

Figure 5

(i) The lamp is rated at 2.0 W at a voltage of 6.0 V. Calculate the resistance of the lamp at this rating.

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(ii) The switch S is now closed. Explain, without calculation, why the voltage across the thermistor will fall from the value in part (b)(ii).

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(4 marks)

4 (a) For a conductor in the form of a wire of uniform cross-sectional area, give an equation which relates its resistance to the resistivity of the material of the conductor. Define the symbols used in the equation.

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(2 marks)

(b) (i) An electrical heating element, made from uniform nichrome wire, is required to dissipate 500 W when connected to the 230 V mains supply. The cross-sectional area of the wire is $8.0 \times 10^{-8} m^2$. Calculate the length of nichrome wire required.

resistivity of nichrome = $1.1 \times 10^{-6} \Omega m$

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(ii) Two heating elements, each rated at 230 V, 500 W are connected to the 230 mains supply

(A) in series,
(B) in parallel.

Explain why only one of the circuits will provide an output of 1 kW.

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(6 marks)

5 A sinusoidal alternating voltage source of frequency 500 Hz is connected to a resistor of resistance 2.0 kΩ and an oscilloscope, as shown in **Figure 6**.

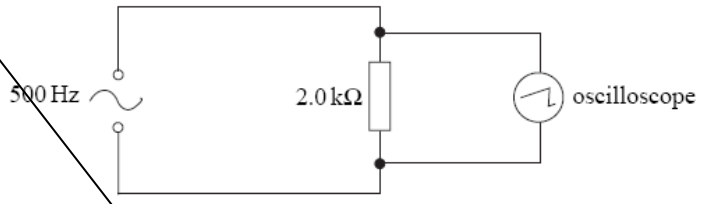

Figure 6

(a) The rms current through the resistor is 5.3 mA. Calculate the peak voltage across the resistor.

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(2 marks)

(b) The settings on the oscilloscope are

timebase: 250 µs per division,
voltage sensitivity: 5.0 V per division.

Draw on the grid, which represents the screen of the oscilloscope, the trace that would be seen.

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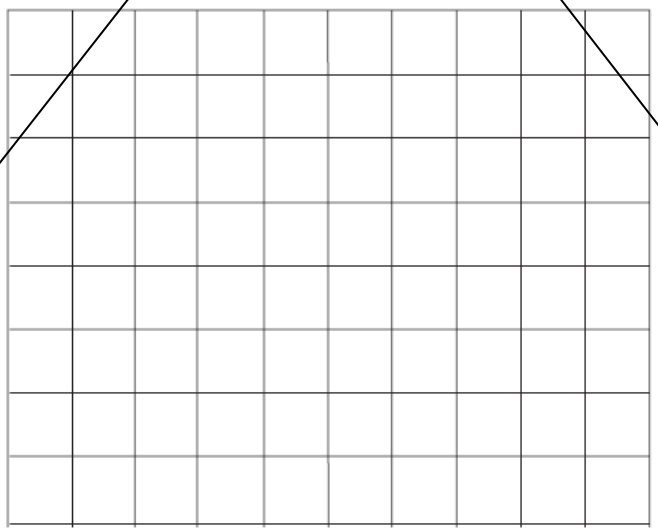

(4 marks)

1 (a) A steady current of 0.25 A passes through a torch bulb for 6 minutes. Calculate the charge which flows through the bulb in this time.

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(2 marks)

(b) The torch bulb is now connected to a battery of negligible internal resistance. The battery supplies a steady current of 0.25 A for 20 hours. In this time the energy transferred in the bulb is 9.0×10^4 J. Calculate

(i) the potential difference across the bulb,

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(ii) the power of the bulb.

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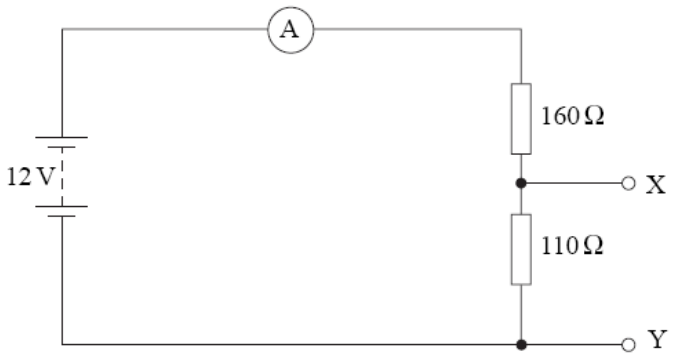
(3 marks)

2 In the circuit shown in **Figure 1**, the battery, of negligible internal resistance, is connected to two resistors which form a potential divider.

Figure 1



(a) (i) Calculate the current through the ammeter.

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(ii) A 20 Ω resistor is now connected between X and Y. State and explain, without further calculation, whether the current through the ammeter will increase or decrease.
You may be awarded marks for the quality of written communication in your answer.

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(4 marks)

(b) The 20 Ω resistor is now removed and replaced with a voltmeter. Stating the assumption made, show that the reading on the voltmeter is 4.9 V.

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(2 marks)

(c) The voltmeter is now removed and the terminals X and Y joined together with a wire. Calculate the reading on the ammeter.

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(2 marks)

3 (a) A student wishes to measure the resistivity of the material of a uniform resistance wire. The available apparatus includes a battery, a switch, a variable resistor, an ammeter and a voltmeter.

(i) Draw a circuit diagram which incorporates some or all of this apparatus and which enables the student to determine the resistivity of the material.

(ii) State the measurements which must be made to ensure that a reliable value of the resistivity is obtained.

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(iii) Explain how a value of the resistivity would be obtained from the measurements.

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(10 marks)

(b) A wire made from tin with cross-sectional area $7.8 \times 10^{-9}\ m^2$, has a pd of 2.0 V across it. Calculate the minimum length of wire needed so that the current through it does not exceed 4.0 A.

resistivity of tin = $1.1 \times 10^{-7}\ \Omega m$

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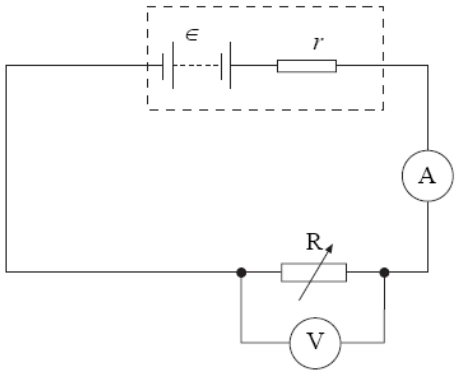
(2 marks)

4 A battery of emf ϵ and internal resistance r is connected in series to a variable resistor R and an ammeter of negligible resistance. A voltmeter is connected across R, as shown in **Figure 2**.

Figure 2



(a) (i) State what is meant by the emf of the battery.

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(ii) The reading on the voltmeter is less than the emf. Explain why this is so.

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(2 marks)

(b) A student wishes to measure ϵ and r. Using the circuit shown in **Figure 2** the value of R is decreased in steps and at each step the readings V and I on the voltmeter and ammeter respectively are recorded. These are shown in the table.

reading on voltmeter/V	reading on ammeter/A
8.3	0.07
6.8	0.17
4.6	0.33
2.9	0.44
0.3	0.63

(i) Give an expression relating V, I, ϵ and r.

.....

(ii) Using **a piece of graph paper**, draw a graph of V (on the y-axis) against I (on the x-axis).

(iii) Determine the values of ϵ and r from the graph, explaining your method.

ϵ: .....

.....

r: .....

.....

(8 marks)

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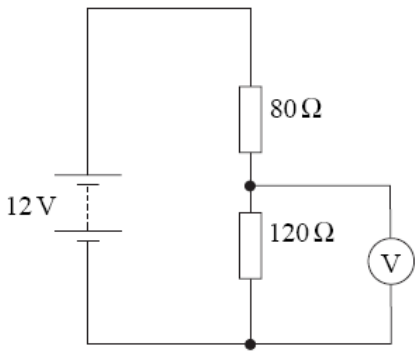
2 (a) In the potential divider circuit shown in **Figure 2**, the battery has negligible internal resistance.

Figure 2



Calculate the reading on the voltmeter, stating the assumption made.

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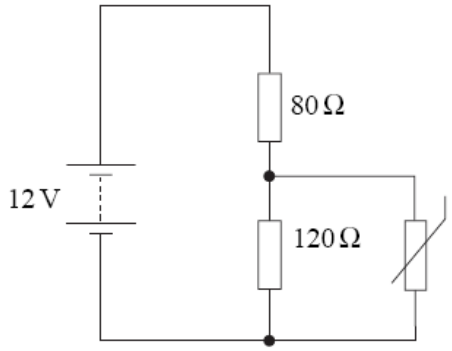
(3 marks)

(b) The voltmeter in **Figure 2** is replaced by a thermistor, giving the circuit shown in **Figure 3**.

Figure 3



The resistance of the thermistor at 0 °C is 120 Ω. As the temperature increases, its resistance decreases. Explain, without calculation, whether the current through the battery increases or decreases as the temperature of the thermistor is increased from 0 °C.

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

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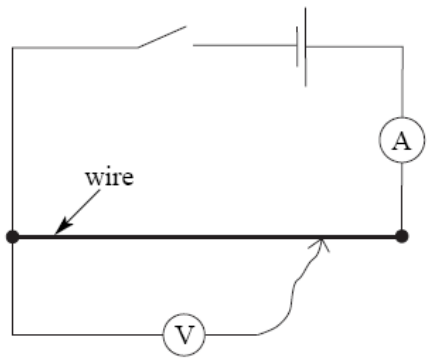
(3 marks)

3 (a) A student is required to measure the resistivity of a material in the form of a uniform resistance wire, using the circuit shown in **Figure 4**. The cross-sectional area of the wire is known.

Figure 4



(i) Describe the measurements the student should make in order to determine the resistivity by a graphical method.

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.....

(ii) Show how the value of the resistivity could be obtained from the measurements, using a suitable graph.

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(7 marks)

(b) A square sheet of carbon-reinforced plastic, measuring 90 mm × 90 mm and 1.1 mm thick, has its two large surfaces coated with a highly conducting metal film. When a pd of 210 V is applied between the metal films a current of 1.4 mA passes through the plastic sheet. Calculate the resistivity of the plastic.

