BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1998
PHYSICS
2 UNIT

Time allowed—Three hours
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- Board-approved calculators may be used.

Section I—Core

- Attempt ALL questions.
- **Part A** 15 multiple-choice questions, each worth 1 mark.
  Complete your answers in blue or black pen, or in pencil on the Answer Sheet provided.
- **Part B** 10 questions, each worth 3 marks.
  Answer this Part in the Part B Answer Book.
- **Part C** 6 questions, each worth 5 marks.
  Answer this Part in the Part C Answer Book.
- Write your Student Number and Centre Number on the cover of each Answer Book.
- You may keep this Question Book. Anything written in the Question Book will NOT be marked.

Section II—Electives

- Attempt ONE question.
- Each question is worth 25 marks.
- Answer each Elective or Half-elective in a SEPARATE Elective Answer Book.
- Write your Student Number and Centre Number on the cover of each Elective Answer Book.
- Write the Course, Elective Name, and Question Number on the cover of each Elective Answer Book.
- You may ask for extra Elective Answer Books if you need them.

A Data Sheet and Periodic Table are provided as a tear-out sheet at the back of this paper.

SECTION I—CORE

(75 Marks)

Attempt ALL questions.

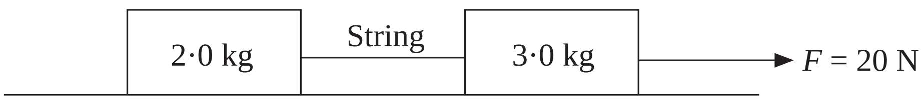
PART A

Questions 1–15 are worth 1 mark each.

Complete your answers in blue or black pen, or in pencil on the Answer Sheet provided.

Select the alternative A, B, C or D that best answers the question.

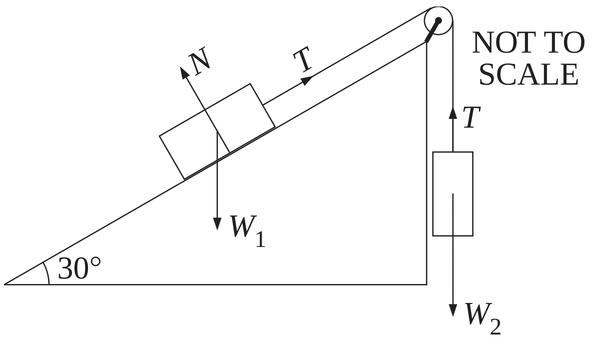
1. Two masses joined by a string are pulled along a horizontal, frictionless surface, as shown in the diagram below.



What is the tension in the string joining the masses?

(A) 4·0 N
(B) 8·0 N
(C) 12 N
(D) 20 N

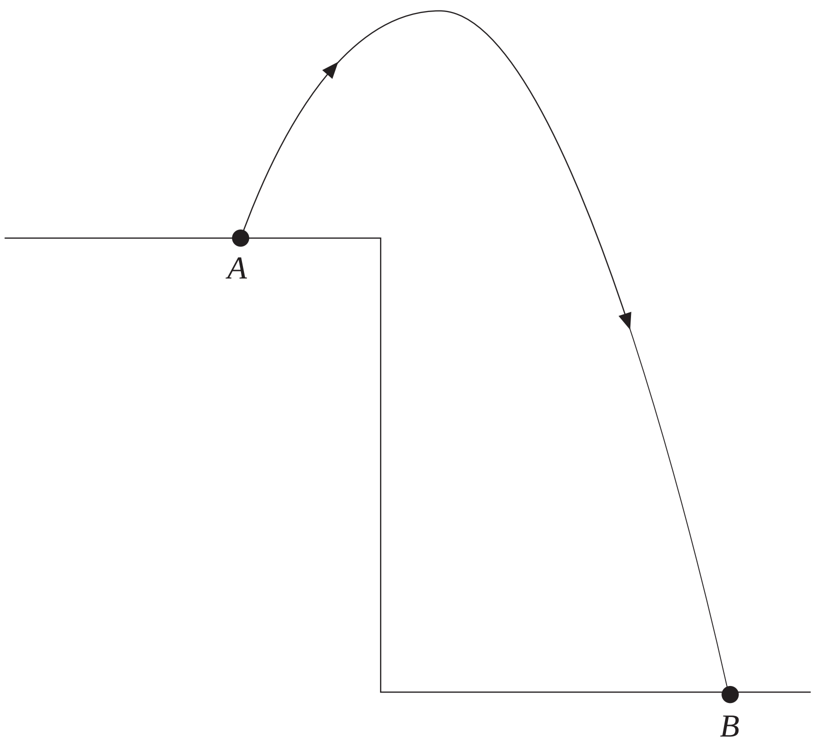
2. A block of weight W_1 sits in equilibrium on a smooth plane that is inclined at an angle of 30° to the horizontal as shown in the diagram below. Other forces acting on the block are the normal force N, and T from the tension in the cord. A block of weight W_2 hangs from the cord that passes over a smooth pulley.



The weight W_2 has a magnitude of

(A) W_1
(B) $W_1 \cos 30°$
(C) $W_1 \sin 30°$
(D) $W_1 \tan 30°$

3. A projectile follows a parabolic arc from point A to point B as sketched in the diagram below. The displacement of the projectile is measured from the launch point.



If air resistance is neglected, which statement is correct?

(A) The total time of flight is twice the time to reach maximum height.

(B) The velocity has maximum magnitude when the displacement is zero.

(C) The vertical component of the acceleration depends on the direction of the initial velocity.

(D) The horizontal component of the final displacement depends on the initial velocity.

4. A block sits on the perimeter of a free-standing, horizontal turntable. The turntable starts rotating from rest and speeds up. At some critical speed the block slides off the turntable. An observer standing next to the turntable measures the acceleration of the block from the instant the block has lost contact with the turntable. The acceleration of the block

(A) is zero.

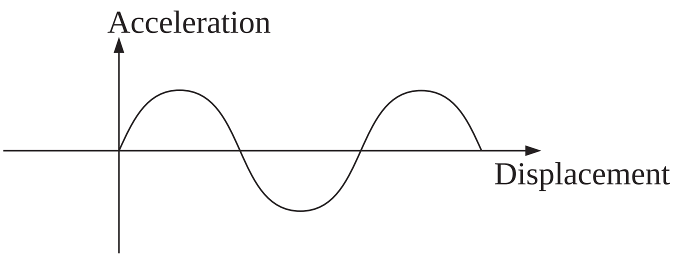
(B) is horizontal.

(C) is vertically downward.

(D) has both horizontal and vertical components.

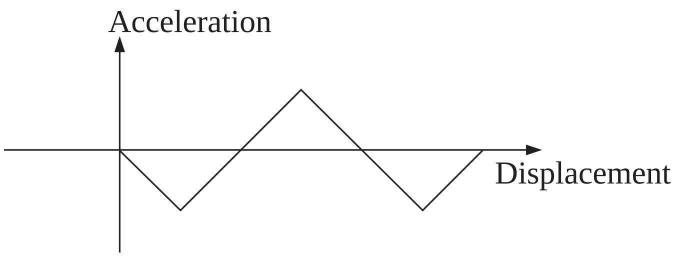
5. Which of the graphs below correctly shows the relationship between acceleration and displacement for an object undergoing simple harmonic motion?

(A)

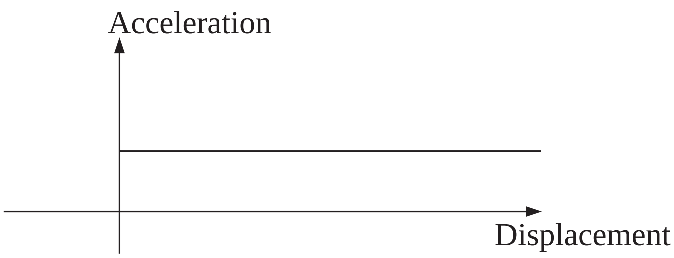


(B)

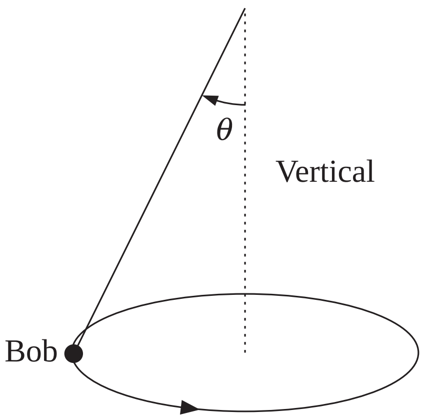
(C)



(D)



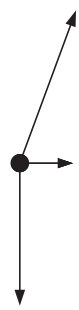
6. The diagram below shows a conical pendulum consisting of a bob and a string. The bob is rotating with constant speed in a horizontal circle. The string makes an angle θ with the vertical.



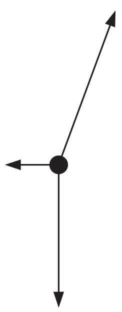
Which diagram best shows the directions of the applied forces acting on the pendulum bob?

(A)

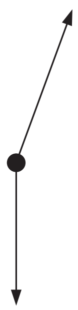
(B)



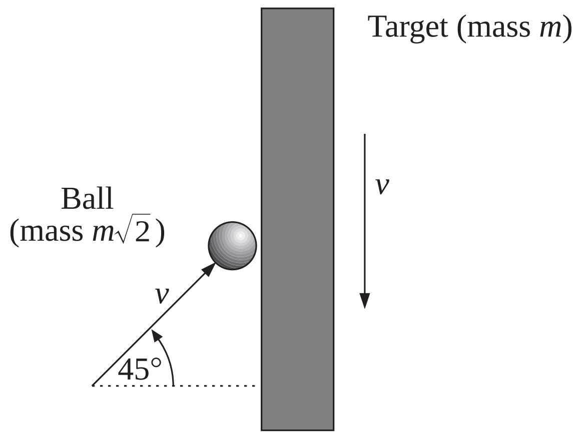
(C)



(D)



7. A ball is thrown so that it collides with and sticks to the centre of a target that is falling vertically. The ball has a mass of $m\sqrt{2}$ and the target has a mass of m. Immediately before the collision, the ball is moving upward at an angle of 45°. The speeds of the ball and the target are both v.



Which vector correctly describes the direction of the combined motion of the ball and target immediately after the collision?

(A) 

(B) 

(C) 

(D) 

8. A space shuttle approaches the Earth at such an angle that it bounces away rather than re-entering the atmosphere. During this process the shuttle heats up. The collision between the shuttle and the Earth/atmosphere system is

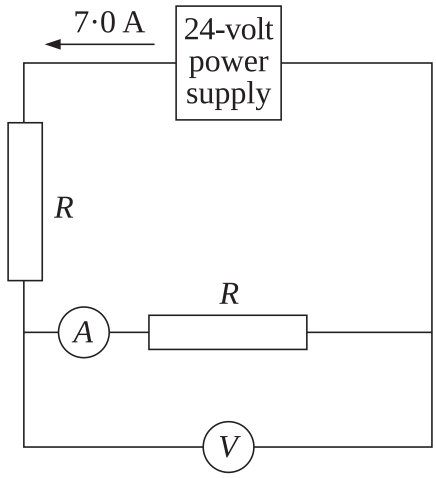
(A) elastic, because momentum is conserved.

