BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
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. Mark your answers 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 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.

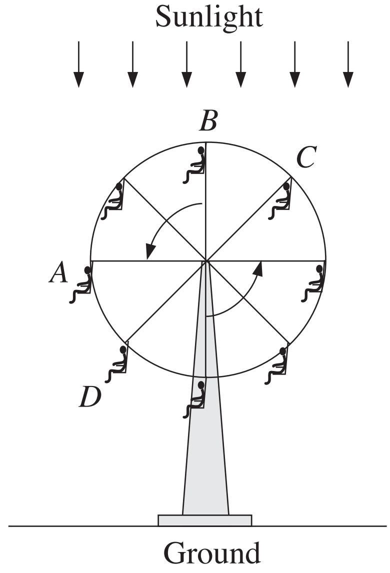
Mark your answers in pencil on the Answer Sheet provided.

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

1. An object is undergoing uniform circular motion. Which of the following alternatives best describes the object's motion?

	Displacement	*Instantaneous speed*	*Instantaneous velocity*
(A)	Constant	Changing	Changing
(B)	Changing	Changing	Constant
(C)	Changing	Constant	Changing
(D)	Constant	Constant	Changing

2 . At midday the Sun shines directly down onto a Ferris-wheel ride as shown below. The children on the ride are undergoing uniform circular motion. Their shadows appear on the ground directly beneath the Ferris wheel.



At the instant shown above, the child whose shadow has the greatest linear speed is

(A) *A*.

(B) *B*.

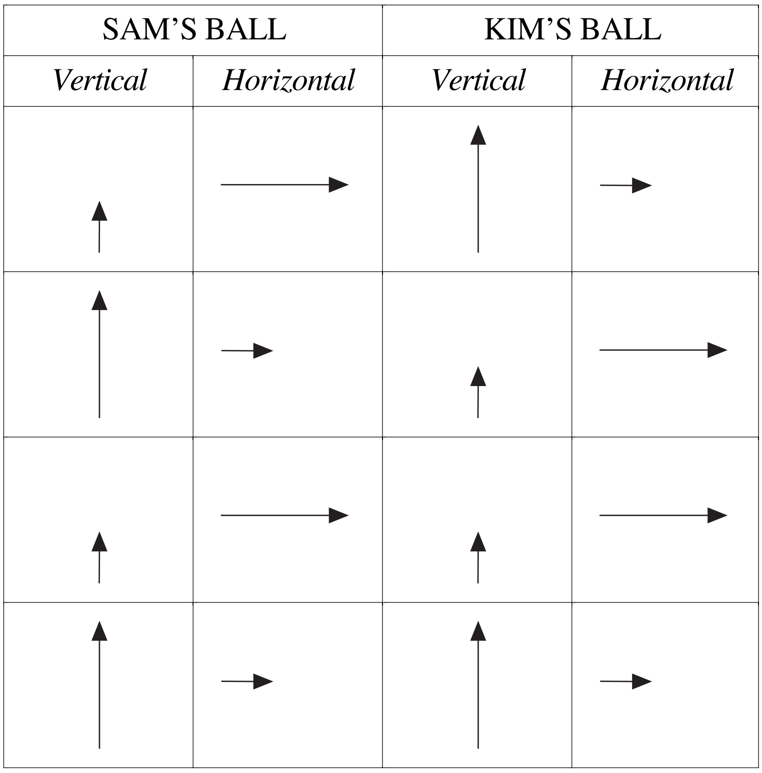
(C) *C*.

(D) *D*.

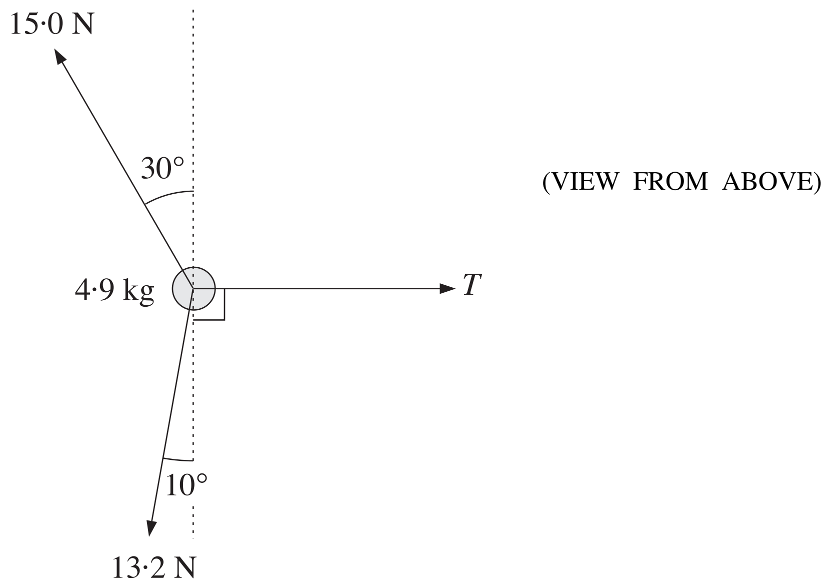
3 . Two golfers, Sam and Kim, used different golf clubs to hit identical golf balls from the same place. Sam's ball went higher than Kim's ball, but both golf balls first hit the ground 100 m away.

Which set of vectors below best represents the horizontal and vertical components of the *initial velocity* of the two balls?

(A)
(B)
(C)
(D)



4. An object of mass 4·9 kg is on a horizontal frictionless surface. It is held in equilibrium by three horizontal strings with different tensions, as shown in the diagram below. The diagram is not drawn to scale.



What is the value of the tension, T?

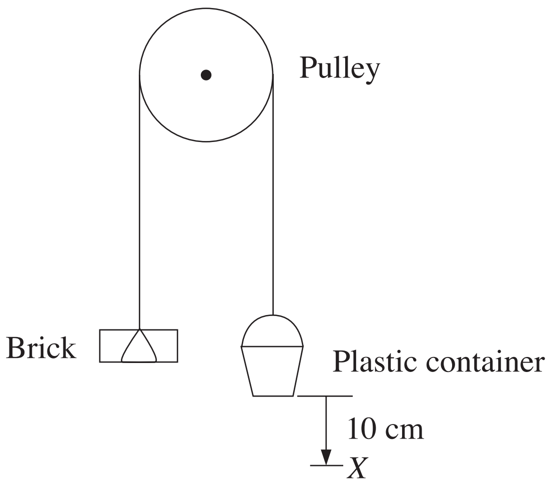
(A) 2·0 N

(B) 5·3 N

(C) 9·8 N

(D) 26 N

5. Some students set up the equipment shown below. They added sand to the plastic container until the weight of the container and its contents exactly balanced the weight of the brick. The string used had negligible mass.



One of the students then moved the plastic container 10 cm downward to position *X*, held it steady, and released it. When the container was released it

(A) moved slowly back to its original position.

(B) started to move downward.

(C) oscillated up and down several times before stopping at its original position.

(D) remained at position *X*.

6 . Figure 1 below shows a railway carriage rounding a curve in a level track. The wheels of the carriage are shaped so that they sit on the rails as shown in Figure 2.