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(3 marks)

1 Four resistors, each having resistance of 50 Ω, are connected to form a square. A resistance meter measured the resistance between different corners of the square. Determine the resistance the meter records when connected between the following corners.

(a) Between A and C, as in **Figure 1**.

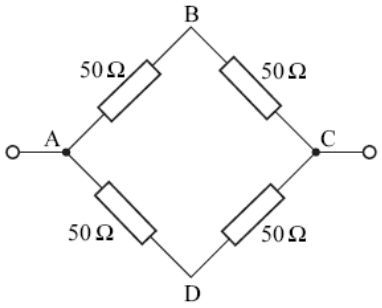

Figure 1

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(2 marks)

(b) Between A and B, as in **Figure 2**.

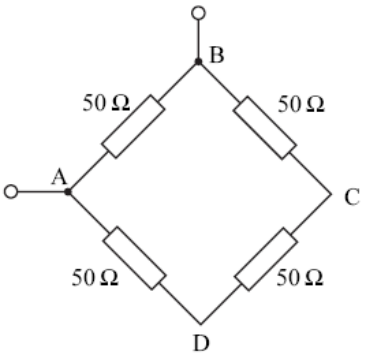

Figure 2

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(3 marks)

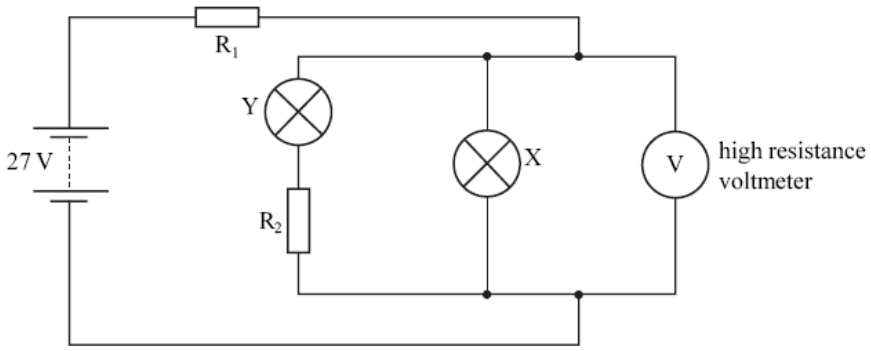
3 (a) X and Y are two lamps. X is rated at 12 V, 24 W and Y at 6 .0 V, 18 W. Calculate the current through each lamp when it operates at its rated voltage.

X: .....

Y: .....

(2 marks)

(b) The two lamps are connected in the circuit shown. The battery has an emf of 27 V and negligible internal resistance. The resistors R_1 and R_2 are chosen so that the lamps are operating at their rated voltage.



(i) What is the reading on the voltmeter?

.....

(ii) Calculate the resistance of R_2.

.....

.....

.....

(iii) Calculate the current through R_1.

.....

(iv) Calculate the voltage across R_1.

.....

(v) Calculate the resistance of R_1.

.....

(7 marks)

4 (a) A student wishes to measure the resistance of a fixed length of uniform constantan wire. The apparatus available includes a battery, a switch, a milliammeter and a voltmeter.

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

(i) Draw a circuit diagram using the apparatus listed above. Include in your diagram an extra piece of apparatus which will enable a range of measurements to be made.

(ii) State how the student should make the necessary measurements, ensuring that a range of readings is recorded.

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(iii) Describe how the results would be used to determine an accurate value for the resistance of the wire.

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(8 marks)

(b) A heating element for an electric fire consists of a single strand of nichrome wire wound around an insulator. The heater is required to produce 1.2 kW when connected to the 230 Vrms ac mains.

(i) Calculate the working resistance of the nichrome wire.

.....

.....

.....

.....

(ii) Calculate the length of nichrome wire required to make the element.

cross-sectional area of the wire $= 9.4 \times 10^{-8} m^2$
resistivity of nichrome $= 1.1 \times 10^{-6} \Omega m$

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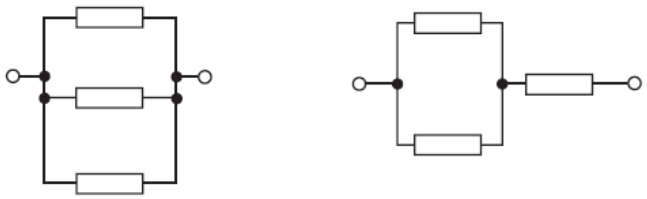
(5 marks)

Jun 04 P3

2 (a) **Figure 1** shows two possible arrangements of connecting three resistors, each resistor having a resistance of 40 Ω.



(i) (ii)

Figure 1

Calculate the equivalent resistance in each case.

(i) .....

.....

.....

(ii) .....

.....

.....

(3 marks)

(b) The designer of a heating element for the rear window of a car decides to connect six separate heating elements together as shown in **Figure 2**. Each element has a resistance of 6.0 Ω and the unit is connected to a 12 V dc supply having zero internal resistance.

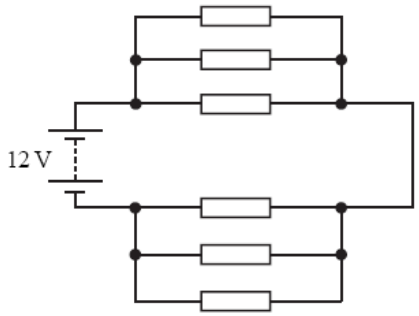


Figure 2

(i) Calculate the current in each single element.

.....

.....

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.....

(ii) With the aid of a similar calculation give a reason why the heater would not be as effective if all six were connected in series.

.....

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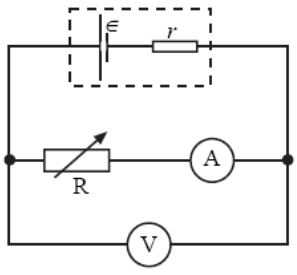
(5 marks)

3 In the circuit shown, a battery of emf ϵ and internal resistance r is connected to a variable resistor R. The current I and the voltage V are read by the ammeter and voltmeter respectively.



(a) The emf is related to V, I and r by the equation

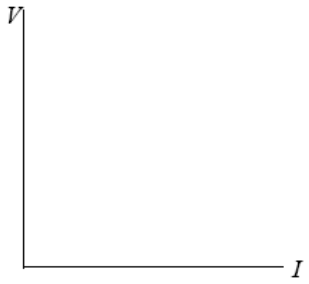
$$\epsilon = V + Ir.$$

Rearrange the equation to give V in terms of ϵ, I and r.

.....

(1 mark)

(b) In an experiment, the value of R is altered so that a series of values of V and the corresponding values of I are obtained. Using the axes, sketch the graph you would expect to obtain as R is changed.



(2 marks)

(c) State how the values of ϵ and r may be obtained from the graph.

ϵ .....

r .....

(2 marks)

4 (a) Give an expression for the *resistivity* of a material in the form of a uniform wire. Define all the symbols used.

.....

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.....

(2 marks)

(b) A thin film of carbon may be used in some electronic systems. Typical dimensions of such a film are shown in **Figure 3**.

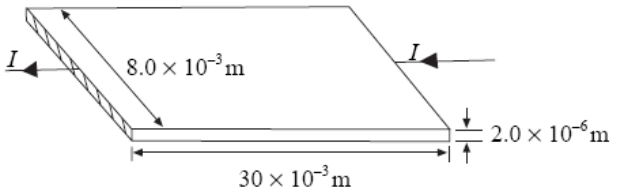

Figure 3

(i) Calculate the resistance of the carbon film to a current I passing through it as shown in **Figure 3**.

resistivity of carbon = $4.0 \times 10^{-5}\,\Omega\,\text{m}$

.....

.....

(ii) Without recalculating the resistance of the carbon film, explain how you would expect the resistance to change if the current flowed as in **Figure 4**. You should consider the numerical ratio or factor by which each dimension affecting the resistance has changed.

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

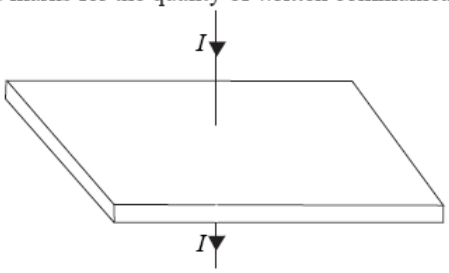

Figure 4

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(4 marks)

5 The circuit in **Figure 5** has a thermistor connected in series to a 200 Ω resistor and a 12 V battery of negligible internal resistance. **Figure 6** shows how the resistance, R_{th}, of the thermistor varies with temperature.

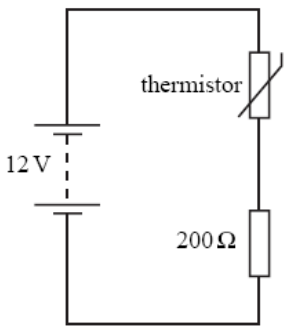

Figure 5

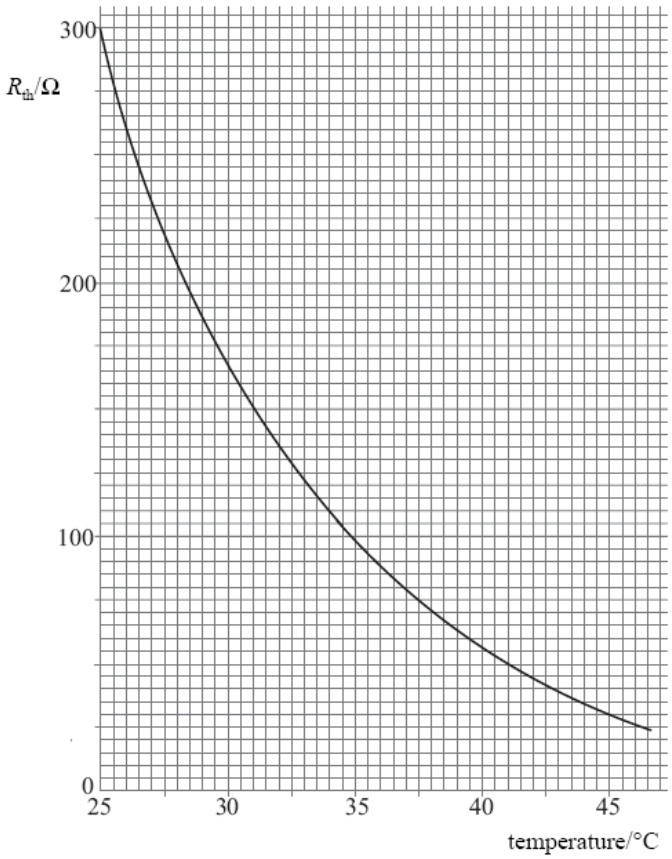

Figure 6

(a) (i) Calculate the current in the circuit when the temperature is 25 °C.