(B) inelastic, because momentum is not conserved.

(C) inelastic, because kinetic energy is not conserved.

(D) elastic, because the shuttle and the Earth do not stick together.

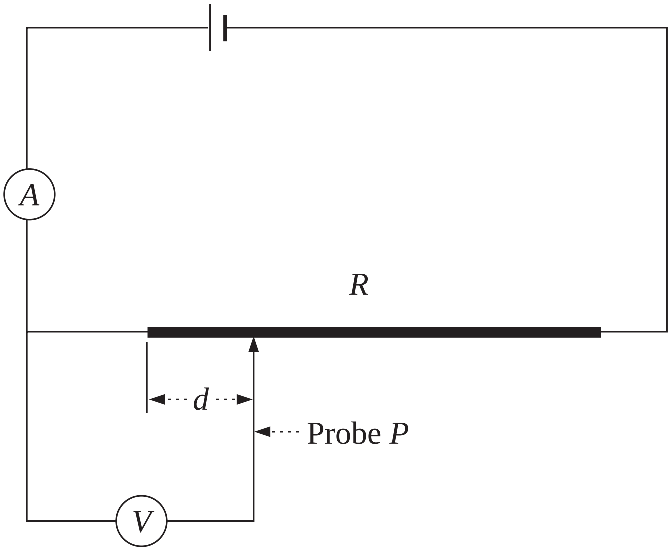
9. The diagram below shows an electrical circuit containing two identical resistors. The current from the 24-volt power supply is 7·0 amperes.



Assuming that both the ammeter and voltmeter are ideal, which pair of readings is correct?

	Ammeter (A)	*Voltmeter* (V)
(A)	7·0	12
(B)	7·0	24
(C)	3·5	24
(D)	3·5	12

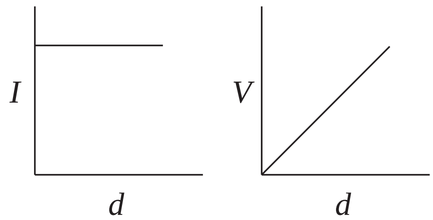
10. An electrical circuit is set up as shown below.

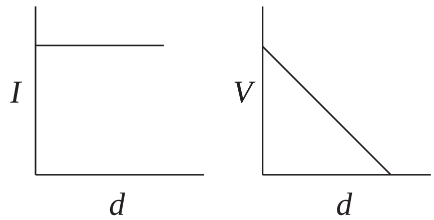


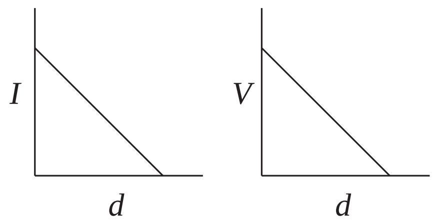
The resistor R is a length of resistance wire and the probe P is able to slide along the wire. The variable distance d of the probe P is measured from the left-hand end of R.

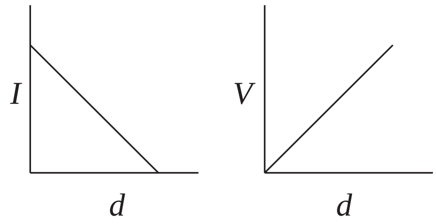
Readings from the voltmeter V and the ammeter A are taken and plotted against distance d.

Which pair of graphs for current I, and voltage V, is correct?

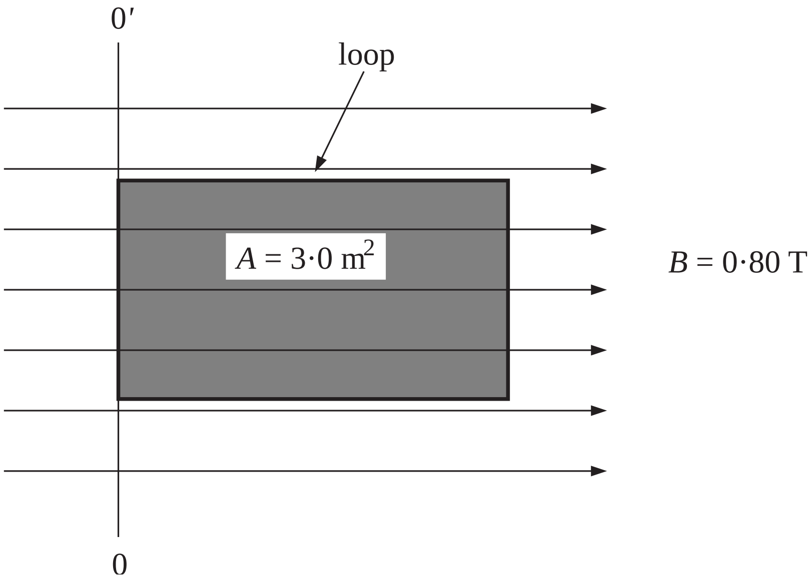
(A)


(B)


(C)


(D)


11. A rectangular loop of area $3{\cdot}0\ \text{m}^2$ is placed in a uniform magnetic field of $0{\cdot}80$ T. The plane of the loop is parallel to the field direction as shown in the diagram below.



The loop is rotated 60° about the axis 0—0′. The magnitude of the change in the magnetic flux through the loop is closest to

(A) 2·4 Wb.

(B) 2·1 Wb.

(C) 1·2 Wb.

(D) zero.

12. A uniform electric field is set up between two parallel metal plates which are of length L. An electron travelling at constant velocity v enters this field midway between the two plates.

The strength of the electric field is adjusted so that the electron just hits the far edge of the bottom plate, following a path similar to that suggested in Figure 1.

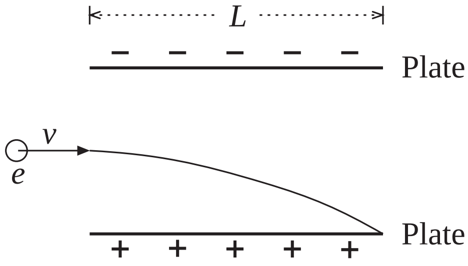


FIG. 1

A uniform magnetic field is now switched on so that the field lines are parallel to v, as shown in Figure 2.

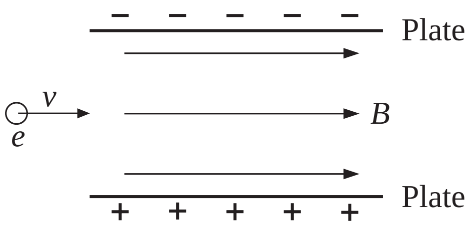


FIG. 2

Which statement best describes the electron's new trajectory?

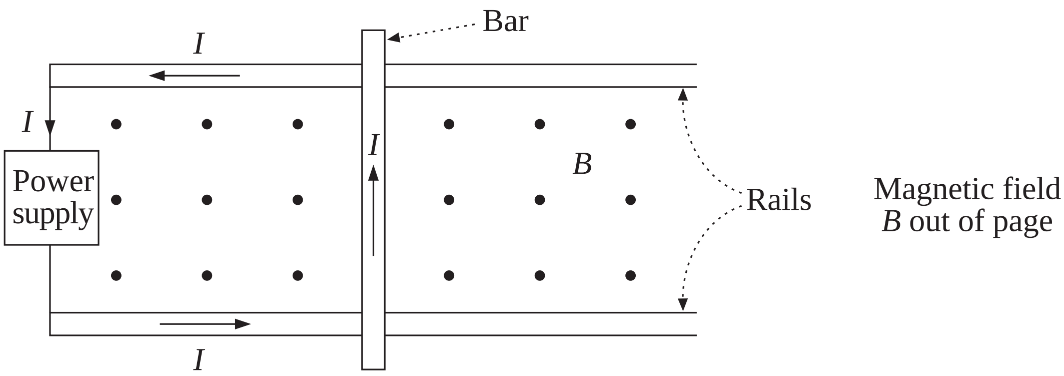
(A) The electron just hits the far edge of the bottom plate.

(B) The electron travels in a straight line, midway between the plates.

(C) The electron hits the bottom plate closer to the front than the far edge.

(D) The electron follows a spiral path and hits neither plate.

13. A rectangular bar makes electrical contact with parallel metal rails and is able to move freely. This arrangement is within a uniform magnetic field that is perpendicular to the rails as shown below. The rails are connected to a power supply at one end. A current I is passed around the circuit in the direction shown. The bar is at rest before the current is switched on.



When the current is switched on, which of the following best describes the initial motion of the bar?

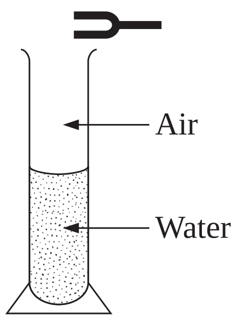
(A) The bar remains at rest.

(B) The bar moves to the left.

(C) The bar moves to the right.

(D) The bar rotates.

14. A student holds a vibrating 256 Hz tuning fork above a measuring cylinder full of water. She then gradually lowers the water height, creating an air column as shown. She observes that the sound produced becomes quite loud for the first time when the length of the air column is 32 cm. The student selects a tuning fork of a different frequency and vibrates it above the 32 cm long air column. It also produces quite a loud sound.



What is a possible frequency for the second tuning fork?

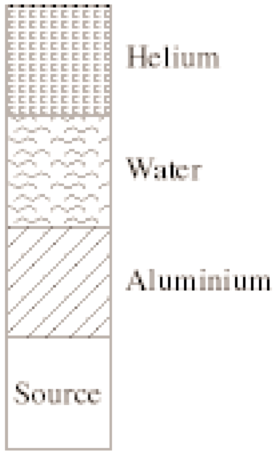
(A) 768 Hz

(B) 512 Hz

(C) 128 Hz

(D) 85 Hz

15. As shown in the diagram, a tube contains three different substances: helium, water and aluminium. A source, at the base of the tube, emits sound waves.



Which of the following is true?

(A) The sound waves travel with the same frequency in all the substances.

(B) The sound waves travel with the same wavelength in all the substances.

(C) The sound waves travel with the same velocity in all the substances.

(D) The sound waves travel with the same amplitude in all the substances.

PART B

Questions 16–25 are worth 3 marks each.

Answer this Part in the Part B Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

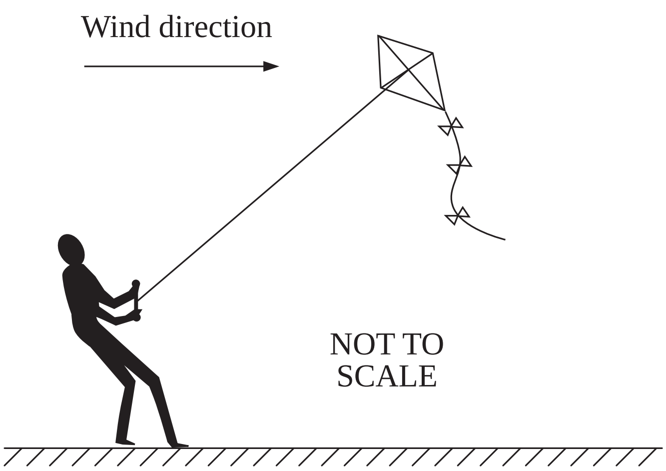
16. A canoeist can paddle at 13 km h^{-1}. He wishes to travel due north across a river flowing at 5·0 km h^{-1} due east.