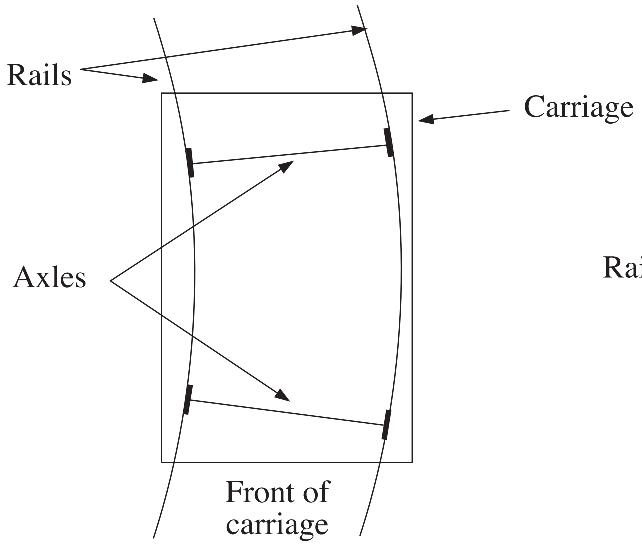


FIG. 1. VIEW FROM ABOVE

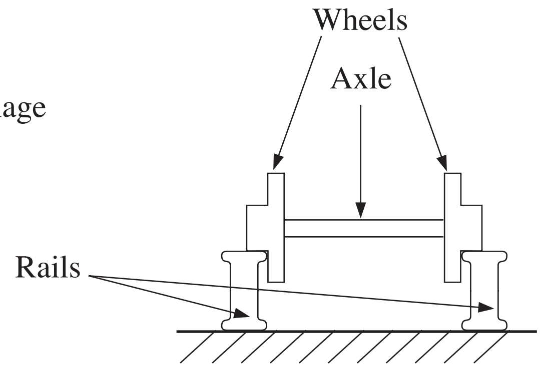
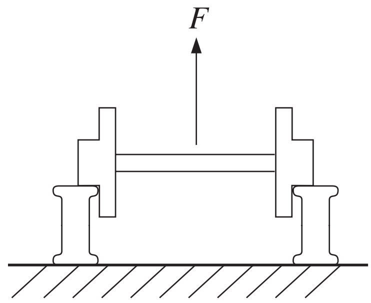


FIG. 2. VIEW FROM THE FRONT

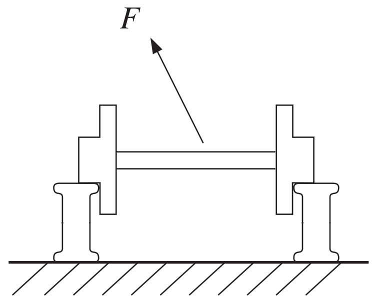
Which alternative below shows the direction of the force F exerted *on the wheels by the track* as the carriage rounds the curve?

(A)



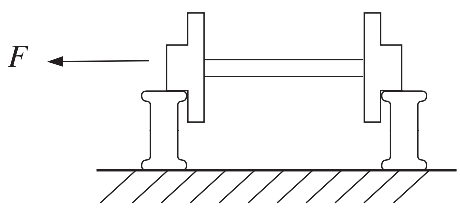
VIEW FROM THE FRONT

(B)



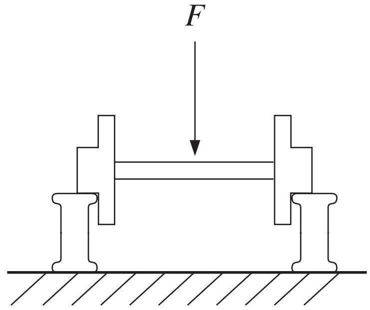
VIEW FROM THE FRONT

(C)



VIEW FROM THE FRONT

(D)



VIEW FROM THE FRONT

7 . A moving ball of mass $2M$ collides with a stationary ball of mass M. Figure 1 shows the balls and their motions just before the collision. Figure 2 shows the balls and their motions just after the collision.

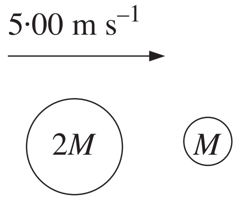


FIG. 1

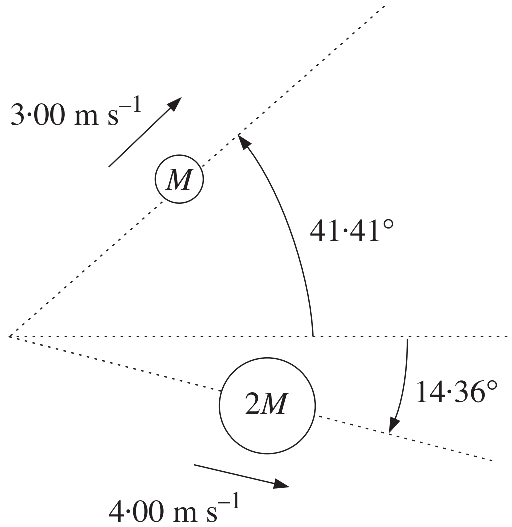


FIG. 2

Which statement correctly describes the collision?

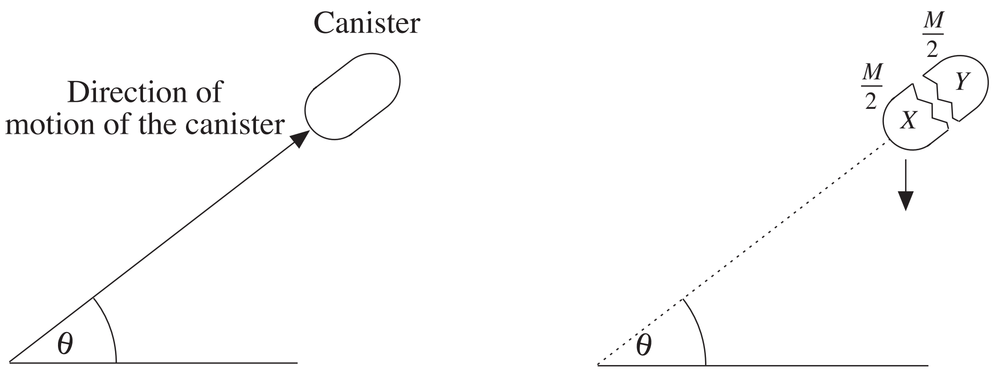
(A) Momentum is conserved and the collision is elastic.

(B) Momentum is not conserved and the collision is elastic.

(C) Momentum is not conserved and the collision is inelastic.

(D) Momentum is conserved and the collision is inelastic.

8 . This question refers to the diagram below.



Just before the canister explodes *Just after the canister explodes*

A firework canister with mass M and speed V, is travelling upward at an angle θ to the *horizontal* Earth's surface. It explodes into two fragments of equal mass. One fragment, X, is observed to fall vertically downward starting from rest. The upward vertical component of the velocity of the other fragment, Y, is

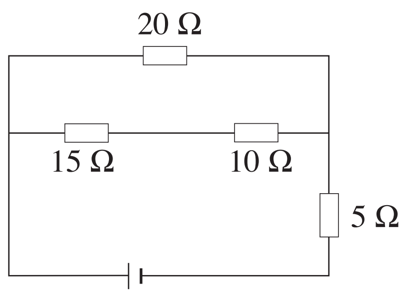
(A) $2V\sin\theta$.