.....

.....

.....

(ii) Calculate the potential difference across the thermistor at 25 °C.

.....

.....

(3 marks)

(b) Without further calculation, explain how you would expect the potential difference across the thermistor to change as the temperature increases from 25 °C.

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

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(3 marks)

(c) The circuit in **Figure 5** is modified by removing the 200 Ω resistance to give the circuit in **Figure 7**.

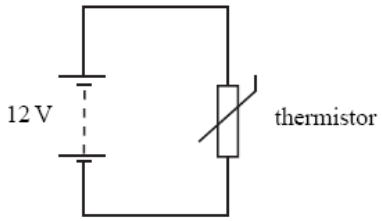

Figure 7

The temperature of the thermistor is increased at a steady rate from 25 °C to 45 °C in 10 minutes.

(i) Calculate the power dissipated in the thermistor at

25 °C .....

.....

45 °C .....

(ii) Use the mean value of the powers determined in part (c)(i) to calculate the energy supplied by the battery during the period in which the temperature of the thermistor increases.

.....

.....

(iii) State why the energy value, determined in part (c)(ii) is not an accurate value.

.....

.....

(6 marks)

Jun 05 P3

1 (a) A set of decorative lights consists of a string of lamps. Each lamp is rated at 5.0 V, 0.40 W and is connected in series to a 230 V supply.
Calculate

(i) the number of lamps in the set, so that each lamp operates at the correct rating,

.....

.....

(ii) the current in the circuit,

.....

.....

(iii) the resistance of each lamp,

.....

.....

(iv) the total electrical energy transferred by the set of lights in 2 hours.

.....

.....

.....

(5 marks)

(b) When assembled at the factory, one set of lights inadvertently contains 10 lamps too many. All are connected in series. Assume that the resistance of each lamp is the same as that calculated in part (a) (iii).

(i) Calculate the current in this set of lights when connected to a 230 V supply.

.....

.....

.....

(ii) How would the brightness of each lamp in this set compare with the brightness of each lamp in the correct set?

.....

(3 marks)

3 (a) In the circuit shown in **Figure 2**, the battery has an emf of 6.0 V. With the switch closed and the lamp lit, the reading on the voltmeter is 5.4 V.

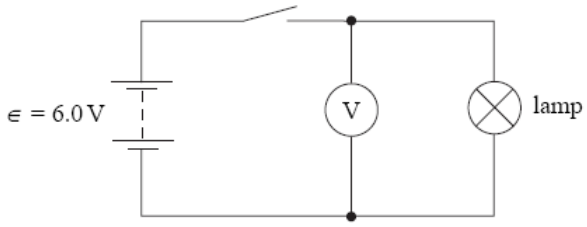

Figure 2

Explain without calculation, why the voltmeter reading is less than the emf of the battery.

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

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(3 marks)

(b) A torch is powered by two identical cells each having an emf of 1.5 V and an internal resistance r. The cells are connected in series. The torch bulb is rated at 1.6 W and the voltage across it is 2.5 V.

(i) Draw the circuit described.

(ii) Calculate the internal resistance of each cell.

.....

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.....

(5 marks)

(c) In the circuit in **Figure 3** the cell has emf ϵ and internal resistance r. The voltage V across the cell is read on the voltmeter which has infinite resistance, and the current I through the variable resistor R is read on the ammeter.

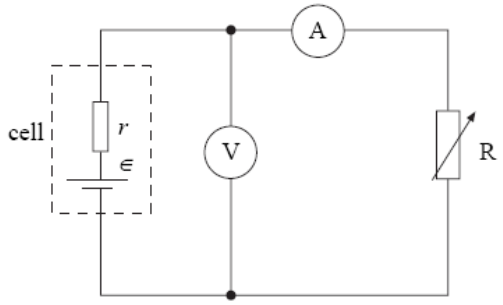

Figure 3

By altering the value of the variable resistor R, a set of values of V and I is obtained. These values, when plotted, give the graph shown in **Figure 4**.

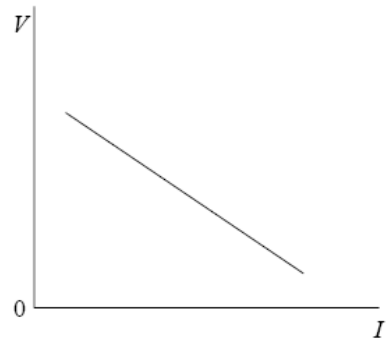

Figure 4

Show how the values of ϵ and r may be obtained from this graph. Explain your method.

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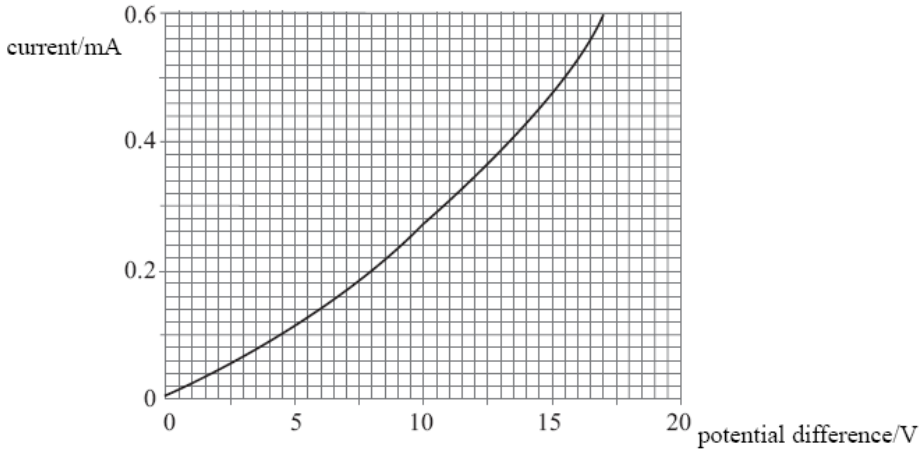
(3 marks)

4 The graph shows how the current through a thermistor varies with the potential difference across it.



(a) Draw the circuit of an experimental arrangement which could be used to collect the data necessary to produce this graph. On your circuit diagram label clearly a component which would enable the current to be changed continuously across the range.

(4 marks)

(b) (i) Using information obtained from the graph, calculate the resistances of the thermistor when the current is 0.10 mA and also when the current is 0.60 mA.

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(ii) Using the results of part (b) (i) deduce how the resistance of the thermistor changes as its **temperature** increases.

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

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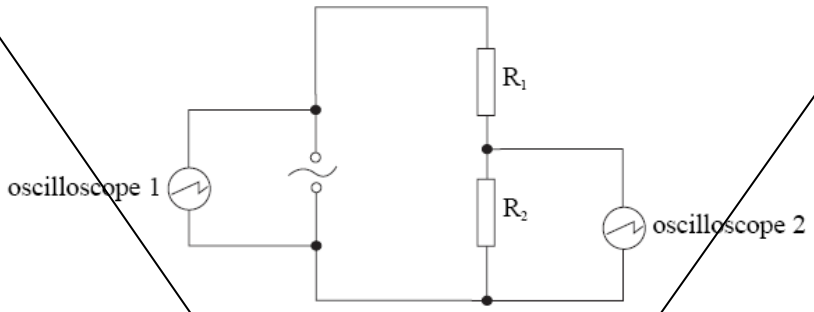
(5 marks)

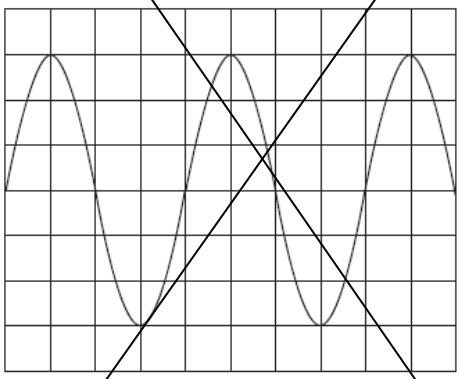
4 The circuit in **Figure 4** shows a sinusoidal ac source connected to two resistors, R_1 and R_2, which form a potential divider. Oscilloscope 1 is connected across the source and oscilloscope 2 is connected across R_2.

Figure 4



(a) **Figure 5** shows the trace obtained on the screen of oscilloscope 1. The time base of the oscilloscope is set at 10 ms per division and the voltage sensitivity at 15 V per division.

Figure 5



For the ac source, calculate

(i) the frequency,

.....

.....

(ii) the rms voltage.

.....

.....

.....

(4 marks)

(b) The resistors have the following values: $R_1 = 450\,\Omega$ and $R_2 = 90\,\Omega$.
Calculate

(i) the rms current in the circuit,

.....

(ii) the rms voltage across R_2.

.....

(2 marks)

(c) Oscilloscope 2 is used to check the calculated value of the voltage across R_2. The screen of oscilloscope 2 is identical to that of oscilloscope 1 and both are set to the same time base. Oscilloscope 2 has the following range for voltage sensitivity: 1 V per div., 5 V per div., 10 V per div. and 15 V per div.
State which voltage sensitivity would give the most suitable trace. Explain the reasons for your choice.