(a) In what direction should the canoeist paddle?

(b) What is the magnitude of the canoeist's velocity relative to the bank if he travels due north?

(c) A log, floating downstream with the current, passes the canoeist. What is the velocity of the canoeist relative to the log?

17. A person is flying a kite in a brisk wind. The kite is holding a steady position as shown in the diagram below.



The forces acting on the kite can be resolved into four parts. These are the horizontal drag *D*, the weight *W*, the vertical lift *L*, and the force due to the tension in the string *T*. The mass of the kite is 0·40 kg.

The magnitude of the drag equals that of the lift, and the magnitude of the lift is twice that of the weight.

In your Part B Answer Book, the weight vector is shown. Complete a scale diagram showing the vector addition of the forces, and determine the tension in the string.

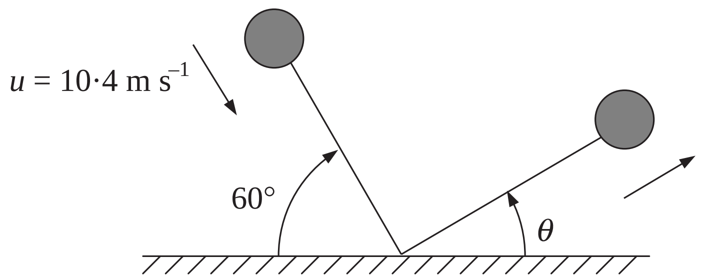
18. Two objects travelling in different directions on a smooth, horizontal plane collide. Before the collision, object A has mass m_A and velocity v_A, and object B has mass m_B and velocity v_B. The masses m_A and m_B remain the same.

(a) Reasoning from the forces involved, explain why momentum is conserved in the collision.

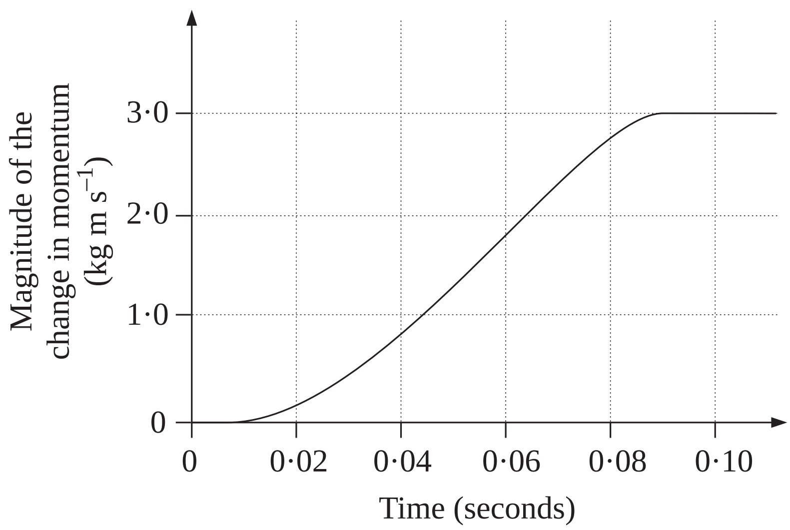
(b) The momentum of A is not conserved. What is the momentum that is conserved?

(c) Clearly explain why the momentum of A is not conserved.

19. A puck of mass 0·20 kg slides along a smooth, horizontal floor and bounces off a wall as shown in the diagram below. While the puck and the wall are in contact, the force that the wall exerts on the puck is always horizontally outward from the wall at 90° to the wall.

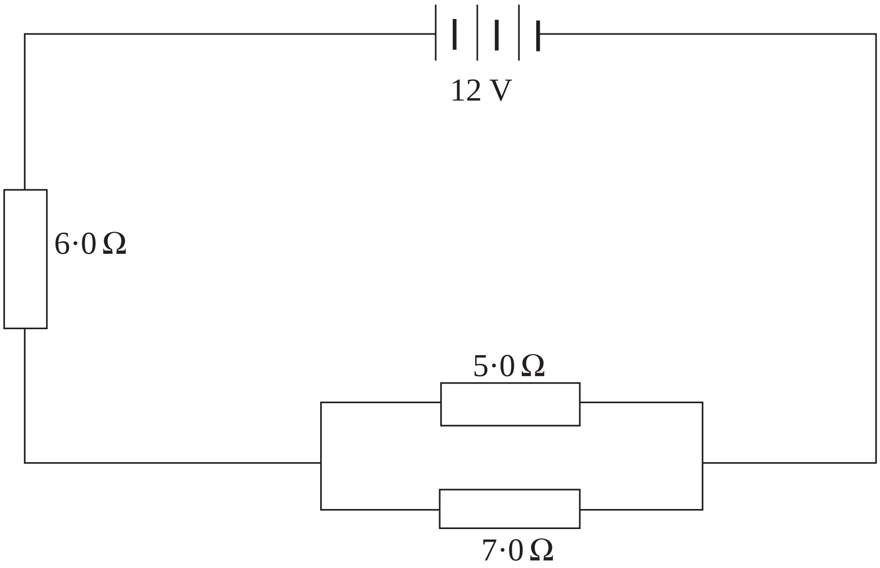


The magnitude of the change in momentum of the puck due to the collision with the wall is shown in the graph below.



After the collision, what is the speed of the puck?

20.



For the circuit shown in the diagram above, calculate:

(a) the voltage across the 6·0 Ω resistor;

(b) the current through the 5·0 Ω resistor;

(c) the total energy dissipated in the 5·0 Ω resistor after the current has been flowing for two minutes.

21. The capacity of a car battery is given in units of ampere-hours. For example, a 40-ampere-hour battery can deliver 40 A for 1 hour, 5 A for 8 hours and so on.

A fully charged 12-volt, 40-ampere-hour battery is connected to an electric motor that draws a current of 2·0 A.

(a) Assuming that the potential difference between the battery terminals remains constant while the battery is delivering current, calculate:

(i) how much charge, in SI units, must pass through the motor for the battery to fully discharge;

(ii) how much energy is initially stored in the battery.

(b) In practice, could all the battery energy be used to do mechanical work? Explain your answer.

22. This question relates to a simple direct current (dc) motor.

(a) Explain the need for each of the following:

(i) split-ring commutator;

(ii) brushes.

(b) The effective area of the 300-turn coil in the motor is $1{\cdot}2 \times 10^{-3}$ m^2, the current is 5·0 A, and the magnetic field strength is 0·40 T. Calculate the maximum torque.

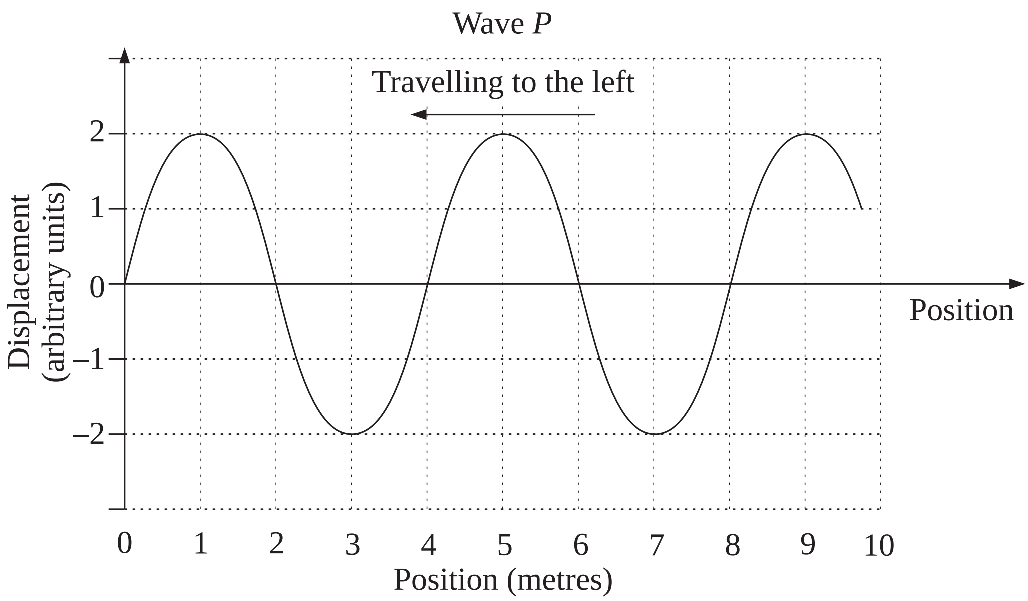
23. Two overhead power lines supply electrical power as direct current (dc) to a pump motor. The wires *A* and *B* are shown in your Part B Answer Book, together with the directions of the currents. The wires run parallel, 0·60 m apart, for a distance of 1·3 km. The electric current of 9·0 A flows along wire *A* and back along wire *B*.

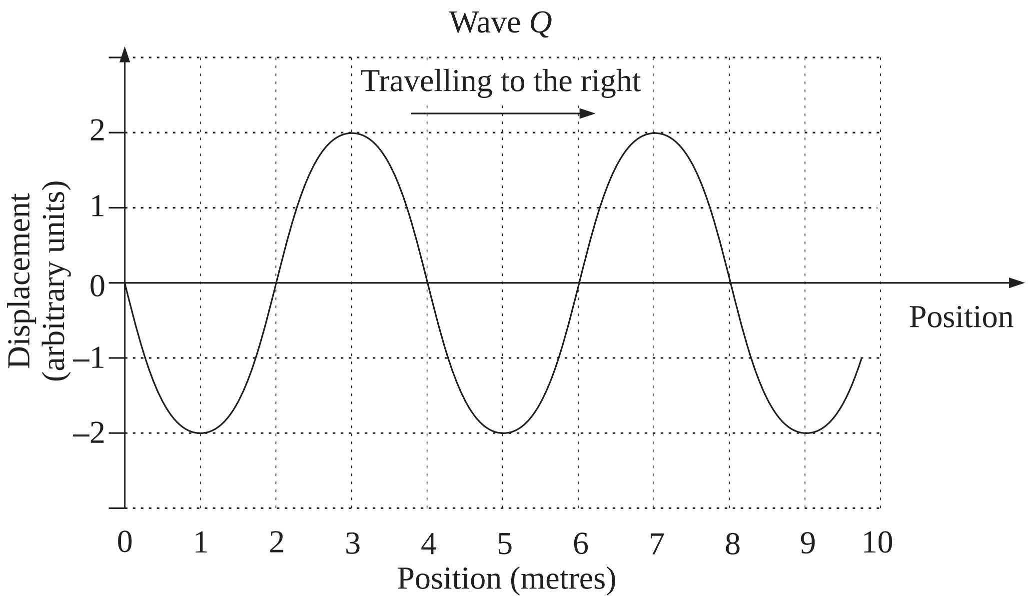
(a) Sketch the magnetic field around the wires.

(b) On the diagram, show the direction of the force on wire *A* due to the current in wire *B*.

(c) What is the magnitude of the magnetic flux density at point *P* midway between the wires?