(B) $2V$.

(C) $V\sin\theta$.

(D) V.

9 . This question refers to the following circuit diagram.



The value of the total resistance of this circuit is closest to

(A) 9·6 Ω.

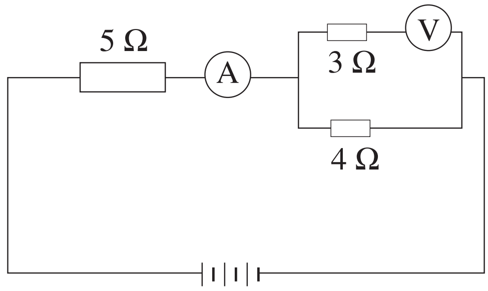
(B) 12 Ω.

(C) 16 Ω.

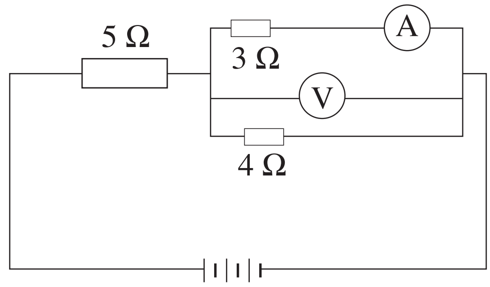
(D) 50 Ω.

10. Which of the following diagrams is correctly wired to *measure* both the current through the 3-ohm resistor and the voltage across it?

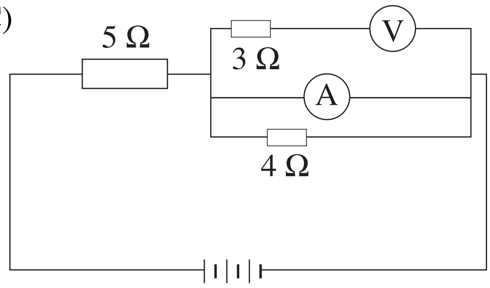
(A)



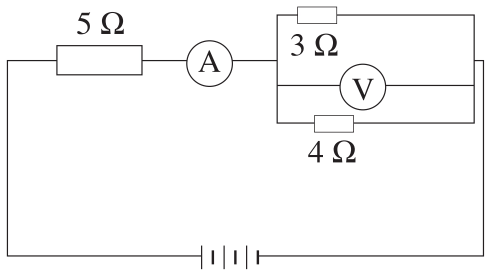
(B)



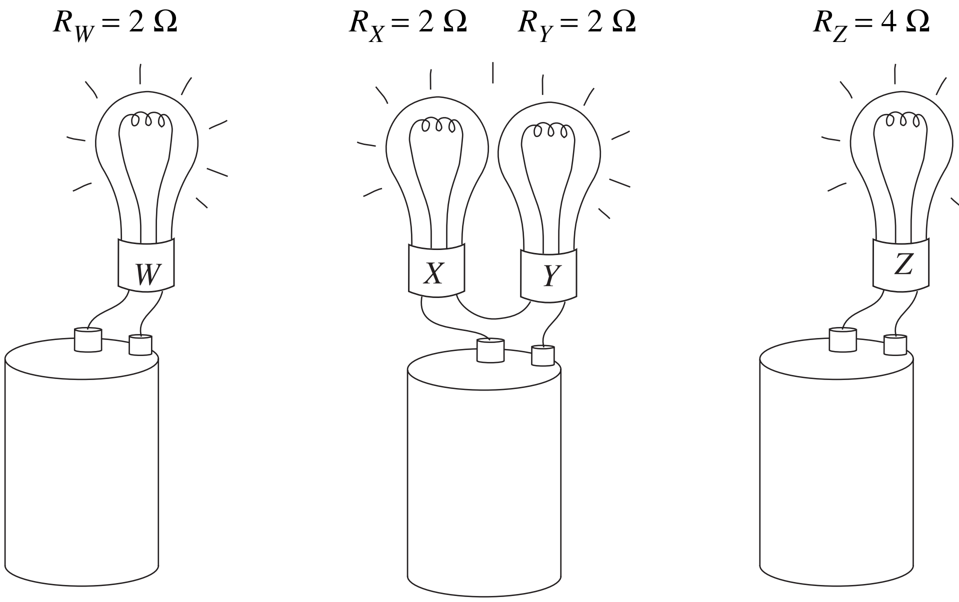
(C)



(D)



11. In each circuit below, the batteries are identical and the resistances of the bulbs W, X, Y, and Z, are as shown.



Which of the following statements about the bulbs is correct?

(A) *W* and *X* are equally bright, and *Z* is less bright.

(B) *W* is brighter than *X*, and *X* is brighter than *Z*.

(C) *W* is brighter than *Z*, and *Z* is brighter than *Y*.

(D) All are equally bright.

12. A circular coil of wire with diameter 5·0 cm is placed so that its plane is at right angles to a magnetic field of flux density $3{\cdot}0 \times 10^{-3}$ T. The coil is then rotated through 90° so that its plane is parallel to the magnetic field. What is the magnitude of the change of magnetic flux through the coil due to this rotation?

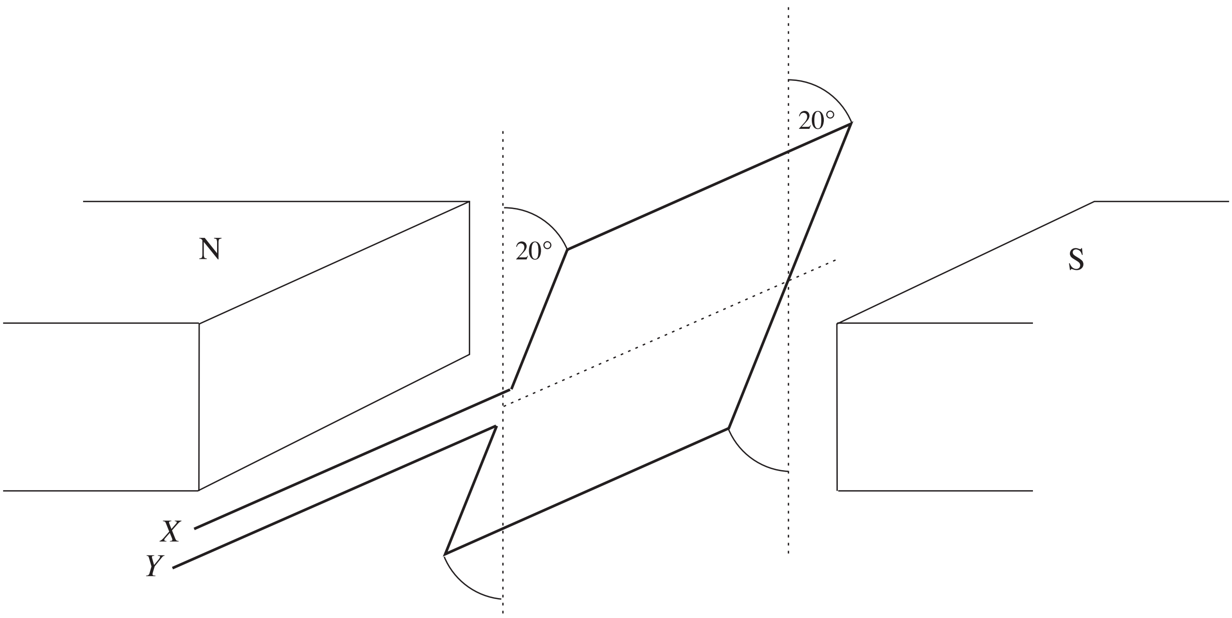
(A) $5{\cdot}9 \times 10^{-6}$ Wb

(B) $1{\cdot}2 \times 10^{-5}$ Wb

(C) $2{\cdot}4 \times 10^{-5}$ Wb

(D) $4{\cdot}7 \times 10^{-5}$ Wb

13. A coil of wire that is free to spin is placed between two magnets as shown in the diagram below.



X is connected to the positive terminal of a power supply, and *Y* is connected to the negative terminal. The coil is set in the position shown and viewed from the front near *X* and *Y*. Which of the following will occur when the power supply is turned on?