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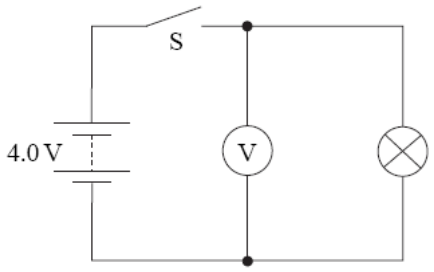
(3 marks)

3 A battery of emf 4.0 V is connected to a lamp and a high resistance voltmeter as shown in **Figure 4**.

Figure 4



(a) (i) When the switch S is closed, the lamp lights and the reading on the voltmeter is 3.8 V. Explain why this reading is less than the emf of the battery.

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(ii) With the switch closed the lamp is operating at its rated power of 1.6 W. Calculate the internal resistance, r, of the battery.

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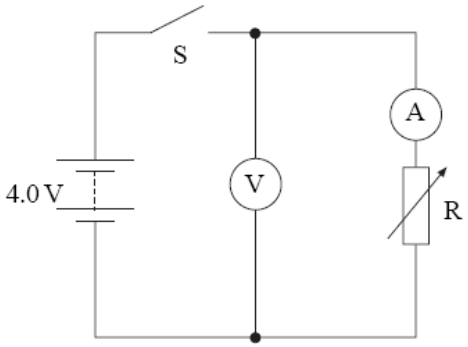
(4 marks)

(b) The lamp is replaced by an ammeter and a variable resistor R, as shown in **Figure 5**.

Figure 5



Describe an experiment, using the circuit in **Figure 5**, which would enable the emf and the internal resistance of the battery to be determined by a graphical method.

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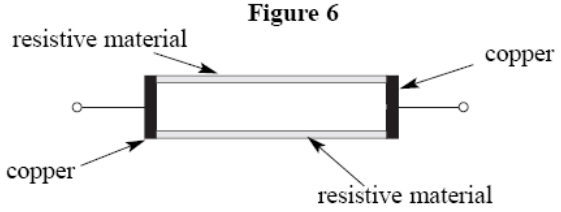
(5 marks)

4 A heating element consists of two strips of resistive material, joined by pieces of copper of negligible resistance, as shown in **Figure 6**.

Figure 6



(a) The resistance of each strip of resistive material is 12 Ω. The element is connected to a battery of emf 12 V and negligible internal resistance.
Show that heat is generated in the element at a rate of 24 W.

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.....

.....

(2 marks)

(b) The heating system of the rear window of a car consists of two of the elements described in **Figure 6**. The two elements can be connected in parallel or in series, as shown in **Figure 7** and **Figure 8** respectively.

Figure 7

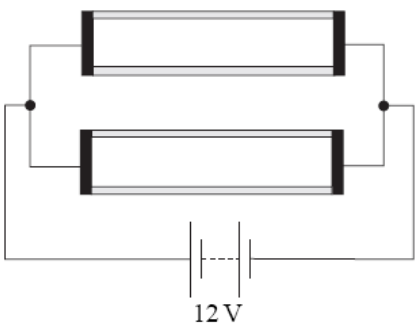
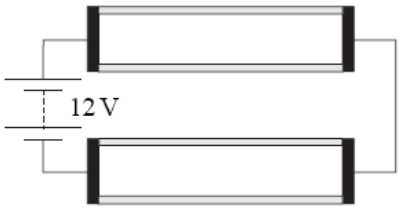


Figure 8



Determine, by calculation, which configuration of the two elements would have the greater heating effect.

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(4 marks)

(c) If each of the strips of resistive material in the element is 2.5 mm wide and 1.2 mm thick, determine the length of each strip.

resistivity of the material = $4.3 \times 10^{-5}\ \Omega\,m$

.....

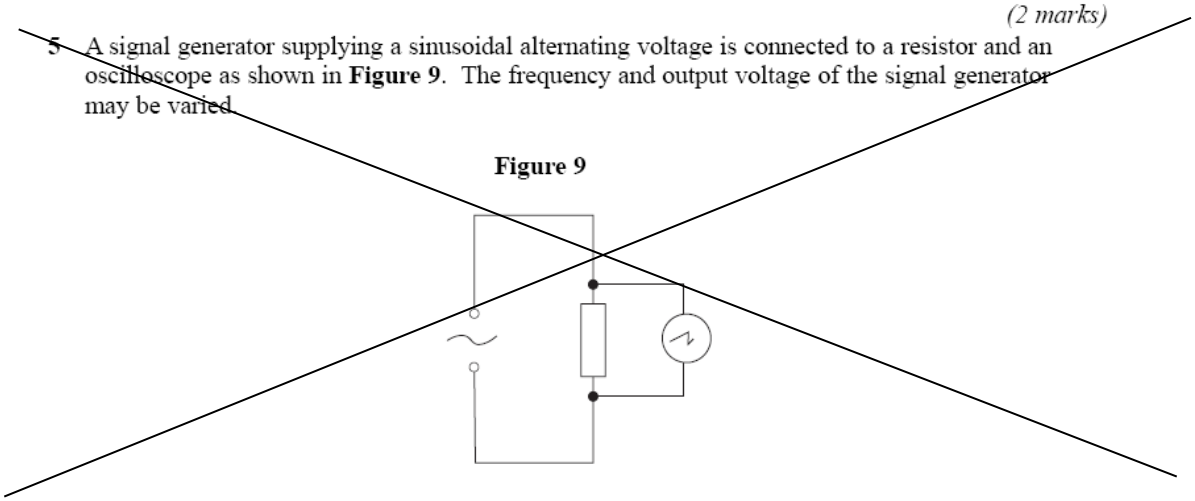
.....

.....

(2 marks)

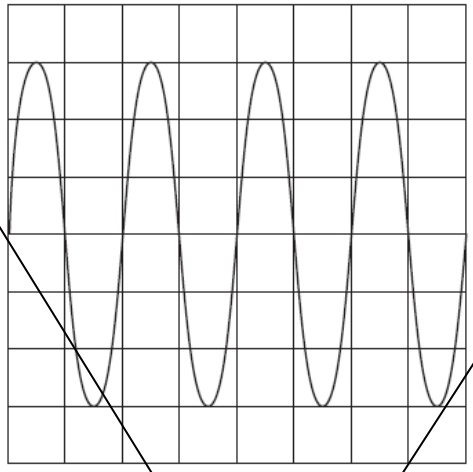
5 A signal generator supplying a sinusoidal alternating voltage is connected to a resistor and an oscilloscope as shown in **Figure 9**. The frequency and output voltage of the signal generator may be varied.

Figure 9



(a) At a certain frequency the trace shown in **Figure 10** is obtained on the screen of the oscilloscope when the time base is set to 2.5 ms div^{-1} and the voltage sensitivity to 5.0 V div^{-1}.

Figure 10



Calculate, for the source,

(i) the rms output voltage,

.....

.....

(ii) the frequency.

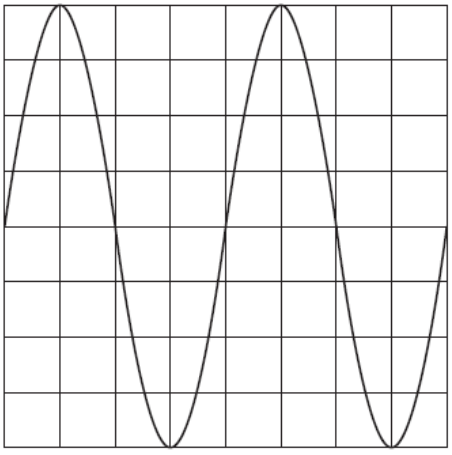
.....

.....

(4 marks)

(b) The frequency is changed to 2500 Hz and the voltage output is changed so that the rms voltage is 42.4 V. The time base and the voltage sensitivity of the oscilloscope are altered until the trace seen is that shown in **Figure 11**.

Figure 11



Determine

(i) the new time base setting.

.....

.....

(ii) the new voltage sensitivity setting.

.....

.....

(2 marks)

Jan 03 P1

1 (a) How many protons, neutrons and electrons are there in an atom of $^{14}_{6}C$?

..... protons

..... neutrons

..... electrons *(2 marks)*

(b) The $^{14}_{6}C$ atom loses two electrons.
For the ion formed;

(i) calculate its charge in C,

.....

(ii) state the number of nucleons it contains,

.....

(iii) calculate the ratio $\frac{\text{charge}}{\text{mass}}$ in C kg^{-1}.

.....

.....

.....

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(4 marks)

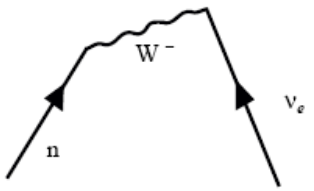
4 (a) A neutrino may interact with a neutron in the following way

$$\nu_e + n \Rightarrow p + e^-.$$

(i) Name the fundamental force responsible for this interaction.

.....

(ii) Complete the Feynman diagram for this interaction and label all the particles involved.



(3 marks)

(b) The neutral kaon, which is a meson of strangeness +1, may decay in the following way

$$K^\circ \Rightarrow \pi^+ + \pi^-.$$

(i) Apart from conservation of energy and momentum, state **two** other conservation laws obeyed by this decay and **one** conservation law which is **not** obeyed.

..... conservation law is obeyed

..... conservation law is obeyed

..... conservation law is not obeyed

(ii) Deduce the quark composition of all the particles involved in the K° decay.

.....

.....

.....

.....

K°.....

π^+ .....

π^- ..... *(6 marks)*

Jan 04 P1

2 (a) Quarks may be combined together in a number of ways to form sub-groups of hadrons. Name **two** of these sub-groups and for each, state its quark composition.

sub-group 1 .....

.....

sub-group 2 .....

.....

(3 marks)

(b) A free neutron is an unstable particle.

(i) Complete the following to give an equation that represents the decay of a neutron.

$$n \rightarrow$$

(ii) Describe the change that occurs to the quark structure when a neutron decays.

.....

.....

.....

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.....

(4 marks)

Jan 05 P1

4 The equation

$$p \longrightarrow n + \beta^{+} + \nu_e$$

represents the emission of a positron from a proton.

(a) Energy and momentum are conserved in this emission.
What other quantities are conserved in this emission?

.....

.....

.....

.....

(3 marks)

(b) Draw the Feynman diagram that corresponds to the positron emission represented in the equation.