24. Two waves, *P* and *Q*, shown in the diagram below, are travelling in opposite directions with equal amplitudes. Both waves are shown to the same scale. Each has a wavelength of 4·0 m, a speed of 20 m s^{-1} and a frequency of 5·0 Hz.

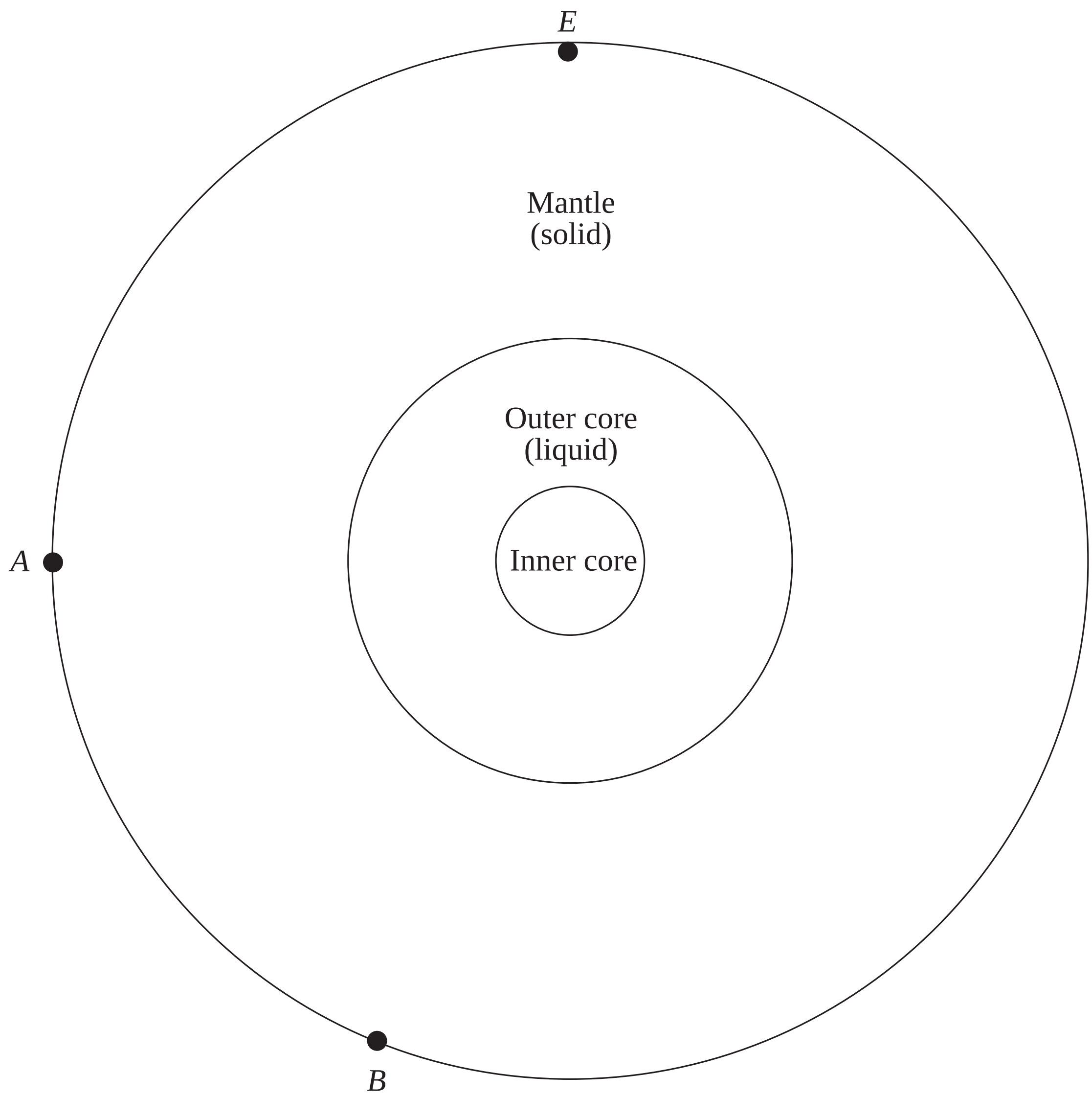




(a) On the grid marked (a) in your Part B Answer Book, draw the resultant wave of *P* and *Q*.

(b) On the grid marked (b) in your Part B Answer Book, draw the resultant wave of *P* and *Q* at an instant 0·05 s later than that shown in the diagram above.

25. The diagram below represents a simple model of the Earth. It is known that the mantle is solid and that the outer core is liquid. An earthquake occurs at *E* and is observed at stations *A* and *B*. (*A*, *B*, and *E* lie in a plane passing through the centre of the core.)



The earthquake generates *S* waves that are transverse waves, and *P* waves that are longitudinal waves.

(a) Assuming that the waves propagate in straight lines from *E* towards both *A* and *B*, what types of waves (*S* and/or *P*) are received by:

(i) station *A*?

(ii) station *B*?

(b) What properties of the waves justify your answers to parts (a) (i) and (a) (ii)?

PART C

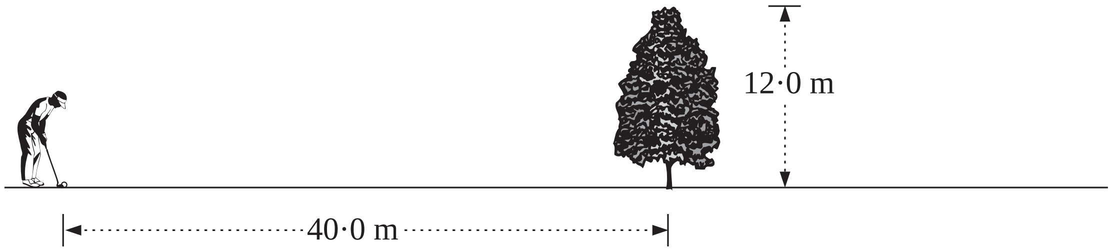
Questions 26–31 are worth 5 marks each.

Answer this Part in the Part C Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

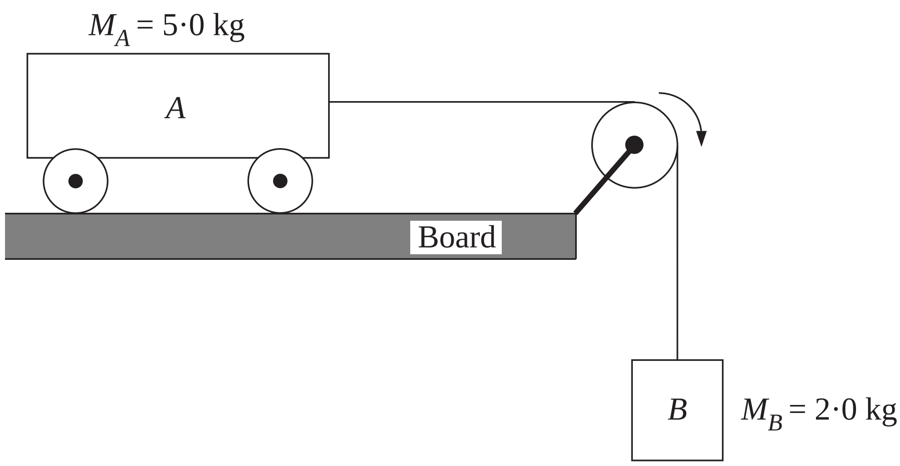
26. A golfer has to hit a ball over a tree, as shown in the diagram. The ball is hit with speed v at an angle θ to the horizontal. Neglect any effect due to the air.



(a) Write equations for the horizontal and vertical components of the displacement of the ball while it is in flight.

(b) The golfer hits the ball with an initial velocity at 30° to the horizontal. Calculate the speed that must be given to the ball for it to just clear the tree.

27. A dynamics trolley A of mass 5·0 kg is placed on a horizontal board. It is connected to block B of mass 2·0 kg by a light, inextensible string over a frictionless pulley as shown in the diagram below.



(a) Assuming no friction force on the trolley, calculate:

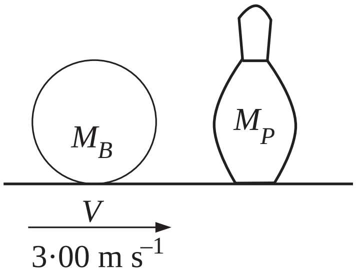
(i) the magnitude of the acceleration of the trolley;

(ii) the tension in the string.

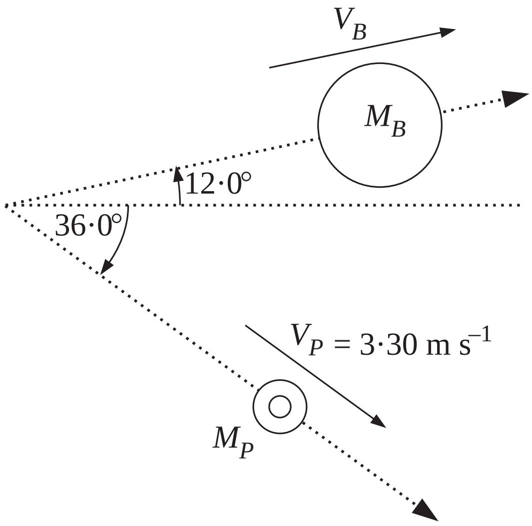
(b) Experiment showed that the actual acceleration of the trolley was $2{\cdot}0\,\mathrm{m\,s^{-2}}$. Calculate the magnitude of the friction force on the trolley.

(c) The trolley is modified to eliminate the effects of friction. The pulley end of the board is now raised so that the board makes an angle θ with the horizontal. Calculate the value of θ so that the trolley remains at rest.

28. In a game of ten-pin bowling, the ball strikes a stationary pin as shown in the diagram below. The ball has a mass M_B of 5·90 kg and a velocity V of 3·00 m s^{-1} just before the collision. Just after the impact, the ball is travelling in a direction inclined at an angle of 12·0° to its initial direction. The pin moves with a velocity V_P of 3·30 m s^{-1} in a direction at an angle of 36·0° to the initial direction of motion of the ball.



Before the impact
(view from the side)



After the impact
(view from above)

(a) Calculate the mass M_P of the pin.

(b) Calculate the speed of the ball V_B immediately after the collision.

(c) Determine if the collision is elastic or inelastic. Show your working.

29. A student measured the potential difference across, and the current through, two circuit elements, *X* and *Y*, and obtained the following data.