(A) The coil will rotate continuously in an anticlockwise direction.

(B) The coil will rotate continuously in a clockwise direction.

(C) The coil will rotate anticlockwise and stop 20° from where it started.

(D) The coil will rotate clockwise and stop 160° from where it started.

14. A 1·0 m long pipe, open at both ends, resonates with a tuning fork of frequency 680 Hz. Given that the speed of sound in air is 340 m s^{-1}, which harmonic does this resonance represent?

(A) 1st

(B) 2nd

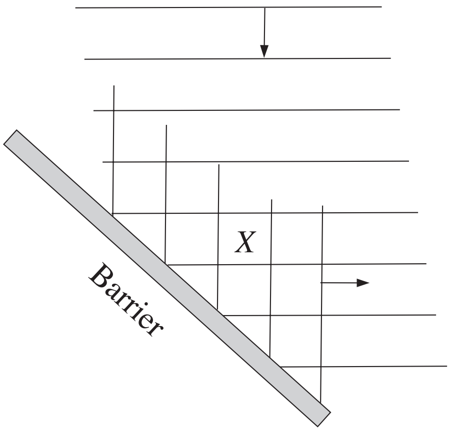
(C) 3rd

(D) 4th

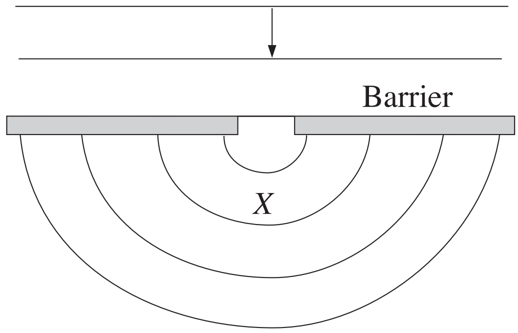
15. Using a ripple tank, a student carries out four demonstrations on water-wave behaviour. The frequencies and amplitudes of the waves created for the demonstrations are identical.

The diagrams below represent only the crests of the wave patterns observed at a given time during the four demonstrations. In which demonstration would the water at the point *X* be found to vibrate with the greatest amplitude?

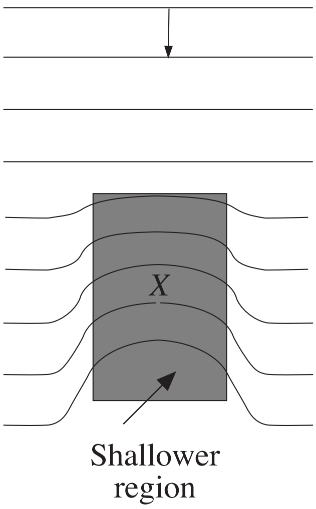
(A)



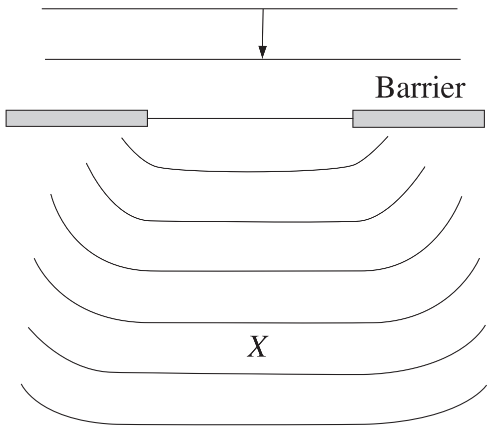
(B)



(C)



(D)



PART B

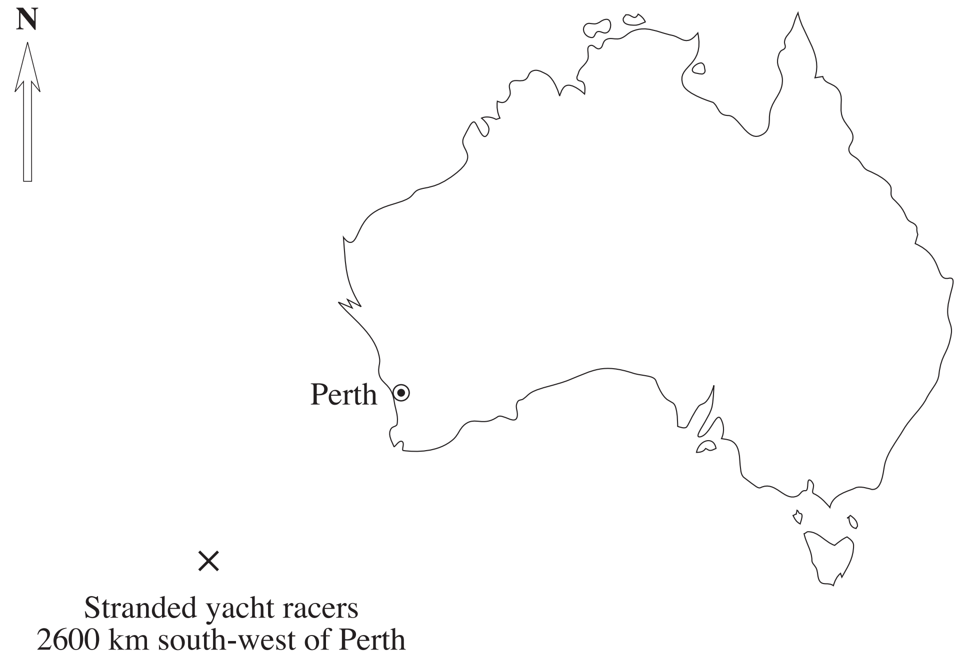
Questions 16–25 are worth 3 marks each.

Answer this Part in the Part B Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

16. Two yacht racers were rescued in the Southern Ocean. It was reported that they were 2600 km south-west of Perth. The naval ship that rescued the racers took 72 hours to travel from the rescue site directly back to Perth.

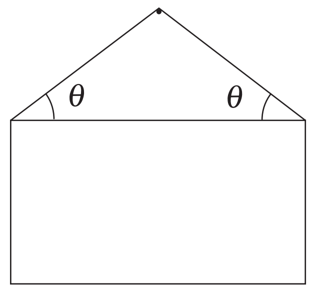


Suppose there was an ocean current of 2·0 km h^{-1} from the west throughout the return trip.