(4 marks)

(c) Complete the following table using ticks ✓ and crosses ×.

particle	fundamental particle	meson	baryon	lepton
p				
n				
β^+				
ν_e				

(4 marks)

Jan 06 P1

1 A radioactive isotope of carbon is represented by ${}^{14}_{6}\mathrm{C}$.

(a) Using the same notation, give the isotope of carbon that has two fewer neutrons.

.....

(1 mark)

(b) Calculate the charge on the ion formed when **two** electrons are removed from an atom of ${}^{14}_{6}\mathrm{C}$.

.....

.....

.....

(2 marks)

(c) Calculate the value of $\frac{\text{charge}}{\text{mass}}$ for the nucleus of an atom of ${}^{14}_{6}\mathrm{C}$.

.....

.....

.....

(2 marks)

1 The equation shows a carbon-carbon fusion reaction.

$$^{12}_{6}\mathrm{C} + {}^{12}_{6}\mathrm{C} \longrightarrow {}^{a}_{b}\mathrm{X} + {}^{3}_{2}\mathrm{He}$$

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

.....

.....

number of protons .....

number of neutrons .....

(2 marks)

(b) Two $^{12}_{6}\mathrm{C}$ nuclei may also undergo a fusion reaction that produces other *isotopes* of X and He.

State what is meant by the term isotopes.

.....

.....

.....

(2 marks)

(c) Calculate the ratio $\frac{\text{charge}}{\text{mass}}$ for the helium nucleus $^{3}_{2}\mathrm{He}$.

.....

.....

.....

.....

(3 marks)

3 (a) The decay shown in the equation

$$\mathrm{p} \longrightarrow \overline{\mathrm{n}} + \mathrm{e}^{+} + \overline{\nu}_{\mathrm{e}}$$

cannot occur because it violates two conservation laws.

(i) State the **two** conservation laws that are violated.

.....

.....

.....

(ii) Give the correct equation for positron emission.

.....

(3 marks)

(b) Draw a Feynman diagram in terms of quarks, to represent positron emission.

(3 marks)

Jun 04 P1

1 (a) (i) Determine the charge, in C, of a $^{239}_{92}U$ nucleus.

.....

.....

(ii) A positive ion with a $^{239}_{92}U$ nucleus has a charge of 4.80×10^{-19} C.
Determine how many electrons are in this ion.

.....

.....

.....

(4 marks)

(b) A $^{239}_{92}U$ nucleus may decay by emitting **two** β^- particles to form a plutonium nucleus $^{X}_{Y}Pu$.
State what X and Y represent and give the numerical value of each.

X .....

.....

Y .....

.....

(4 marks)

1 (a) What are isotopes?

.....

.....

.....

.....

.....

(2 marks)

(b) One of the isotopes of nitrogen may be represented by $^{15}_{7}\mathrm{N}$.

(i) State the number of each type of particle in its nucleus.

.....

.....

(ii) Determine the ratio $\frac{\text{charge}}{\text{mass}}$, in C kg^{-1}, of its nucleus.

.....

.....

.....

.....

(4 marks)

(c) (i) What is the charge, in C, of an atom of $^{15}_{7}\mathrm{N}$ from which a single electron has been removed?

.....

(ii) What name is used to describe an atom from which an electron has been removed?

.....

(2 marks)

6 (a) (i) Complete the equation that represents the collision between a proton and an antineutrino.

$$\overline{\nu_e} + \mathrm{p} \longrightarrow$$

(ii) What fundamental force is responsible for the interaction shown in part (i)?

.....

(iii) Name an exchange particle that could be involved in this interaction.

.....

(4 marks)

(b) Describe what happens in pair production and give **one** example of this process.

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

.....

.....

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.....

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.....

(3 marks)

Jun 06 P1

2 Under certain conditions a γ photon may be converted into an electron and a positron.

(a) What is this process called?

.....

(1 mark)

(b) (i) Explain why there is a minimum energy of the γ photon for this conversion to take place and what happens when a γ photon has slightly more energy than this value.

.....

.....

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.....

.....

(ii) Using values from the data sheet calculate this minimum energy in MeV.

.....

.....

(3 marks)

(c) Under suitable conditions, a γ photon may be converted into two other particles rather than an electron and positron.
Give an example of the two other particles it could create.

.....

(1 mark)

6 (a) Complete the following equations

$$p + e^- \rightarrow \_\_\_ + \_\_\_$$

$$n + \nu_\mu \rightarrow p + \_\_\_$$

$$p + p \rightarrow p + p + K^- + \_\_\_$$

(4 marks)

(b) Give an equation that represents β^- decay, using quarks in the equation rather than nucleons.

.....

.....

(2 marks)

(c) (i) Which fundamental force is responsible for electron capture?

.....

(ii) What type of particle is an electron?

.....

(iii) State the other fundamental forces that electrons may experience.

.....

(3 marks)

June 07 P1

1 (a) Give the number of protons, neutrons and electrons in an atom of the isotope $^{55}_{26}Fe$.

protons .....

neutrons .....

electrons .....

(2 marks)

(b) Calculate the ratio $\frac{\text{charge}}{\text{mass}}$ for the nucleus of a $^{55}_{26}Fe$ atom.

.....

.....

.....

.....

(3 marks)

(c) Determine the values of a and b in the decay represented by the equation

$$ {}^{a}_{b}\mathbf{X} \longrightarrow {}^{55}_{26}\mathrm{Fe} + e^{+} + \nu_e . $$

.....

.....

$a =$ .....

$b =$ .....

(2 marks)

2 The Ω^- particle is a baryon with strangeness –3. It rapidly decays in stages to a baryon and several pions.

(a) State the general quark structure of a baryon.

.....

(1 mark)

(b) State what class of particle a pion is. Give its general quark structure.

class .....

structure .....

(2 marks)

(c) State what pion is identical to its antiparticle.

.....

(1 mark)

(d) State what baryon the Ω^- particle finally decays into.

.....

(1 mark)

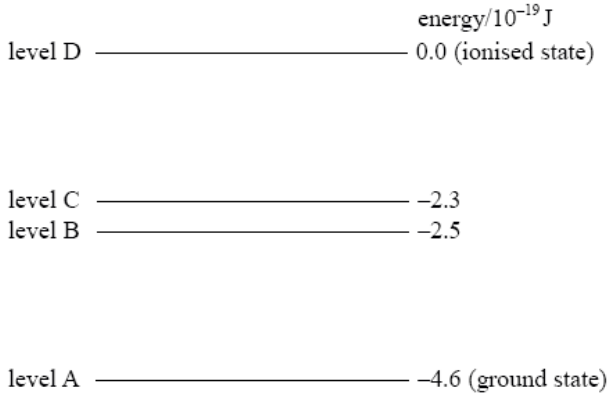
(e) State why the weak interaction must be involved at some stage in the decay of the Ω^- particle.

.....

.....

(1 mark)

5 The diagram shows four energy levels of an atom not drawn to scale.



(a) (i) Explain how this atom emits a line spectrum following excitation.

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

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(ii) The longest wavelength of emitted radiation is produced by a transition between which two levels?

.....

(iii) Draw on the diagram **two** vertical arrows between levels to indicate two different transitions that result in emitted radiation of the same frequency. *(4 marks)*

(b) In its ground state the atom absorbs 2.3×10^{-19} J of energy from a collision with an electron.

(i) Calculate all the possible frequencies of radiation that the atom may subsequently emit.

.....

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.....

.....

(ii) How much energy, in eV, would be required to ionise the atom in its ground state?

.....

.....

(5 marks)

6 (a) (i) Explain the meaning of the term *work function* of a metal.

.....

.....

.....

(ii) State what you would need to change in an experiment to investigate the effect of the work function on the photoelectric effect.

.....

(3 marks)

(b) Experiments based on the photoelectric effect support the particle theory of light. State **one** conclusion drawn from these experiments and explain how it supports the particle theory.

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

.....

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.....

(2 marks)

(c) Monochromatic light of wavelength 4.80×10^{-7} m falls onto a metal surface which has a work function of 1.20×10^{-19} J.

Calculate

(i) the energy, in J, of a single photon of this light,

.....

.....

.....

.....

.....

(ii) the maximum kinetic energy, in J, of an electron emitted from the surface.

.....

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(5 marks)

6 Electromagnetic waves and electrons have properties of both particles and waves.
Explain what evidence there is to support this statement.
Experimental details are not required.

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

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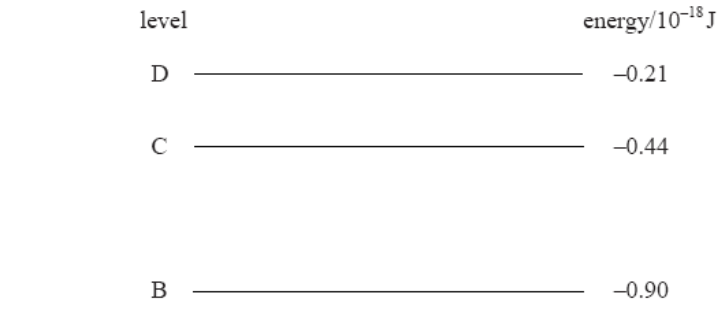
(6 marks)

2 The diagram shows some of the electron energy levels of an atom.



An incident electron of kinetic energy 4.1×10^{-18} J and speed 3.0×10^{6} m s^{-1} collides with the atom represented in the diagram and excites an electron in the atom from level B to level D.

(a) For the incident electron, calculate

(i) the kinetic energy in eV,

.....

.....

(ii) the de Broglie wavelength.

.....

.....

.....

.....

(4 marks)

(b) When the excited electron returns directly from level D to level B it emits a photon. Calculate the wavelength of this photon.

.....

.....

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.....

.....

.....

(3 marks)

5 (a) The photoelectric effect is represented by the equation

$$hf = \phi + E_k.$$

What does E_k represent?

.....

.....

(2 marks)

(b) A metal plate is illuminated with electromagnetic radiation of wavelength 190 nm. The metal has a work function of 7.9×10^{-19} J.

(i) Calculate the frequency of the incident electromagnetic radiation.

.....

.....

.....