ELEMENT *X*

Potential difference (V)	*Current* (A)
1·0	1·0
3·0	2·0
10·0	3·0
20·0	4·0
35·0	5·0

ELEMENT *Y*

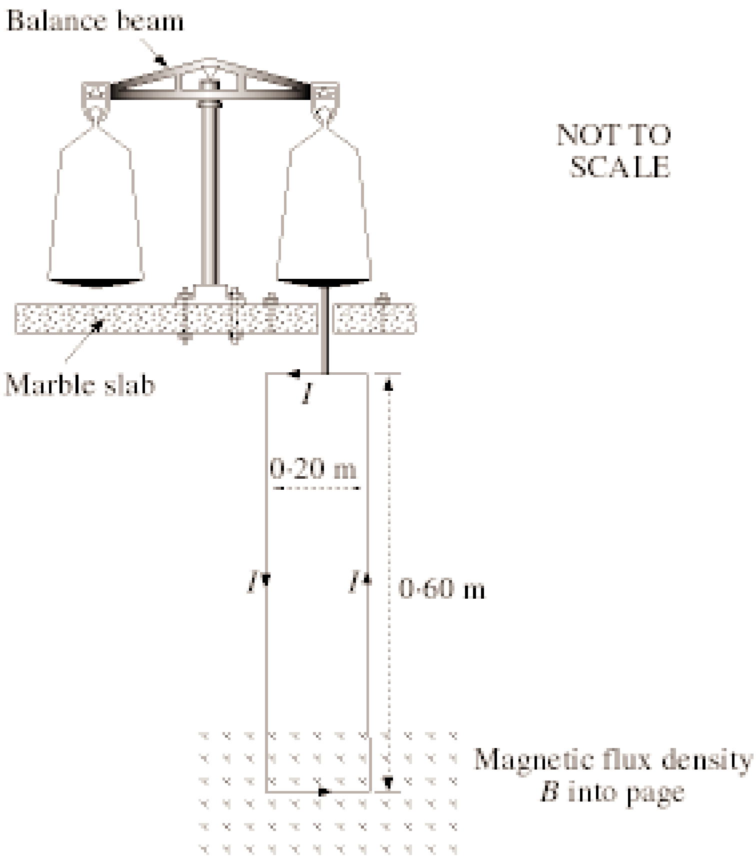
Potential difference (V)	*Current* (A)
5·0	1·0
10·0	2·0
15·0	3·0
20·0	4·0
25·0	5·0

(a) Using the ONE set of axes in your Part C Answer Book, draw curve-of-best-fit graphs of potential difference against current for elements *X* and *Y*.

(b) Does element *X* obey Ohm's law? Give ONE reason for your answer.

(c) Calculate the resistance of element *Y*.

30. An apparatus, shown below, is designed to measure the magnetic flux density B of a magnet.



The rectangle is a coil of 7 turns of width 0·20 m and length 0·60 m. A current I of 0·30 A flows anticlockwise around the loop. Under these conditions the balance is in equilibrium.

(a) What is the direction of the magnetic force on the lower, horizontal section of the loop?

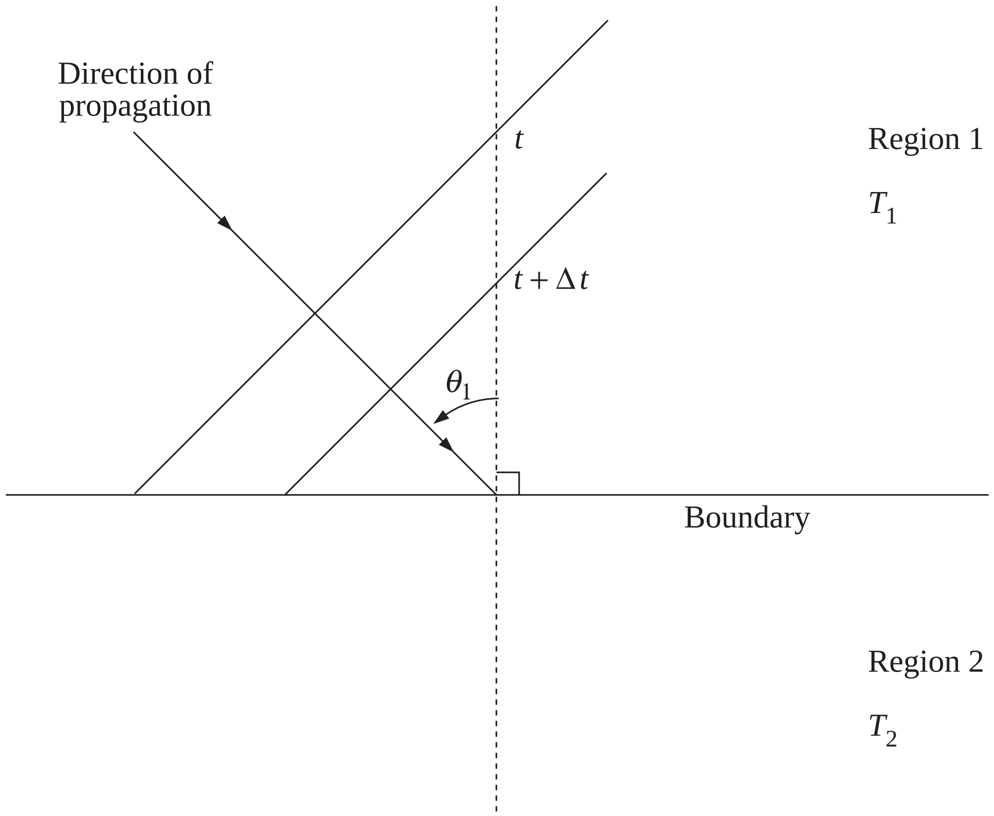
(b) The force on the lower, horizontal section of the loop may be written $F = \alpha B$. Calculate the value of α using the information given above.

(c) The current is reversed so that it now flows clockwise with unchanged magnitude. It is found that an 8·0 gram mass needs to be added to the left pan of the balance to restore equilibrium. Calculate the magnetic flux density B.

31. The speed of sound waves in a gas depends on the square root of the temperature of the gas, that is, $v = k\sqrt{T}$, where k is a constant that depends on the particular gas.

The diagram below shows the boundary between two regions of the atmosphere, labelled 1 and 2. They are at different temperatures T_1 and T_2, where $T_2 > T_1$.

A plane sound-wave is propagating through region 1. The position of its wavefront is shown at two instants of time, Δt apart. The direction of travel of the wave in region 1 makes an angle θ_1 with the normal to the boundary.



(a) In your Part C Answer Book, complete diagram (a) to show the wavefronts and the direction in which the wave propagates through region 2.

(b) As shown on page 7, diagram (b), in your Part C Answer Book, a third region, at temperature T_3, is added beneath region 2 such that $T_3 > T_2 > T_1$. Complete the diagram to show the direction of propagation of the sound in each of regions 2 and 3.

(c) In the atmosphere, temperature decreases as height above the ground increases. This situation can be modelled as many layers, each with different temperatures, with the topmost layer being at the lowest temperature.

It is possible for someone on the ground to see lightning but not hear thunder.

Using a clearly labelled diagram and your result in part (b), explain how it is possible for someone on the ground not to hear the thunder.

SECTION II—ELECTIVES

(25 Marks)

Attempt ONE question.

Each question is worth 25 marks.

Answer each Elective or Half-elective in a SEPARATE Elective Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

QUESTION 32. History of Ideas in Physics (25 marks) **Marks**

If you are attempting this elective, you must do TWO half-electives.

Answer each half-elective in a SEPARATE Elective Answer Book.

A. Half-elective: Gravitation ($12\frac{1}{2}$ marks)

(a) Outline TWO of the reasons for the rejection, by his contemporaries, of the heliocentric model of Aristarchus. **2**

(b) (i) In 1548, Copernicus' book *On the Revolutions of the Heavenly Spheres* was published. **$5\frac{1}{2}$**

What were the spheres referred to in the title?

(ii) In his preface to Copernicus' book, Osiander wrote:

> 'But since for one and the same movement varying hypotheses are proposed from time to time as eccentricity or epicycle for movement of the Sun . . .'

He points out that different mathematical (geometrical) models may reproduce the same motion.

Copernicus did this by switching the origin of the coordinate system from the Earth to the Sun. You can also do this by using different models based on the Earth as origin.

Using the *geocentric system*, show, with the aid of TWO separate diagrams, how the same apparent motion of the Sun may be reproduced by a movement that is:

1. eccentric;

2. epicyclic.

(iii) Brahe summarised his observations in a planetary model that put the planets in orbit about the Sun, with the Sun, in turn, orbiting a stationary Earth. This arrangement predicted phases for Venus.

Name a model in use at Brahe's time that could NOT account for the phases of Venus.

Question 32 A continues on page 27

QUESTION 32. (Continued) **Marks**

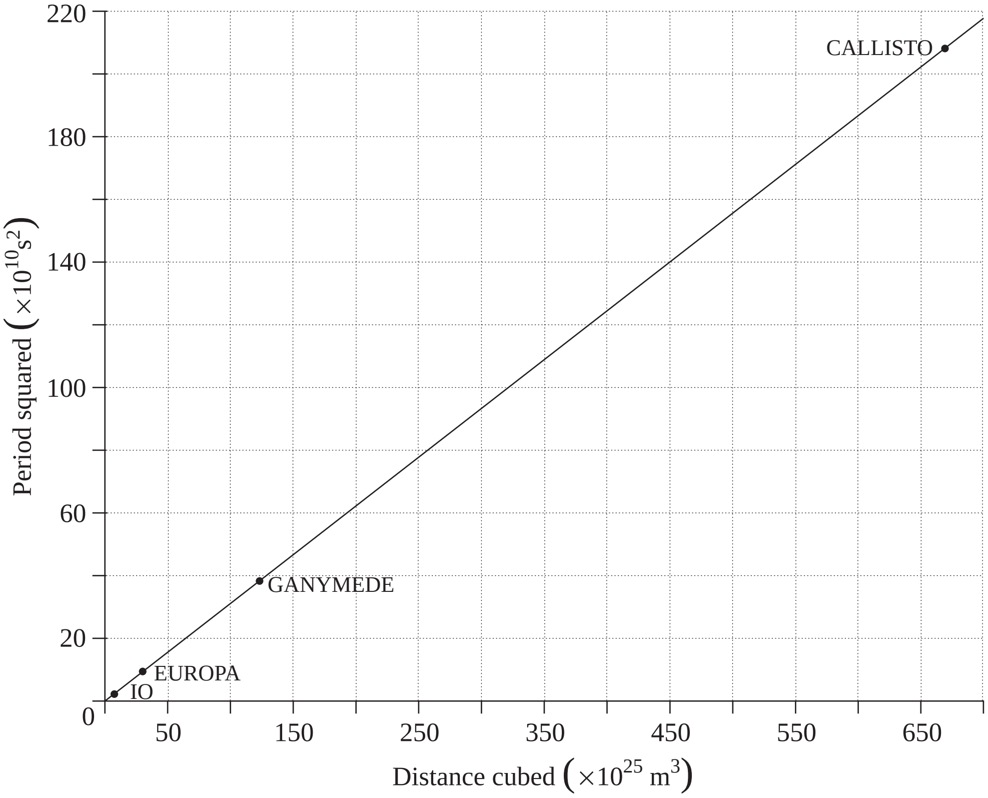
(iv) To confirm the Earth's orbital motion, a particular piece of evidence was sought. This was not observed at the time of Galileo or at the time of Newton.

What was this evidence?

(v) Newton's law of gravitation incorporated all of Kepler's laws in its successful prediction of planetary motions. It also gave a reason, other than mathematical success, for preferring the Sun as the (near) centre of the motions.

What was this reason?

(c) The graph below relates to four moons of Jupiter. Each moon has a period denoted by T and a distance from Jupiter's centre denoted by R. The graph is a plot of the period squared against distance cubed. **5**



(i) What TWO features of the graph show that Kepler's third law applies to the moons of Jupiter?

(ii) When Newton's law of gravitation is combined with Kepler's third law, the equation becomes:

$$T^2 = \frac{4\pi^2}{GM} R^3 .$$

From the graph, determine the mass M of Jupiter.