(a) Using a scale of 1·0 cm = 5 km h^{-1}, draw a vector diagram showing the direction in which the ship should head to return *direct* to Perth.

(b) What would be the easterly component of the ship's velocity through the water?

17. A picture is suspended by a single piece of wire that hangs over a hook in a wall. The wire makes an angle θ with the horizontal edge of the frame as shown below.



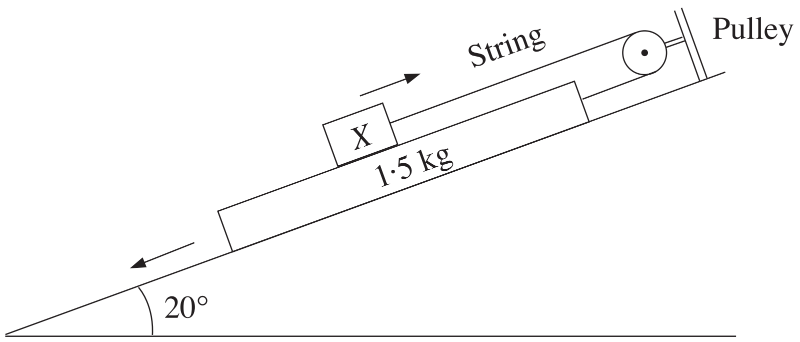
(a) A vector representing the weight of the picture is provided in your Answer Book. Complete the vector diagram of the forces that maintain the picture in equilibrium.

(b) Suppose that the wire is significantly shortened.

(i) Describe what will happen to the tension in the wire.

(ii) Complete the second vector diagram in your Answer Book to show the way the tension would change.

18. The apparatus shown below is allowed to move without friction. The pulley has negligible mass, and the string is inextensible. The 1·5 kg mass accelerates down the slope at 1·2 m s^{-2}. The other mass, X, slides upward along the top surface of the 1·5 kg mass.

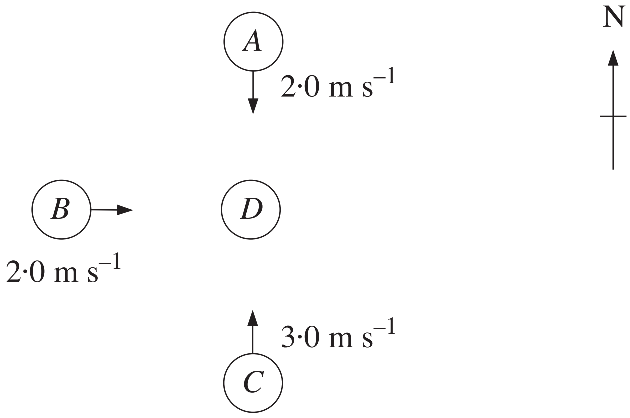


(a) What is the magnitude of the net force on the 1·5 kg mass?

(b) What is the tension in the string?

(c) What is the mass of X?

19. Four identical objects *A*, *B*, *C*, and *D*, each of mass 1·0 kg, collided simultaneously and moved off as one on a smooth horizontal surface. *D* was stationary before the collision. *A*, *B*, and *C* were released from the positions, and with the velocities, shown below. (The diagram is not to scale.)



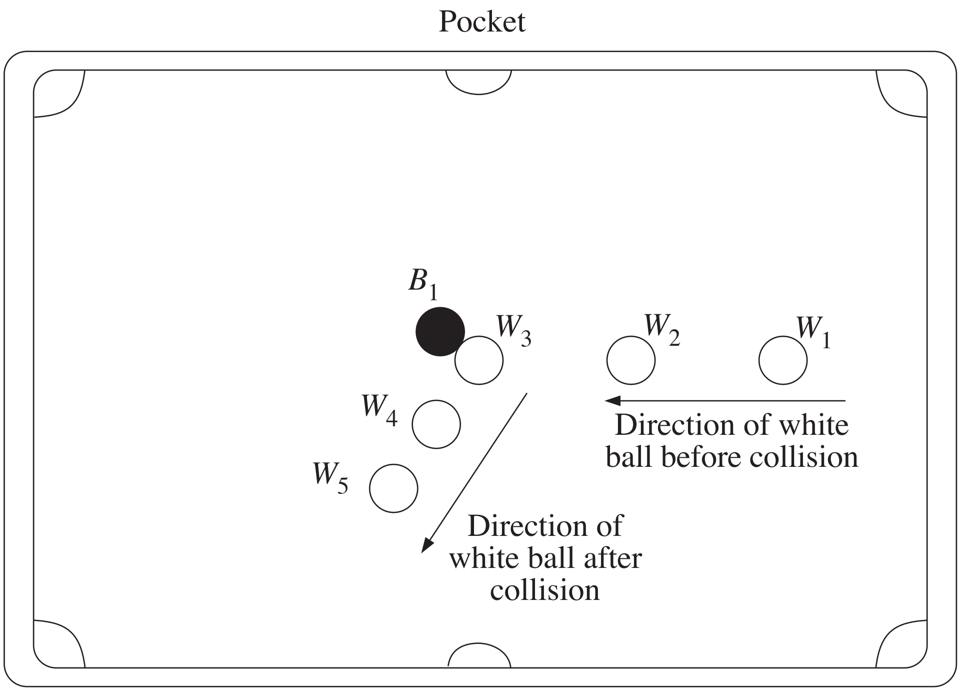
A and *B* were fired at 2·0 m s^{-1} and were initially 1·0 m away from *D*.

(a) If *C* was fired at 3·0 m s^{-1}, how far was it initially placed from *D* so that all objects collided at the same time?

(b) Assuming no external forces, calculate the direction and magnitude of the velocity of the combined mass after the collision.

20. A snooker player attempts to pocket the black ball with the white ball. The strobe image drawn below shows the position (B_1) of the black ball before the collision. It also shows the positions (W_1 to W_5) of the white ball before, during, and after the collision. The positions of the two images of the black ball after the collision are missing. Both balls have the same mass.

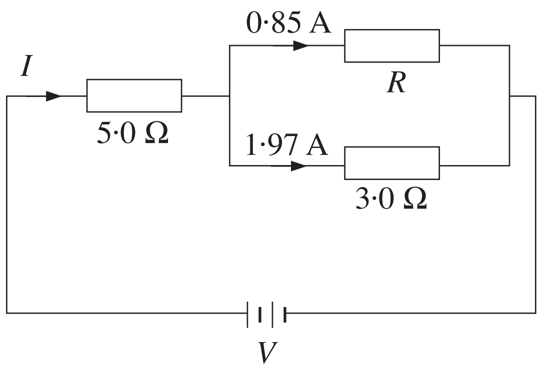
The initial speed of the white ball was 2·0 m s^{-1} and its final speed was 1·0 m s^{-1}. The black ball was initially at rest.



(a) Calculate the ratio of the kinetic energy of the white ball before the collision to the kinetic energy of the white ball after the collision.

(b) On the diagram in your Answer Book, mark the position of the black ball when the white ball was at position W_5.

21. A circuit is wired as shown in the diagram below.



Calculate:

(a) the current I through the 5·0 Ω resistor;

(b) the value of the resistor R;

(c) the potential difference V across the battery.