(ii) Show that the metal plate will emit photoelectrons when illuminated with radiation of this wavelength.

.....

.....

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(iii) The radiation incident on the metal plate remains at a constant wavelength of 190 nm but its intensity is now doubled.
State and explain the effect this has on the emitted photoelectrons.

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

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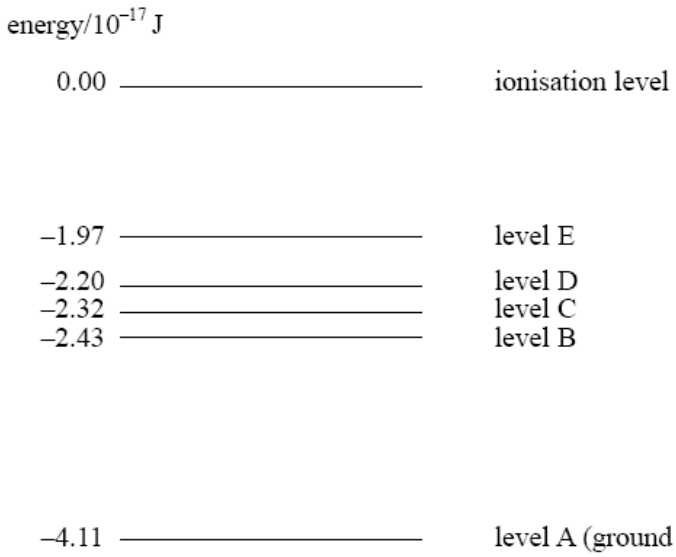
(6 marks)

6 Some of the energy levels of an atom are shown below. The atom may be *ionised* by electron impact.



(a) (i) State what is meant by the ionisation of an atom.

.....

.....

(ii) Calculate the minimum kinetic energy, in eV, of an incident electron that could ionise the atom from its ground state.

.....

.....

(2 marks)

(b) You may be awarded marks for the quality of written communication in your answer to parts (b)(i) and (b)(ii).

The atom in the ground state is given 5.00×10^{-17} J of energy by electron impact.

(i) State what happens to this energy.

.....

.....

(ii) Describe and explain what could happen subsequently to the electrons in the higher energy levels.

.....

.....

.....

.....

.....

(4 marks)

(c) Identify **two** transitions between energy levels that would give off electromagnetic radiation of the same frequency.

_____ to _____

and

_____ to _____

(2 marks)

Jan 07 P1

4 (a) (i) In relation to the photoelectric effect explain the meaning of the term *threshold frequency*.

.....

.....

.....

(ii) Sketch on the axes a graph of the maximum kinetic energy of photoelectrons against the frequency of the incident electromagnetic radiation. Label the position of the threshold frequency, f_o.
Values are not required on the axes.

(4 marks)

(b) The table gives the work function of some metals.

metal	**work function/10^{-19} J**
caesium	3.0
lithium	3.7
beryllium	6.2
mercury	7.2
tungsten	7.4

(i) Calculate the threshold frequency for caesium.

.....

.....

.....

(ii) A caesium surface is illuminated with electromagnetic radiation of wavelength 3.0×10^{-7} m. Determine the maximum kinetic energy of the ejected photoelectrons.

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(iii) State which metals listed in the table will not emit photoelectrons when illuminated with electromagnetic radiation of wavelength 3.0×10^{-7} m.

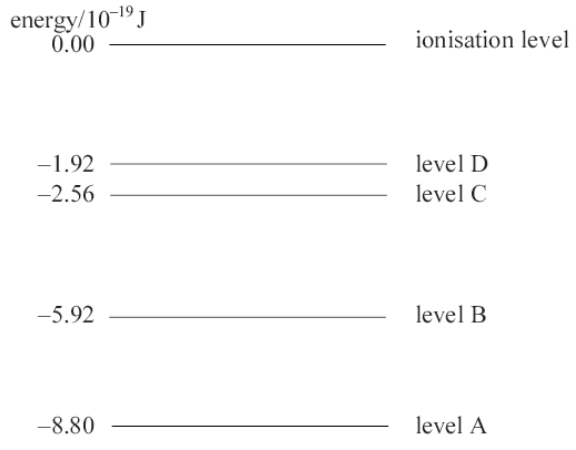
.....

.....

(7 marks)

Jun 03 P1

6 The diagram shows some of the energy levels of the mercury atom.



(a) When electrons collide with mercury atoms, the atoms may be *excited* or may be *ionised.*

Explain what is meant by

(i) excitation,

.....

.....

.....

(ii) ionisation.

.....

.....

.....

(2 marks)

(b) Determine the lowest frequency of emitted radiation with reference to the energy levels in the diagram.

.....

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(2 marks)

7 (a) Electrons behave in two distinct ways. This is referred to as the *duality of electrons*.

(i) State what is meant by the duality of electrons.

.....

.....

(ii) Give **one** example of each type of behaviour of electrons.

.....

.....

(3 marks)

(b) Calculate the speed of electrons that have a de Broglie wavelength of 1.70×10^{-10}m.

.....

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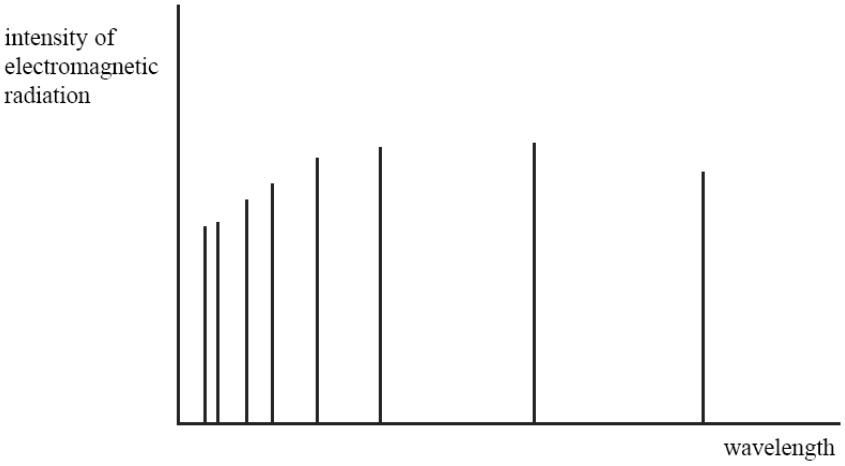
.....

(2 marks)

5 (a) Explain what happens to electrons in hydrogen atoms when a spectrum, such as that represented below, is produced.

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



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(4 marks)

(b) A fluorescent tube is normally coated on the inside with a powder. The tube is then filled with mercury vapour at low pressure. When the tube is switched on, the mercury vapour emits ultraviolet electromagnetic radiation.

Explain how this ultraviolet radiation causes the powder to emit electromagnetic radiation as well. State the difference between the radiations emitted by the mercury vapour and the powder.

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

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(4 marks)

6 A proton and an electron have the same velocity. The de Boglie wavelength of the electron is 3.2×10^{-8} m.

(a) Calculate,

(i) the velocity of the electron,

.....

.....

.....

.....

(ii) the de Broglie wavelength of the proton.

.....

.....

.....

(4 marks)

(b) (i) State what kind of experiment would confirm that electrons have a wave-like nature. Experimental details are not required.

.....

.....

(ii) State why it is easier to demonstrate the wave properties of electrons than to demonstrate wave properties of protons.

.....

.....

.....

(2 marks)

Jun 05 P1

2 Some energy levels of an atom of a gas are shown in **Figure 1**.

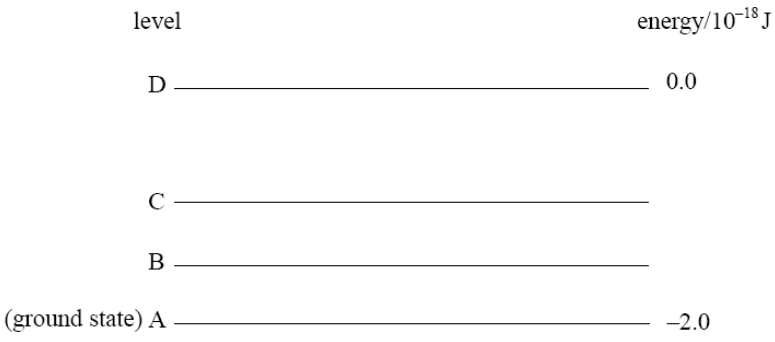

Figure 1

When a current is passed through the gas at low pressure, a line spectrum is produced. Two of these lines, which correspond to transitions from levels B and C respectively to the ground state, are shown in **Figure 2**.

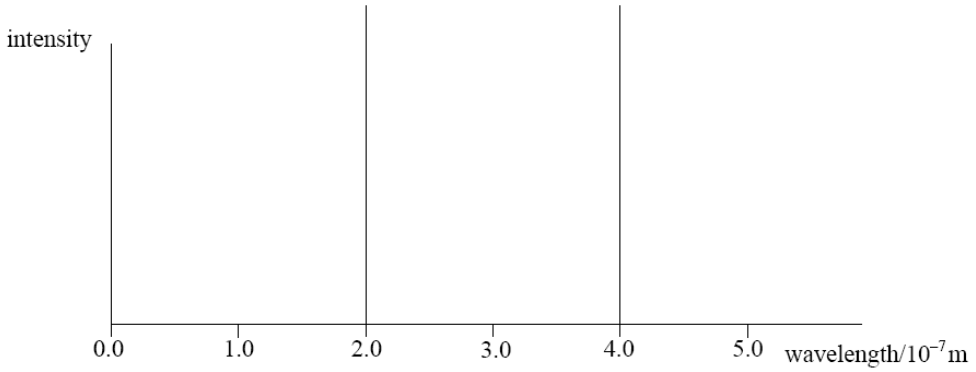

Figure 2

(a) Describe what happens to an electron in an atom in the ground state in order for the atom to emit light of wavelength 4.0×10^{-7}m.

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

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.....

(3 marks)

(b) Determine the energy, in J, of

(i) the photons responsible for each of the two lines shown in **Figure 2**,

.....

.....

.....

.....

.....

(ii) levels B and C in **Figure 1**.

.....

.....