Question 32 continues on page 28

QUESTION 32. (Continued) **Marks**

Answer this half-elective in a SEPARATE Elective Answer Book.

B. Half-elective: Nature of Light ($12\frac{1}{2}$ marks)

(a) At the beginning of the nineteenth century, the work of Thomas Young challenged some of the existing views about the nature of light, and supported others. **6**

(i) What were the TWO differing models proposed during the seventeenth century to explain the behaviour of light?

(ii) For EACH model in part (i):

1. name ONE seventeenth-century scientist who supported the model;

2. give his explanation of ONE property of light, using the model he supported.

NOTE: It is not necessary to use the same property for each model.

(iii) Which of these models did the work of Young support? Give a brief outline of an observation Young made that supported this model of light.

(b) In the history of ideas about the nature of light, the contributions of Maxwell stand out as being of great significance. State TWO of the properties of light that are accounted for by Maxwell's theory. **2**

(c) (i) In considering the photoelectric effect, explain what is meant by the *work function* of a metal. **$4\frac{1}{2}$**

(ii) Suppose that light at the red end of the visible spectrum has a wavelength of 700 nm, whilst that at the violet end has a wavelength of 400 nm. Sodium metal has a work function of 2·28 eV. Show which, if any, of the above two wavelengths will produce the photoelectric effect in sodium.

Question 32 continues on page 29

QUESTION 32. (Continued) **Marks**

Answer this half-elective in a SEPARATE Elective Answer Book.

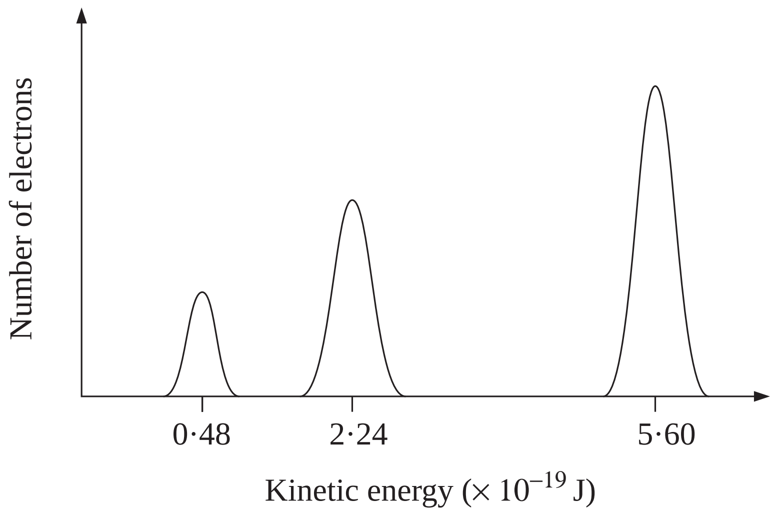
C. Half-elective: Atomic Structure ($12\frac{1}{2}$ marks)

(a) (i) Briefly describe ONE experiment of Lenard and the model of the atom he developed to explain the results. **5**

(ii) Describe ONE difference and ONE similarity between the atomic models of Lenard and Rutherford.

(iii) Describe ONE contribution to our understanding of atomic structure that resulted from charge-to-mass ratio measurements of atomic and subatomic particles.

(b) Electrons, each with an initial kinetic energy close to $5{\cdot}6 \times 10^{-19}$ J, are fired through a gas. The graph below shows how the number of electrons emerging from the gas varies as a function of their kinetic energies. **5**



(i) Assuming that the gas atoms were initially in their ground state (with energy E_1) explain:

1. the reason for the peak at $5{\cdot}60 \times 10^{-19}$ J;

2. the cause of the other two peaks.

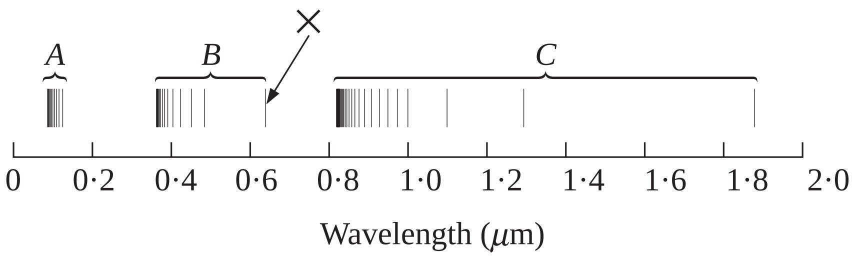
(ii) Sketch a suitable atomic energy-level diagram for the gas.

(iii) Calculate THREE energies of photons emitted by the gas.

Question 32 C continues on page 30

QUESTION 32. (Continued) **Marks**

(c) (i) Part of the spectrum of hydrogen is sketched below. **2 ½**



In your Elective Answer Book, identify the name given to the series of discrete lines labelled *B*.

(ii) An explanation for the appearance of discrete spectral lines was proposed by Neils Bohr. He assumed that the angular momentum of the electron was quantised. Write down ONE other physical parameter of the hydrogen atom that is also quantised.

(iii) The wavelength λ of the lines in the series labelled *B* is given by:

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n^2}\right).$$

Calculate the wavelength of the line marked ✕ in the hydrogen spectrum shown above.

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QUESTION 33. Wave Properties of Light (25 marks) **Marks**

(a) (i) Draw a diagram that shows how Huygens' principle allows us to describe the change in direction of the wavefronts as light passes from air (n_a = 1·0) to glass (n_g = 1·5). **7**

(ii) Use your diagram to derive Snell's law for light.

(iii) A ray of light is incident on the glass surface at an angle of 25° to the normal. What angle does the refracted ray make with the normal?

(b) Light of wavelength 542 nm falls on a double slit. A screen is placed 1·50 m from the slits. First-order bright bands appear on the screen 5·00 cm from the central bright band. **3**

(i) Draw a diagram and use it to explain the formation of the bright bands.

(ii) Calculate the separation of the slits.

(c) A quality camera lens appears bluish-red when illuminated by white light. This is caused by a special coating on the lens. **5**

(i) How does the lens coating produce this effect?

(ii) What is the purpose of this coating?

(iii) For infra-red photography a coated camera lens must transmit infra-red radiation that has a wavelength of 800 nm in air. The coating is 150 nm thick. Determine the optimum refractive index of the coating.

(d) (i) On the Earth, just before sunset on a clear day, the sky overhead has a blue colour, while the Sun has a yellowish-red colour. Explain both these observations. **6**

(ii) Explain the difference between *plane-polarised* light and *unpolarised* light.

(iii) Light leaving the Sun is unpolarised, but scattering in the atmosphere results in partial polarisation of light from the sky. A girl uses a piece of Polaroid sheet to determine the amount of polarisation of the light from a clear, blue sky. Just before sunset, when the Sun is in the west, she scans the sky in a vertical arc from west to east.

Sketch a graph to show the variation in the amount of polarisation that she would determine from her observations. Justify the shape of your graph.

Question 33 continues on page 33

QUESTION 33. (Continued) **Marks**

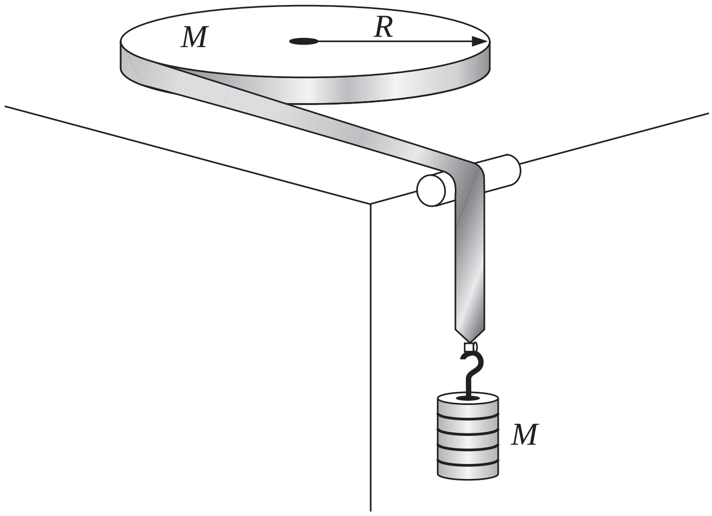
(e) (i) Explain what is meant by the Doppler effect for light. What is observed when the source and the observer are moving towards each other? **4**

(ii) An early Earth satellite had an orbital speed of $7{\cdot}5 \times 10^3$ m s^{-1} and a radio transmitter which gave out a signal at exactly 40 MHz.

An observer found that the received frequency was shifted down by 1·00 kHz. Was the satellite moving towards or away from the observer? Justify your answer.

QUESTION 34. Rotation (25 marks) **Marks**

(a) A horizontally mounted disc forms a turntable on a bench top. The mass of the turntable is 400·0 g and its radius is 15·00 cm. The turntable has a tape wrapped around its perimeter, with the free end of the tape attached to some weights. The weights, in turn, are hung over the edge of a smooth cylinder, accelerating the turntable as they fall. The weights have the same total mass as the turntable. **13**



NOTE: 1. The moment of inertia of a uniform disc, of mass M and radius R, about its axis of symmetry is $\frac{1}{2}MR^2$.

2. The tape does not stretch, does not slip on the turntable, and has negligible mass.

(i) The weights are released from rest. At the instant when they have descended 94·25 cm, the elapsed time is 5·371 s.

Calculate the magnitudes of the following quantities at this instant:

1. the angular displacement of the turntable;
2. the linear acceleration of the weights;
3. the angular acceleration of the turntable;
4. the angular velocity of the turntable;
5. the kinetic energy of the turntable;
6. the torque exerted on the turntable about its axis.

Question 34 continues on page 35

QUESTION 34. (Continued) **Marks**

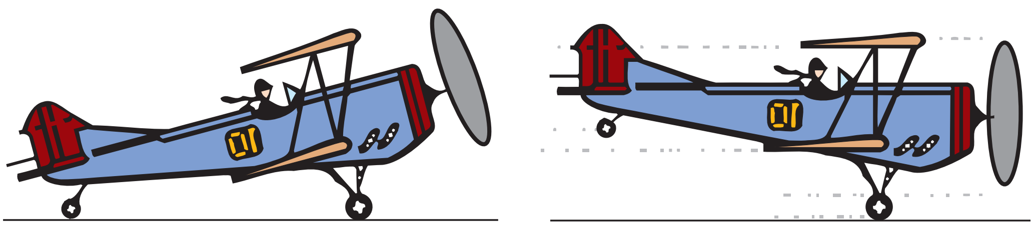
(ii) 1. If the turntable is held fixed, calculate the torque exerted by the weights on the turntable about its axis.

2. Why does this torque exceed that calculated above in part (i) point 6?

(iii) Another disc has the same mass as the turntable but only half the radius of the turntable. Suppose that this disc is placed on the turntable prior to its release.

The disc is placed either with its centre above the centre of the turntable, or with its centre half-way along a radius of the turntable. Without detailed calculations, compare the times for descent of the weights through the same distance in each of these two cases. Justify your answer.

(b) **5**



A light, propeller-driven aircraft sits on the runway supported by three wheels as shown above. The propeller rotates clockwise as viewed by the pilot.