22. An X-ray apparatus has an X-ray tube in which a beam of electrons is emitted from the cathode. The electrons are accelerated through a potential difference of 25 kV before striking the anode and producing X-rays. The current provided by the electron beam is 60 μA.

(a) Assuming that the electrons leave the cathode with negligible velocity, what is the energy in joules of *each* electron when it strikes the anode?

(b) How many electrons strike the anode in one second?

(c) What is the power dissipated in the X-ray tube?

23. The following diagrams show an alpha particle and a beta particle entering identical uniform magnetic fields of intensity 0·025 T. Both particles have the same initial speed of $1{\cdot}4 \times 10^5$ m s^{-1}.

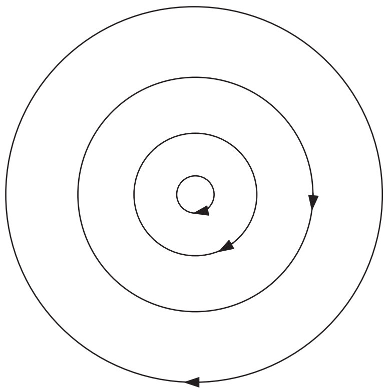
(a) Calculate the magnitude of the magnetic force on the beta particle.

(b) Briefly describe TWO differences between the motions of the particles after they enter the magnetic fields as shown above.

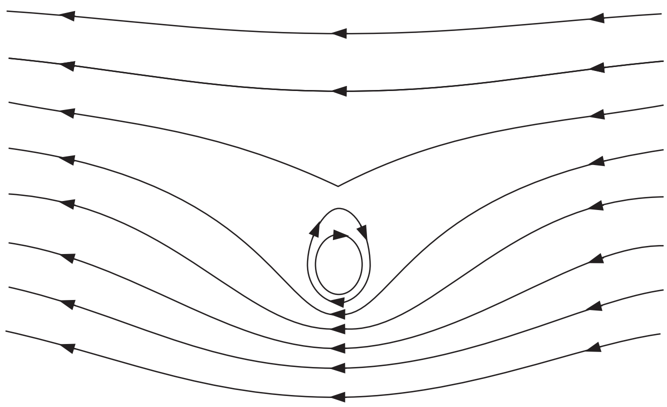
24. The diagrams below indicate the magnetic fields produced by different arrangements of current-carrying wires. In your Answer Book, sketch and label the arrangement of wire(s) that would produce *each* of the fields given, and indicate the direction of the current(s) in *each* case.

(a)

(b)

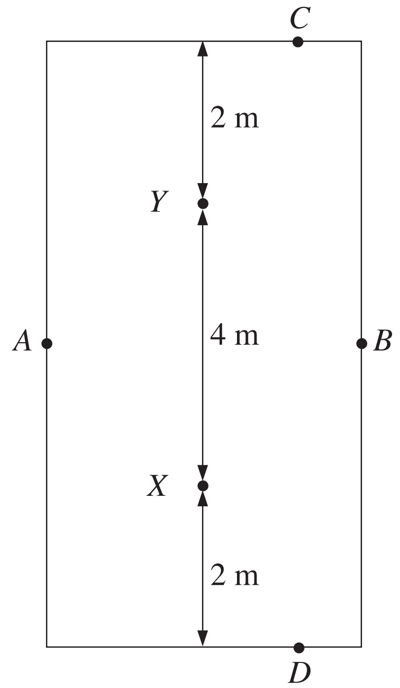


(c)



25. A room was lined with sound-absorbent material on the floor, ceiling, and walls, so that no reflection of sound occurred.

Two identical sources of high-pitched sound, *X* and *Y*, were placed as shown in the diagram below. The sounds produced by *X* and *Y* were in phase.



A tiny robot moved along the floor of the room in a straight line from *A* to *B*. It measured and graphed the loudness of the sound. It then moved along the path *CD* and produced another graph of loudness.

(a) Describe ONE difference between the patterns of loudness that would be seen on the two graphs.

(b) Explain why this difference would occur.

PART C

Questions 26–31 are worth 5 marks each.

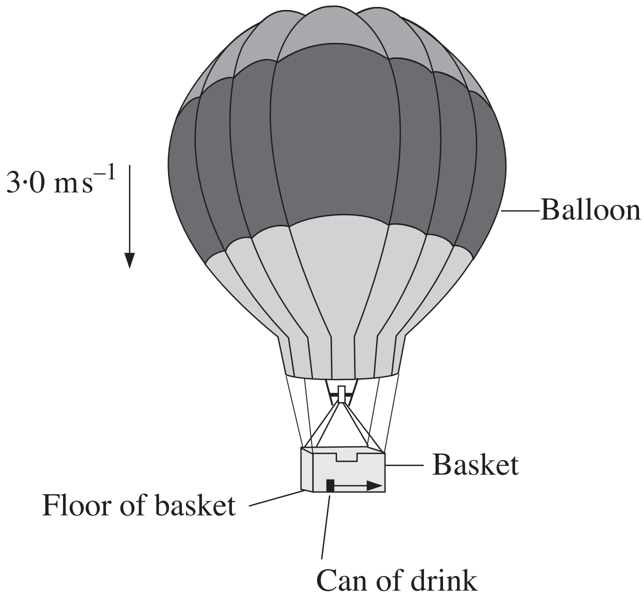
Answer this Part in the Part C Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

26. A balloon with a basket attached moves vertically towards the ground. As it descends it maintains a constant velocity of 3·0 m s^{-1}.

A can of drink slides across the horizontal floor of the basket at 1·2 m s^{-1}. It slides out of a gap in the side of the basket 10·0 seconds before the basket hits the ground.



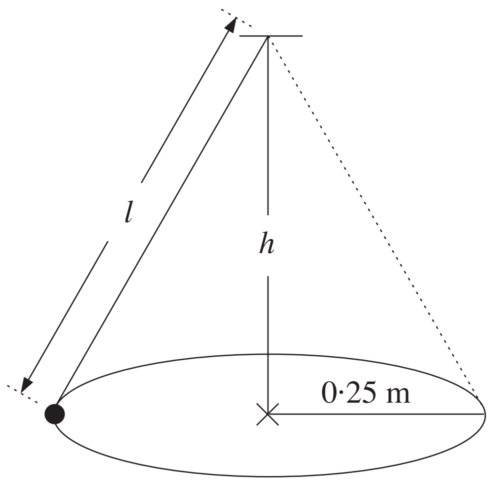
(a) How high is the floor of the basket above the ground when the can leaves the basket?

(b) What is the vertical component of the can's velocity as it leaves the basket?

(c) How long does it take the can of drink to hit the ground once it leaves the balloon? (Ignore air resistance on the can.)

(d) How far apart will be the initial impact sites of the basket and the can of drink?

27. A $5{\cdot}0 \times 10^{-2}$ kg mass traces a circular path with radius 0·25 m as shown in the diagram below.



The period of rotation for a conical pendulum is given by $T = 2\pi\sqrt{\frac{h}{g}}$.

(a) Determine the length l if the mass completes 10 revolutions in 15 seconds.

(b) Calculate the magnitude of the centripetal force acting on the mass.