.....

energy of level B =.....

energy of level C =.....

(5 marks)

5 (a) Explain what is meant by the term *work function* of a metal.

.....

.....

(2 marks)

(b) In an experiment on the photoelectric effect, the maximum kinetic energy of the emitted photoelectrons is measured over a range of incident light frequencies. The results obtained are shown in **Figure 4**.

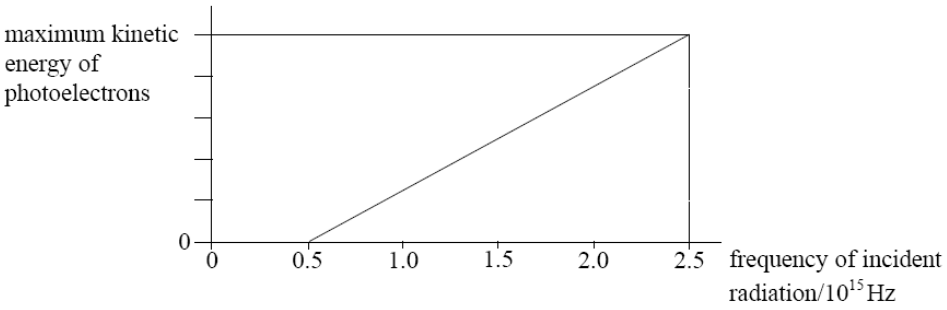


Figure 4

(i) A metal of work function ϕ is illuminated with light of frequency f. Write down the equation giving the maximum kinetic energy, E_K, of the photoelectrons emitted in terms of ϕ and f.

$E_K =$

(ii) Use the data in **Figure 4** to determine the work function of the metal.

.....

.....

.....

(iii) Determine the maximum kinetic energy of the photoelectrons when the frequency of the incident radiation is 2.5×10^{15} Hz.

.....

.....

.....

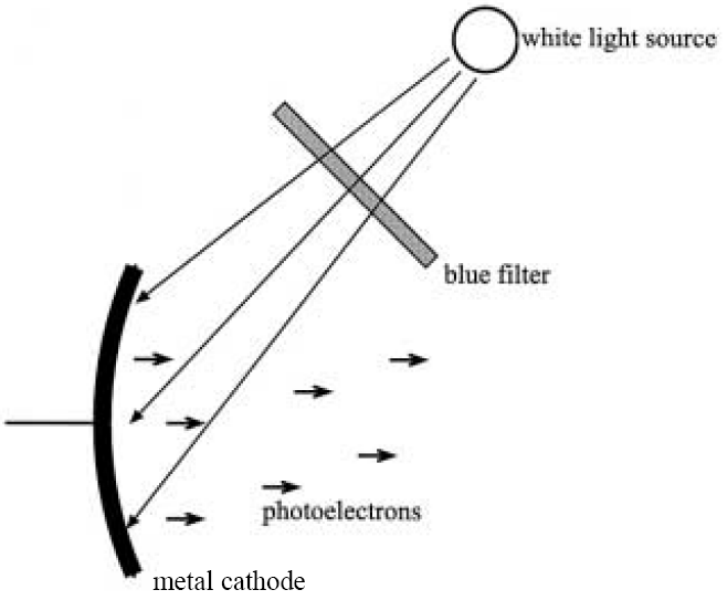
.....

(6 marks)

(c) The experiment is repeated but with the light incident on a metal of lower work function. Draw a new line on **Figure 4** that results from this change. *(2 marks)*

4 The apparatus shown in **Figure 3** can be used to demonstrate the photoelectric effect. Photoelectrons are emitted from the metal cathode when it is illuminated with white light which has passed through a blue filter.

Figure 3



You may be awarded additional marks to those shown in brackets for the quality of written communication in your answers to parts (a) and (b).

(a) The intensity of the light source is reduced. State and explain the effect of this on the emitted photoelectrons.

.....

.....

.....

.....

(3 marks)

(b) Explain why no photoelectrons are emitted when the blue filter is replaced by a red filter.

.....

.....

.....

.....

(3 marks)

(c) When a metal of work function 2.30×10^{-19} J is illuminated with ultraviolet radiation of wavelength 200 nm, photoelectrons are emitted.

Calculate

(i) the frequency of the ultraviolet radiation,

.....

.....

(ii) the threshold frequency of the metal,

.....

.....

.....

(iii) the maximum kinetic energy of the photoelectrons, in J.

.....

.....

.....

.....

(5 marks)

5 **Figure 4** shows the energy level diagram of a hydrogen atom. Its associated spectrum is shown in **Figure 5**.

The transition labelled **A** in **Figure 4** gives the spectral line labelled **B** in **Figure 5**.

Figure 4

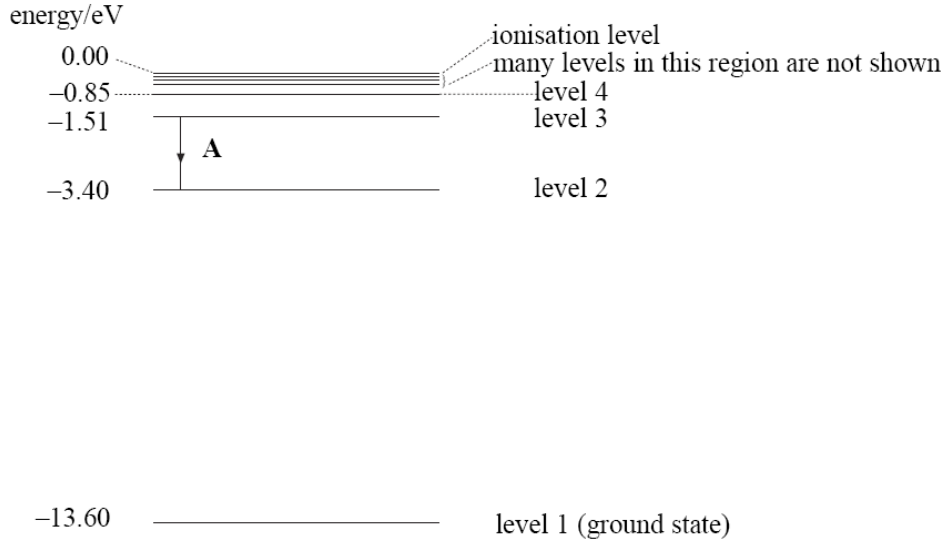
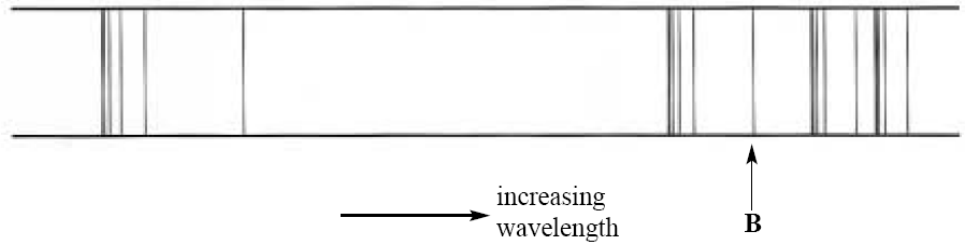


Figure 5

hydrogen spectrum showing some of the main spectral lines



(a) (i) Show that the frequency of spectral line B is about 4.6×10^{14} Hz.

.....

.....

.....

(ii) Calculate the wavelength represented by line B.

.....

.....

(3 marks)

(b) The hydrogen atom is excited and its electron moves to level 4.

(i) How many different wavelengths of electromagnetic radiation may be emitted as the atom returns to its ground state?

.....

(ii) Calculate the energy, in eV, of the longest wavelength of electromagnetic radiation emitted during this process.

.....

.....

(2 marks)

(c) In a fluorescent tube, explain how the mercury vapour and the coating of its inner surface contribute to the production of visible light.

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

.....

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(3 marks)

3 (a) Describe and explain the principal features of the spectrum from excited gas atoms.

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

.....

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.....

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(3 marks)

(b) The energy levels of atomic hydrogen, in J, are given by the equation

$$E_n = -\frac{22 \times 10^{-19}}{n^2},$$

where n is a whole number corresponding to the energy level. Therefore the ground state, level 1, has energy $E_1 = -22 \times 10^{-19}$ J and level 2 has energy

$$E_2 = -\frac{22 \times 10^{-19}}{2^2} = -5.5 \times 10^{-19} \text{ J}.$$

A photon is emitted from atomic hydrogen as the atom undergoes a transition from level 4 to level 2.

Calculate

(i) the energy of the emitted photon,

.....

.....

.....

.....

.....

(ii) the frequency of the photon.

.....

.....

.....

(4 marks)

(c) How many different wavelengths of electromagnetic radiation can be emitted after atomic hydrogen is excited to level 4?

.....

.....

(1 mark)

5 (a) Explain the term *work function*.

.....

.....

.....

(2 marks)

(b) When a clean lithium surface is illuminated with ultraviolet radiation of photon energy 7.9×10^{-19} J, photoelectrons of energies up to 4.2×10^{-19} J are emitted.

Calculate

(i) the wavelength of the ultraviolet radiation,

.....

.....

.....

.....

(ii) the work function of lithium, in J,

.....

.....

.....

.....

(iii) the work function of lithium, in eV.

.....

.....

.....

.....

(6 marks)

(c) Describe and explain the effect of increasing the intensity of the incident ultraviolet radiation on the emitted photoelectrons.

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

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(3 marks)

5 (a) State the principle of conservation of linear momentum for two colliding bodies.

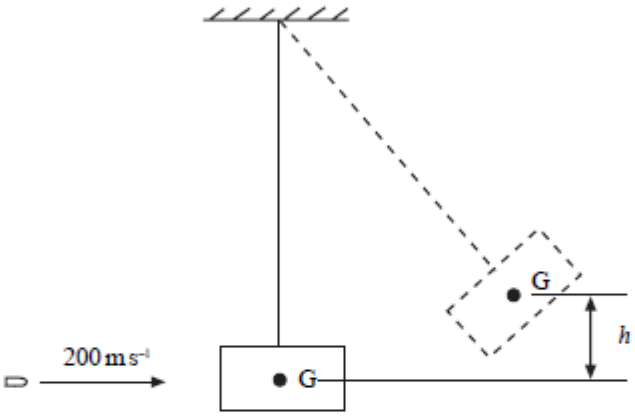
.....