As the plane gathers speed down the runway to take off, the tail rises so that the fuselage becomes horizontal. As the tail rises, the fuselage swings sideways.

(i) In a view from above, draw labelled vectors showing the initial angular momentum of the propeller and the direction of the torque exerted by the rising tail on the propeller.

(ii) Draw a vector diagram showing the initial angular momentum of the propeller and the change in angular momentum generated by the torque. Complete the vector diagram and suggest how the sideways swing of the tail of the aircraft comes about.

Question 34 continues on page 36

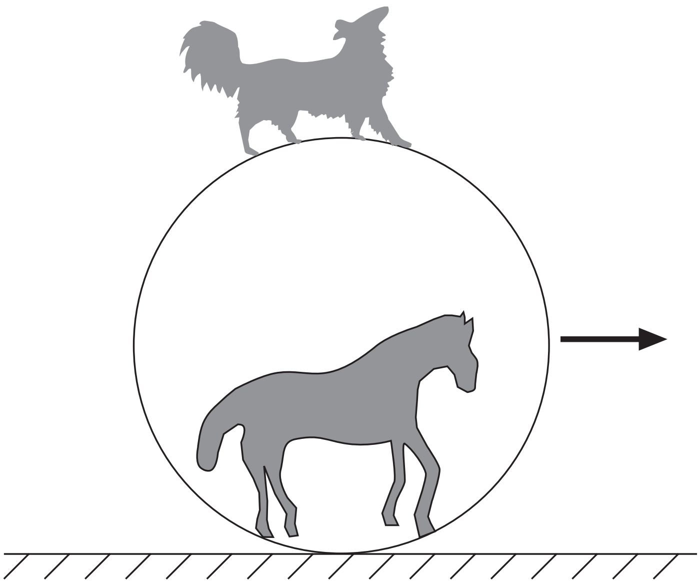
QUESTION 34. (Continued) **Marks**

(c) A rotating star cools and contracts. Its mass remains the same. **4**

(i) What happens to the star's rate of spin as it contracts? Explain your answer.

(ii) Is the rotational kinetic energy of the star conserved during this contraction? Explain your answer.

(d) A dog and a pony are both walking around the circumference of a hoop as shown in the picture below. The hoop has slats to enable the dog and pony to walk on it. The hoop is rolling forward, without slipping, at a speed of $0{\cdot}8\ \text{m s}^{-1}$. As the hoop rolls forward, the pony and dog walk to maintain their positions at the bottom and top respectively. **3**



(i) What is the velocity of the dog relative to the ground?

(ii) What is the velocity of the dog relative to the slat on the hoop which is immediately below the dog? Justify your answer.

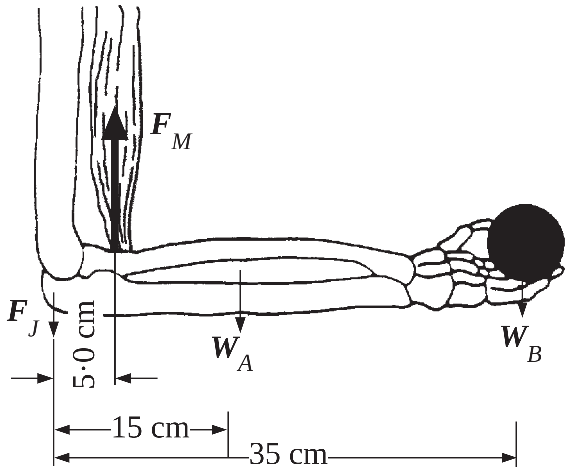
QUESTION 35. Physics in Technology (25 marks) **Marks**

If you are attempting this elective, you must do TWO half-electives.

Answer this half-elective in a SEPARATE Elective Answer Book.

A. Half-elective: Engineering Materials and Structures ($12\frac{1}{2}$ marks)

(a) Below is a diagram of a human arm. **2**



The forearm is lifted by the biceps muscle, which is attached approximately 5·0 cm from the joint.

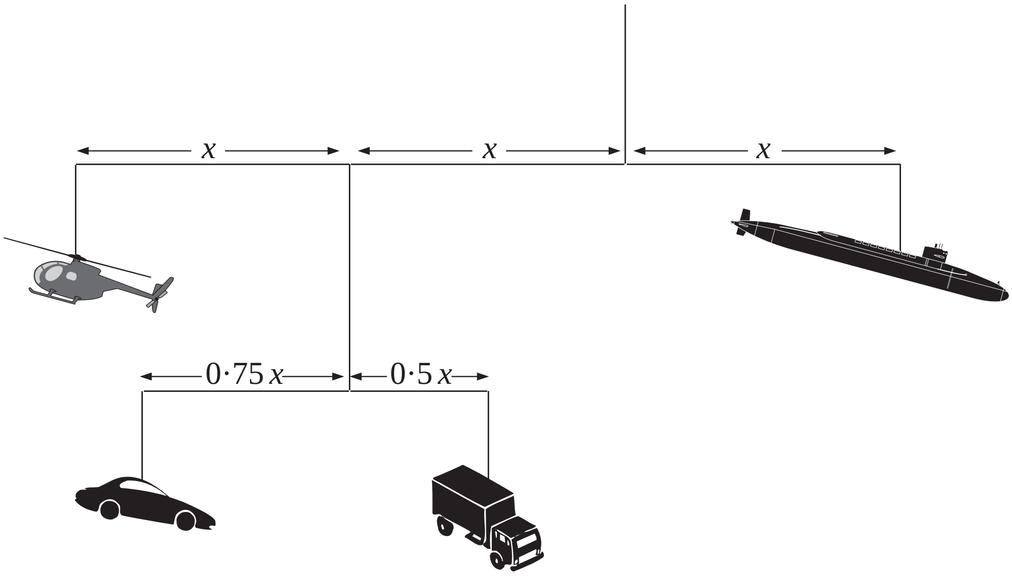
Champion athletes are often found to have muscle attachments farther from the joint than the average person (e.g. 5·5 cm).

Why does this small change in the muscle attachment position give an advantage when lifting or throwing? Explain clearly, referring to the above diagram.

Question 35 A continues on page 38

QUESTION 35. (Continued) **Marks**

(b) A child's mobile hangs in static equilibrium. **3**



The weight of the helicopter is W.

The weight of the car is $\dfrac{W}{4}$.

(i) What is the weight of the truck?

(ii) What is the weight of the submarine?

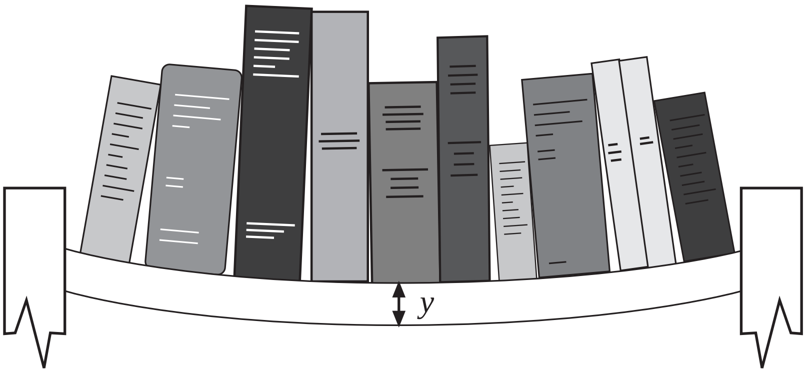
(iii) What is the horizontal location of the centre of mass of the mobile?

(c) A piece of human thigh bone 15·0 cm long stretched by 0·50 mm when a load of 1800 N was applied. Young's modulus for human bone is 2×10^{10} N m^{-2}. What was the cross-sectional area of the bone? Show your working. **$1\frac{1}{2}$**

Question 35 A continues on page 39

QUESTION 35. (Continued) **Marks**

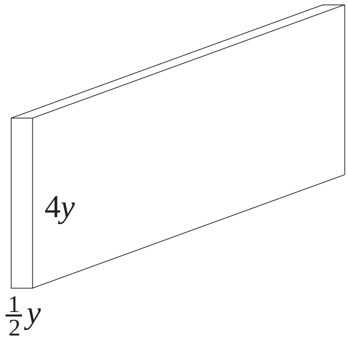
(d) **6**



A library shelf of thickness y is supported at its ends. It sags under the weight of the books it carries.

(i) Draw a labelled diagram showing how the stress is distributed vertically through a cross-section of the shelf.

(ii) You are given a length of timber to reduce the sag. Its width is $4y$ and its thickness is $\frac{1}{2}y$, as shown below.



You cut the timber to the same length as the shelf. Justifying your answers in each case, explain:

1. where you should position the timber length;

2. how you should orient the timber length to reduce the sag to a minimum.

Question 35 continues on page 40

QUESTION 35. (Continued) **Marks**

Answer this half-elective in a SEPARATE Elective Answer Book.

B. Half-elective: Optical Instruments ($12\frac{1}{2}$ marks)

(a) (i) Draw a labelled ray diagram showing how an image of a distant object is formed by a Cassegrain telescope. **3**

(ii) List TWO advantages of the Cassegrain telescope compared with other reflecting telescopes.

(b) Light is reflected by flat mirrors such as a rear-view mirror in a car. **5**

(i) Why do some vehicles have lettering on their fronts transposed as shown in the following example?

(ii) In a simpler example, a driver is followed by a vehicle with the panel below painted on its front.

Draw a ray diagram to show how the driver will see THIS panel in the rear-view mirror.

(iii) Light may also be reflected by a triangular prism. State TWO advantages of using triangular prisms in prismatic binoculars.

(c) (i) Define the term *refractive index*. **$2\frac{1}{2}$**

(ii) Draw two separate, labelled diagrams showing how a convex lens can produce an image that is:

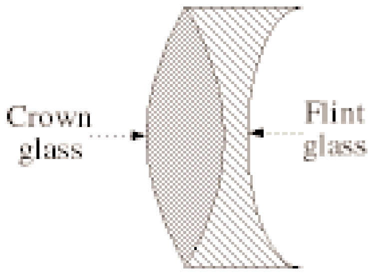
1. real, inverted and magnified;

2. virtual, upright and magnified.

Question 35 B continues on page 41

QUESTION 35. (Continued) **Marks**

(d) An achromatic doublet is often used to correct chromatic aberration. The sketch below shows an achromatic doublet made from a strongly-converging, crown-glass lens and a less-strongly-diverging, flint-glass lens. **2**



Explain how chromatic aberration is reduced by the use of these two lenses.

Question 35 continues on page 42

QUESTION 35. (Continued) **Marks**

Answer this half-elective in a SEPARATE Elective Answer Book.

C. Half-elective: Transformation of Energy ($12\frac{1}{2}$ marks)

(a) A low-voltage set of Christmas lights operates through a transformer. There are 20 lights, each of which consumes 0·5 W. The transformer has an efficiency of 70%. **4**

(i) What is the power consumption of the transformer?

(ii) The lights are used from 7 pm to midnight on the twelve days before Christmas.

1. How much energy will be used?

2. If electricity costs 13·5 cents per kilowatt hour, what will be the cost of using the lights?

(iii) What is the reason for the difference between the energy supplied to the transformer and the energy used by the lights?