(c) Determine the tension in the string.

28. The following nuclear equation represents what occurs when a radioactive carbon-14 nucleus decays by emitting an electron and an antineutrino.

$$^{14}_{6}\text{C} \rightarrow {}^{0}_{-1}\text{e} + {}^{14}_{7}\text{N} + {}^{0}_{0}\bar{\nu}$$

The radioactive carbon-14 nucleus is initially stationary. The electron and antineutrino are emitted at 90° to each other and the nitrogen-14 nucleus recoils. The following data are provided for use by students:

Mass of nitrogen-14 nucleus = $2{\cdot}32 \times 10^{-26}$ kg
Velocity of electron (magnitude) = $5{\cdot}00 \times 10^{6}$ m s^{-1}
Momentum of antineutrino (magnitude) = $4{\cdot}55 \times 10^{-24}$ kg m s^{-1}

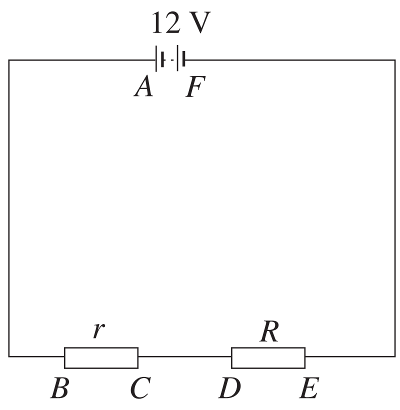
(a) Calculate the magnitude of the momentum of the electron after the decay.

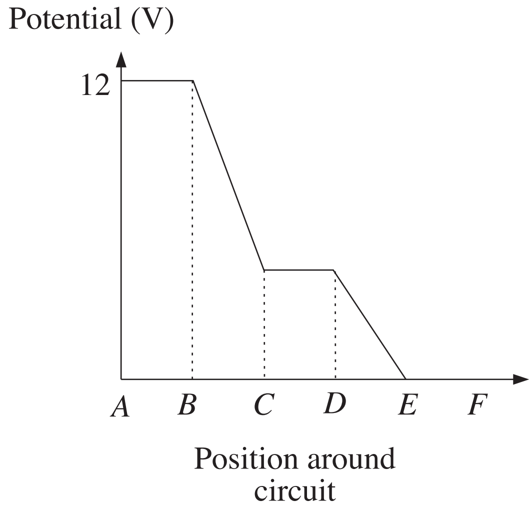
(b) Why does the nitrogen-14 nucleus recoil?

(c) Determine the magnitude of the recoil velocity of the nitrogen-14 nucleus.

(d) Determine the angle between the direction of motion of the electron and the direction of motion of the nitrogen-14 nucleus.

29. Below is a diagram of a simple circuit, and next to it is a graph that shows how the potential varies around the circuit. *R* and *r* are resistors in the circuit. ONE resistor has a value of 2·0 ohms and the OTHER resistor has a value of 4·0 ohms.





(a) Calculate the power dissipated in the circuit.

(b) What is the resistance of *R*?

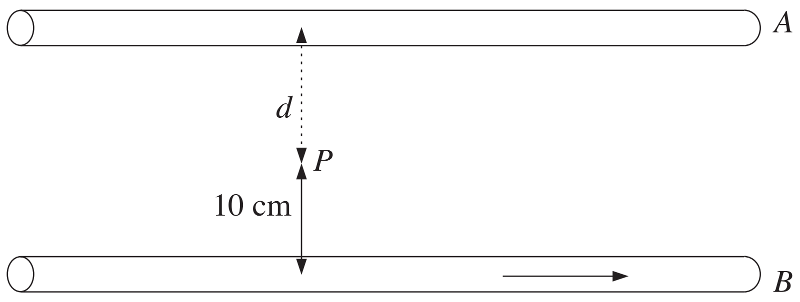
(c) If *R* were removed and replaced by a conducting wire with negligible resistance:

(i) use the axes provided in your Answer Book to show how the potential would vary in the circuit.

(ii) in what way would the current in the circuit change?

(iii) explain how this would affect the life of the battery.

30. Two current-carrying wires are placed parallel to each other as shown below. The magnetic field is measured at point *P*, a perpendicular distance of 10 cm from wire *B* and a perpendicular distance *d* from wire *A*. (The diagram is not drawn to scale.)



Readings are taken of the magnetic field strength and direction at *P* due to the current in both wires. The current in wire *A* was varied as shown in the table below. The current in wire *B* was kept constant throughout the experiment.

Current in wire A (amperes)	*Field direction at P*	*Field strength at P* (tesla)
0	Out of page	$3{\cdot}4 \times 10^{-6}$
0·4	Out of page	$4{\cdot}4 \times 10^{-6}$
0·7	Out of page	$4{\cdot}9 \times 10^{-6}$
1·5	Out of page	$6{\cdot}7 \times 10^{-6}$
2·1	Out of page	$8{\cdot}0 \times 10^{-6}$
2·9	Out of page	$9{\cdot}7 \times 10^{-6}$

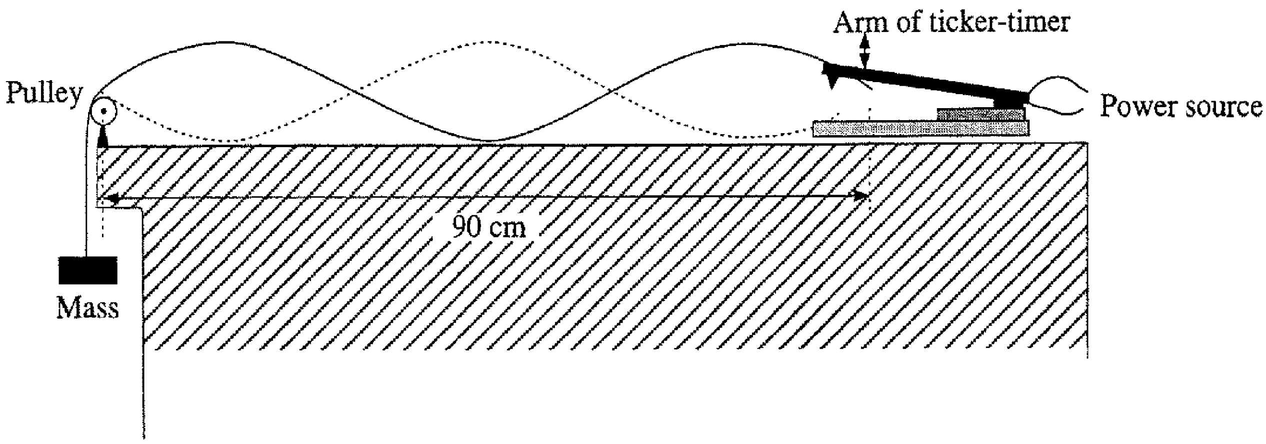
(a) Calculate the magnitude of the current in wire *B*. (Show your working.)

(b) Plot the results from the table above on the axes in your Answer Book. Draw a straight line of best fit.

(c) Calculate the slope of your line of best fit.

(d) Use your answer to part (c) to calculate the value of the distance *d*.

31. A standing wave can be set up in a string that is attached at one end to the arm of a ticker-timer, and to a mass hanging over a pulley at the other. An example is shown below.