.....

.....

(2 marks)

(b)



A bullet of mass 0.010 kg travelling at a speed of 200 m s^{-1} strikes a block of wood of mass 0.390 kg hanging at rest from a long string. The bullet enters the block and lodges in the block. Calculate

(i) the linear momentum of the bullet before it strikes the block,

.....

(ii) the speed with which the block first moves from rest after the bullet strikes it.

.....

.....

(4 marks)

(c) During the collision of the bullet and block, kinetic energy is converted into internal energy which results in a temperature rise.

(i) Show that the kinetic energy of the bullet before it strikes the block is 200 J.

.....

(ii) Show that the kinetic energy of the combined block and bullet immediately after the bullet has lodged in the block is 5.0 J.

.....

(iii) The material from which the bullet is made has a specific heat capacity of 250 $J kg^{-1} K^{-1}$. Assuming that all the lost kinetic energy becomes internal energy in the bullet, calculate its temperature rise during the collision.

.....

.....

.....

(5 marks)

(d) The bullet lodges at the centre of mass G of the block. Calculate the vertical height h through which the block rises after the collision.

.....

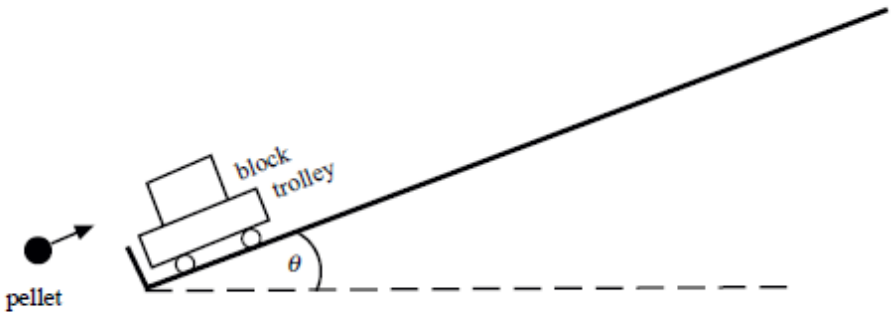
.....

.....

(2 marks)

Jan 03 P2

2 The diagram represents part of an experiment that is being used to estimate the speed of an air gun pellet.



The pellet which is moving parallel to the track, strikes the block, embedding itself. The trolley and the block then move along the track, rising a vertical height, h.

(a) Using energy considerations explain how the speed of the trolley and block immediately after it has been struck by the pellet, may be determined from measurements of h.
Assume frictional forces are negligible.

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(3 marks)

(b) The following data is collected from the experiment

mass of trolley and block	0.50 kg
mass of pellet	0.0020 kg
speed of trolley and block immediately after impact	0.40 $m\,s^{-1}$

Calculate

(i) the momentum of the trolley and block immediately after impact,

.....

.....

(ii) the speed of the pellet just before impact.

.....

.....

.....

(4 marks)

(c) (i) State what is meant by an inelastic collision.

.....

.....

.....

(ii) Use the data from part (b) to show that the collision between the pellet and block is inelastic.

.....

.....

.....

(4 marks)

2 A constant resultant horizontal force of 1.8×10^3 N acts on a car of mass 900 kg, initially at rest on a level road.

(a) Calculate

(i) the acceleration of the car,

.....

.....

(ii) the speed of the car after 8.0 s,

.....

.....

(iii) the momentum of the car after 8.0 s,

.....

.....

(iv) the distance travelled by the car in the first 8.0 s of its motion,

.....

.....

.....

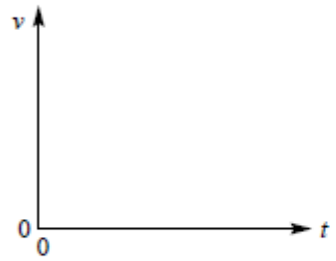
(v) the work done by the resultant horizontal force during the first 8.0 s.

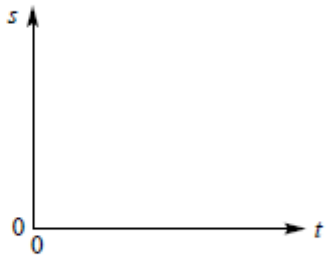
.....

.....

(9 marks)

(b) On the axes below sketch the graphs for speed, v, and distance travelled, s, against time, t, for the first 8.0 s of the car's motion.





(2 marks)

(c) In practice the resultant force on the car changes with time. Air resistance is one factor that affects the resultant force acting on the vehicle.
You may be awarded marks for the quality of written communication in your answer.

(i) Suggest, with a reason, how the resultant force on the car changes as its speed increases.

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(ii) Explain, using Newton's laws of motion, why the vehicle has a maximum speed.

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(5 marks)

6 **Figure 3** shows two trolleys, A and B, of equal mass, travelling towards each other at the same speed, u.

Figure 3

(a) State and explain why the initial total momentum of the trolleys is zero.

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(2 marks)

(b) The trolleys collide and then move apart. If no resultant external forces are acting, explain why

(i) the velocity of trolley A must be equal and opposite to the velocity of trolley B,

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.....

(ii) the speed of each trolley will be smaller as a result of the collision.

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(4 marks)

(c) Describe how you would measure the speed of trolley A after the collision.

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

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(3 marks)

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.

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.....

(5 marks)

(b) Water arrives at the wall at a rate of $18\,kg\,s^{-1}$. It strikes the wall horizontally, at a speed of $7.2\,m\,s^{-1}$ 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.

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(2 marks)

1 (a) Collisions can be described as *elastic* or *inelastic*.
State what is meant by an inelastic collision.

.....

.....

(1 mark)

(b) A ball of mass 0.12 kg strikes a stationary cricket bat with a speed of 18 m s^{-1}. The ball is in contact with the bat for 0.14 s and returns along its original path with a speed of 15 m s^{-1}.

Calculate

(i) the momentum of the ball before the collision,

.....

.....

(ii) the momentum of the ball after the collision,

.....

.....

(iii) the total change of momentum of the ball,

.....

.....

(iv) the average force acting on the ball during contact with the bat,

.....

.....

(v) the kinetic energy lost by the ball as a result of the collision.

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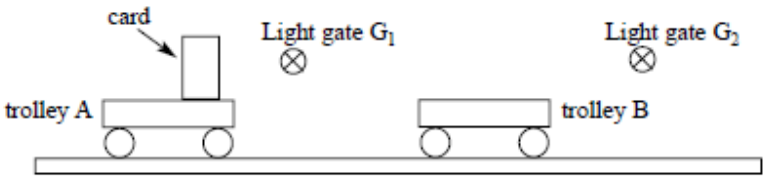
(6 marks)

4 The simplified diagram shows an experimental arrangement to investigate the collision of two trolleys.



In the experiment, trolley A is travelling at speed v. It collides with and sticks to, the initially stationary trolley B.

(a) State the measurements you would need to take so that you could determine the speed of

(i) trolley A before the collision,

.....

.....

(ii) trolleys A and B after the collision.

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(3 marks)

(b) Explain how you would verify that momentum was conserved in this collision, indicating what other measurements would be required.

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(2 marks)

(c) State and explain what you would do to minimise the effects of friction on the motion of the trolleys.

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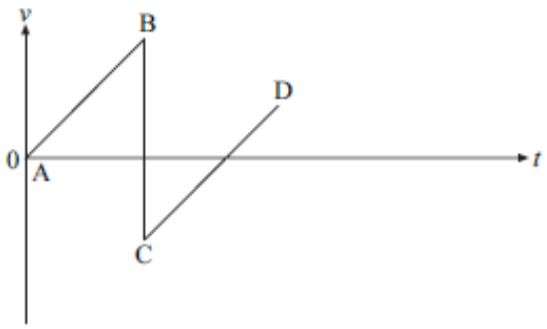
(2 marks)

5 The diagram shows the velocity-time graph for a vertically bouncing ball, which is released above the ground at A and strikes the floor at B. The effects of air resistance have been neglected.



(a) (i) What does the gradient of a velocity-time graph represent?

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(ii) Explain why the gradient of the line CD is the same as line AB.

.....

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(iii) What does the area between the line AB and the time axis represent?

.....

(iv) State why the velocity at C is negative.

.....

.....

(v) State why the speed at C is less than the speed at B.

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(5 marks)

(b) The ball has a mass of 0.15 kg and is dropped from an initial height of 1.2 m. After impact the ball rebounds to a height of 0.75 m.

Calculate

(i) the speed of the ball immediately before impact,

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.....

(ii) the speed of the ball immediately after impact,

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.....

(iii) the change in momentum of the ball as a result of the impact,

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.....

(iv) the magnitude of the resultant average force acting on the ball during impact if it is in contact with the floor for 0.10 s.

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(8 marks)

6 A golf club undergoes an *inelastic* collision with a golf ball and gives it an initial velocity of $60\,m\,s^{-1}$. The ball is in contact with the club for 15 ms and the mass of the ball is 4.5×10^{-2} kg.

(a) Explain what is meant by an inelastic collision.

.....

.....

(1 mark)

(b) Calculate

(i) the change in momentum of the ball,

.....

(ii) the average force the club exerts on the ball.

.....

.....

(4 marks)

(c) (i) State the value of the force exerted by the ball on the club and give its direction.

.....

.....

(ii) Explain how your answer to part (i) follows from an appropriate law of motion.

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

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(4 marks)

1 (a) State **two** quantities that are conserved in an elastic collision.

quantity 1: .....

quantity 2: .....

(2 marks)

(b) A gas molecule makes an elastic collision with the walls of a gas cylinder. The molecule is travelling at 450 $m\,s^{-1}$ at right angles towards the wall before the collision.

(i) What is the magnitude and direction of its velocity after the collision?

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(ii) Calculate the change in momentum of the molecule during the collision if it has a mass of 8.0×10^{-26} kg.

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(4 marks)

(c) Use Newton's laws of motion to explain how the molecules of a gas exert a force on the wall of a container.

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)