(b) Most electrical power stations use either fossil fuels or nuclear fission to generate electricity. **$5\frac{1}{2}$**

(i) In the process of burning fossil fuels, what energy transformation occurs?

(ii) State the source of energy in nuclear fission.

(iii) Describe a problem that is shared by both fossil-fuel and nuclear-fission power stations in their conversion of energy.

(iv) Describe ONE problem that fossil-fuel power stations have that nuclear-fission stations do not have.

(v) Describe ONE problem that nuclear-fission power stations have that fossil-fuel stations do not have.

Question 35 C continues on page 43

QUESTION 35. (Continued) **Marks**

(c) Before the time of James Joule, heat was not thought to be a form of energy. Joule set out to show experimentally that heat was, in fact, a form of energy. He did this by measuring, in a variety of ways, a quantity called the *mechanical equivalent of heat*, and showed that it always had the same value. **3**

The mechanical equivalent of heat can be found by measuring mechanical energy in joules and comparing it with heat energy measured in calories.

The unit of heat called the calorie is defined as the amount of heat needed to raise the temperature of 1 gram of water by 1 Celsius degree.

The following figures approximate those obtained by Joule in one of his paddle-wheel experiments. In those experiments, the mechanical energy released by falling weights was converted into heat energy by stirring water in a calorimeter with an arrangement of paddles.

Total mass allowed to fall	26 kg
Height of fall	1·6 m
Number of descents	20
Equivalent mass of water	6·3 kg
Rise in temperature	0·30°C

Calculate:

(i) the amount of mechanical work done, in joules;

(ii) the amount of heat energy supplied to the water, in calories;

(iii) the mechanical equivalent of heat, in joules per calorie, determined from this experiment.

QUESTION 36. Astronomy (25 marks) **Marks**

(a) (i) In the Elective Answer Book, sketch a Hertzsprung–Russell diagram for the stars found in the spiral arms of our galaxy. On the diagram, label the axes, the main sequence, red-giant and white-dwarf regions. **5**

(ii) Name ONE alternative characteristic that could be used to label the horizontal axis.

(b) The Hipparcos satellite (launched in 1989) has measured the distances to more than a million stars. As a result, the distance to the stars in the Pleiades cluster has been revised from 424 light years to 378 light years. **5**

Explain what effect this revision has on:

(i) the apparent magnitudes of these stars;

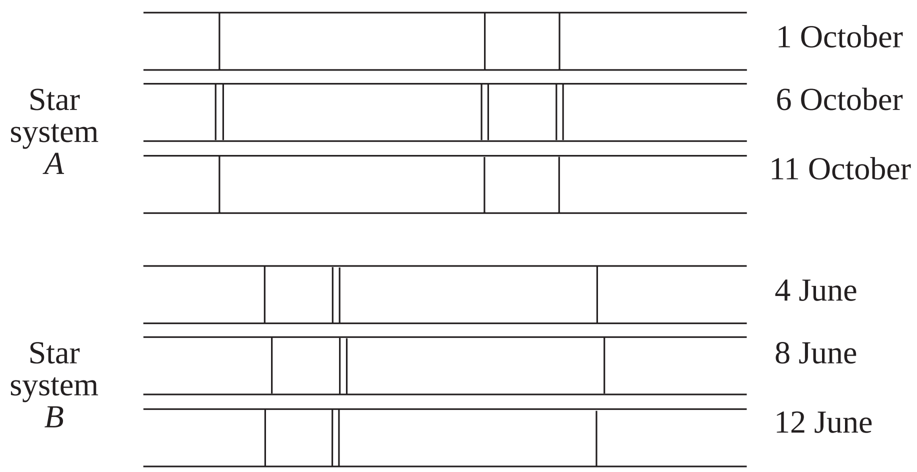
(ii) the absolute magnitudes of these stars.

Recent measurements of the δ – Cepheid variable show that it may be up to 10% farther away than previously thought.

(iii) Discuss the effect this observation has on the estimated mass of δ – Cepheid.

(iv) What implications does this have for the estimated age of globular clusters and galaxies containing Cepheids?

(c) The diagrams below show observations of the spectra of two different star systems, *A* and *B*. **5**



Explain why the spectra change during the periods shown for:

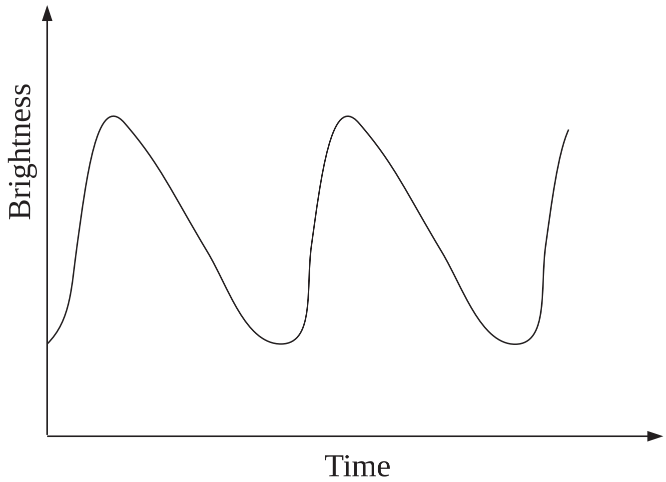
(i) star system *A*;

(ii) star system *B*.

Question 36 continues on page 45

QUESTION 36. (Continued) **Marks**

(d) **4**



It is known that a Cepheid star expands and contracts in a regular pattern. The diagram above shows the observed light curve of a Cepheid star.

(i) Describe the reasons for the expansion and contraction.

(ii) Describe how the expansion and contraction of a Cepheid star are related to its brightness.

(iii) Name ONE other physical characteristic of Cepheid stars, apart from radius, density and brightness, that you would expect to vary in a regular pattern.

(e) Using the Hubble Space Telescope, astronomers have discovered a new star, called the Pistol star, in our galaxy. This star seems to have a luminosity about 10 million times that of our Sun. **6**

Discuss:

(i) the likely mass of this star;

(ii) the likely age of this star;

(iii) a possible final state of this star.

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PHYSICS DATA SHEET

Numerical values of several constants

Charge on the electron, q_e	$-1{\cdot}602 \times 10^{-19}$ C
Mass of electron, m_e	$9{\cdot}109 \times 10^{-31}$ kg
Mass of neutron, m_n	$1{\cdot}675 \times 10^{-27}$ kg
Mass of proton, m_p	$1{\cdot}673 \times 10^{-27}$ kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	$9{\cdot}8$ m s^{-2}
Speed of light, c	$3{\cdot}00 \times 10^{8}$ m s^{-1}
Magnetic force constant, $\left(k \equiv \dfrac{\mu_0}{2\pi}\right)$	2×10^{-7} N A^{-2}
Universal gravitational constant, G	$6{\cdot}67 \times 10^{-11}$ N m^2 kg^{-2}
Mass of Earth	$6{\cdot}0 \times 10^{24}$ kg
Planck's constant, h	$6{\cdot}626 \times 10^{-34}$ J s
Rydberg's constant, R_H	$1{\cdot}097 \times 10^{7}$ m^{-1}
Atomic mass unit, u	$1{\cdot}661 \times 10^{-27}$ kg $931{\cdot}5$ MeV/c^2
1 eV	$1{\cdot}602 \times 10^{-19}$ J
Density of water, ρ	$1{\cdot}00 \times 10^{3}$ kg m^{-3}
Specific heat capacity of water	$4{\cdot}18 \times 10^{3}$ J kg^{-1} K^{-1}

PERIODIC TABLE

KEY

Atomic Number	79	Symbol of element
Atomic Mass	Au 197·0	
	Gold	Name of element

				1 H 1·008 Hydrogen													2 He 4·003 Helium
3 Li 6·941 Lithium	4 Be 9·012 Beryllium											5 B 10·81 Boron	6 C 12·01 Carbon	7 N 14·01 Nitrogen	8 O 16·00 Oxygen	9 F 19·00 Fluorine	10 Ne 20·18 Neon
11 Na 22·99 Sodium	12 Mg 24·31 Magnesium											13 Al 26·98 Aluminium	14 Si 28·09 Silicon	15 P 30·97 Phosphorus	16 S 32·07 Sulfur	17 Cl 35·45 Chlorine	18 Ar 39·95 Argon
19 K 39·10 Potassium	20 Ca 40·08 Calcium	21 Sc 44·96 Scandium	22 Ti 47·88 Titanium	23 V 50·94 Vanadium	24 Cr 52·00 Chromium	25 Mn 54·94 Manganese	26 Fe 55·85 Iron	27 Co 58·93 Cobalt	28 Ni 58·69 Nickel	29 Cu 63·55 Copper	30 Zn 65·39 Zinc	31 Ga 69·72 Gallium	32 Ge 72·59 Germanium	33 As 74·92 Arsenic	34 Se 78·96 Selenium	35 Br 79·90 Bromine	36 Kr 83·80 Krypton
37 Rb 85·47 Rubidium	38 Sr 87·62 Strontium	39 Y 88·91 Yttrium	40 Zr 91·22 Zirconium	41 Nb 92·91 Niobium	42 Mo 95·94 Molybdenum	43 Tc 98·91 Technetium	44 Ru 101·1 Ruthenium	45 Rh 102·9 Rhodium	46 Pd 106·4 Palladium	47 Ag 107·9 Silver	48 Cd 112·4 Cadmium	49 In 114·8 Indium	50 Sn 118·7 Tin	51 Sb 121·8 Antimony	52 Te 127·6 Tellurium	53 I 126·9 Iodine	54 Xe 131·3 Xenon
55 Cs 132·9 Cesium	56 Ba 137·3 Barium	57 La 138·9 Lanthanum	72 Hf 178·5 Hafnium	73 Ta 180·9 Tantalum	74 W 183·9 Tungsten	75 Re 186·2 Rhenium	76 Os 190·2 Osmium	77 Ir 192·2 Iridium	78 Pt 195·1 Platinum	79 Au 197·0 Gold	80 Hg 200·6 Mercury	81 Tl 204·4 Thallium	82 Pb 207·2 Lead	83 Bi 209·0 Bismuth	84 Po — Polonium	85 At — Astatine	86 Rn — Radon
87 Fr — Francium	88 Ra 226·0 Radium	89 Ac — Actinium	104	105	106												

58 Ce 140·1 Cerium	59 Pr 140·9 Praseodymium	60 Nd 144·2 Neodymium	61 Pm — Promethium	62 Sm 150·4 Samarium	63 Eu 152·0 Europium	64 Gd 157·3 Gadolinium	65 Tb 158·9 Terbium	66 Dy 162·5 Dysprosium	67 Ho 164·9 Holmium	68 Er 167·3 Erbium	69 Tm 168·9 Thulium	70 Yb 173·0 Ytterbium	71 Lu 175·0 Lutetium
90 Th 232·0 Thorium	91 Pa 231·0 Protactinium	92 U 238·0 Uranium	93 Np 237·0 Neptunium	94 Pu — Plutonium	95 Am — Americium	96 Cm — Curium	97 Bk — Berkelium	98 Cf — Californium	99 Es — Einsteinium	100 Fm — Fermium	101 Md — Mendelevium	102 No — Nobelium	103 Lr — Lawrencium

This sheet should be REMOVED for your convenience.