(a) For the example shown, what is the wavelength of the standing wave in the string?

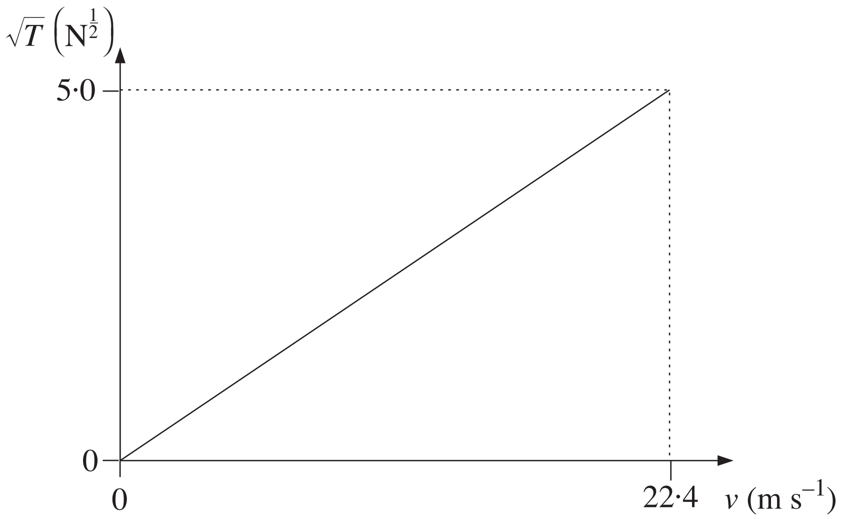
(b) If the frequency of the vibration of the ticker-timer is 50 Hz, what is the velocity of waves in the string in this example?

(c) Suggest TWO simple ways to modify this apparatus to enable the string to vibrate in the fundamental mode.

(d) The velocity of the waves in strings depends on the mass per unit length of the string (μ) and the tension in the string (T). The formula for the velocity is:

$$v = \sqrt{\frac{T}{\mu}}.$$

From the graph below, find the mass per unit length of the string.



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 Answer Book.

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

(a) (i) With reference to the Ptolemaic system, sketch a clearly-labelled diagram that shows the Earth and a planet. Your diagram should illustrate the meaning of each of the following terms: **5**

- deferent
- epicycle
- eccentric.

(ii) State TWO pieces of observational evidence that led to the introduction of the features in part (i).

(b) Using his telescope, Galileo observed that the planet Venus had phases like Earth's moon. From diagrams similar to the ones below, he argued that this proved conclusively that Venus orbited the Sun and not the Earth. Explain how the phases shown in the diagrams support that conclusion. **2**

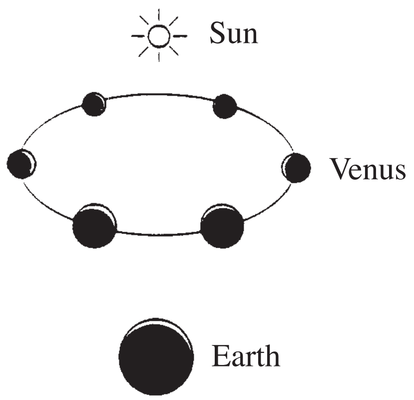


DIAGRAM 1

GEOCENTRIC VIEW SHOWING VENUS ON ITS EPICYCLE

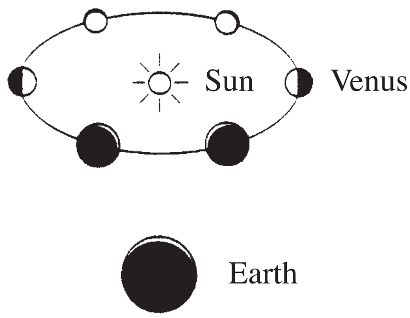


DIAGRAM 2

HELIOCENTRIC VIEW SHOWING VENUS ON ITS ORBIT

Question 32 continues on page 28

QUESTION 32. (Continued) **Marks**

(c) Newton based his study of planetary motions on: **5½**

- the laws of motion on Earth;
- Kepler's Laws;
- the motion of the Moon around the Earth.

(i) For an object moving in a circle with radius R and period T, show that the centripetal acceleration required is given by $a = \dfrac{4\pi^2 R}{T^2}$.

(ii) For planets moving in an orbit of radius R and period T, Kepler's Third Law can be written as $T^2 = k_1 R^3$ (where k_1 is a constant). Combine this information with the expression given in part (c) (i) to show that $g = \dfrac{k_2}{R^2}$ (where k_2 is another constant).

(iii) Taking this last result, and again using the result in part (c) (i), Newton was able to produce a formula that predicted the period, T_M, of the Moon's orbit. It is

$$T_M = 2\pi\left(\frac{R_M}{R_E}\right)\left(\frac{R_M}{g_E}\right)^{\frac{1}{2}}$$

where:

- R_M = radius of the Moon's orbit around the Earth
- R_E = radius of the Earth
- g_E = acceleration due to gravity at the surface of the Earth.

The observed value of T_M is approximately 28 days. Use Newton's formula to predict T_M given that

$$R_M = 3{\cdot}82 \times 10^8 \text{ m and } R_E = 6{\cdot}38 \times 10^6 \text{ m.}$$

(iv) Newton drew several important conclusions from comparing his predicted value with the observed one. Briefly explain what TWO of those conclusions were.

QUESTION 32. (Continued) **Marks**

Answer this half-elective in a *new* Elective Answer Book.

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

(a) In 1676, Roemer estimated the speed of light. To do this he used the variation in timing of the eclipses of one of the moons of Jupiter, and a knowledge of the size of the Earth's orbit around the Sun. His estimated value was near to 3×10^8 m s^{-1}. How was this result different from Descartes' assertion about the speed of light? **1**

(b) Newton's view of light was that it was propagated by means of swarms of material *corpuscles* which travelled in straight lines. On the other hand, Huygens had the view that light was propagated by means of wave motions in the ether, travelling in straight lines generated by *secondary wavelets*. Each person had a major criticism of the other's point of view. What were those criticisms? **2**

(c) (i) What is Poisson's Spot? **$2\frac{1}{2}$**

(ii) Who discovered Poisson's Spot?

(iii) How did the discovery of Poisson's Spot provide support for the wave model of light?

(d) Maxwell made a huge contribution to the modern theory of light. However, it was not until about fifteen years after publication of his work that his ideas were demonstrated experimentally. **3**

(i) What are TWO features of Maxwell's theory of light?

(ii) Briefly describe an experiment that demonstrated Maxwell's ideas about the propagation of light.

(e) In experiments on the *photoelectric effect* it is found that electrons may be emitted from the surface of a metal when light is shone on the surface. When the light is above a certain cut-off frequency, some of the experimental observations are: **4**

- electrons are emitted, no matter what the intensity of the light is;
- the rate at which electrons are emitted is proportional to the light intensity;
- for light of a fixed frequency, there is a maximum kinetic energy for the emitted electrons;
- there is a straight-line relationship between the maximum kinetic energy for the emitted electrons and the frequency of the light.

Explain how Einstein's theory of the photoelectric effect accounts for *each* of these observations.

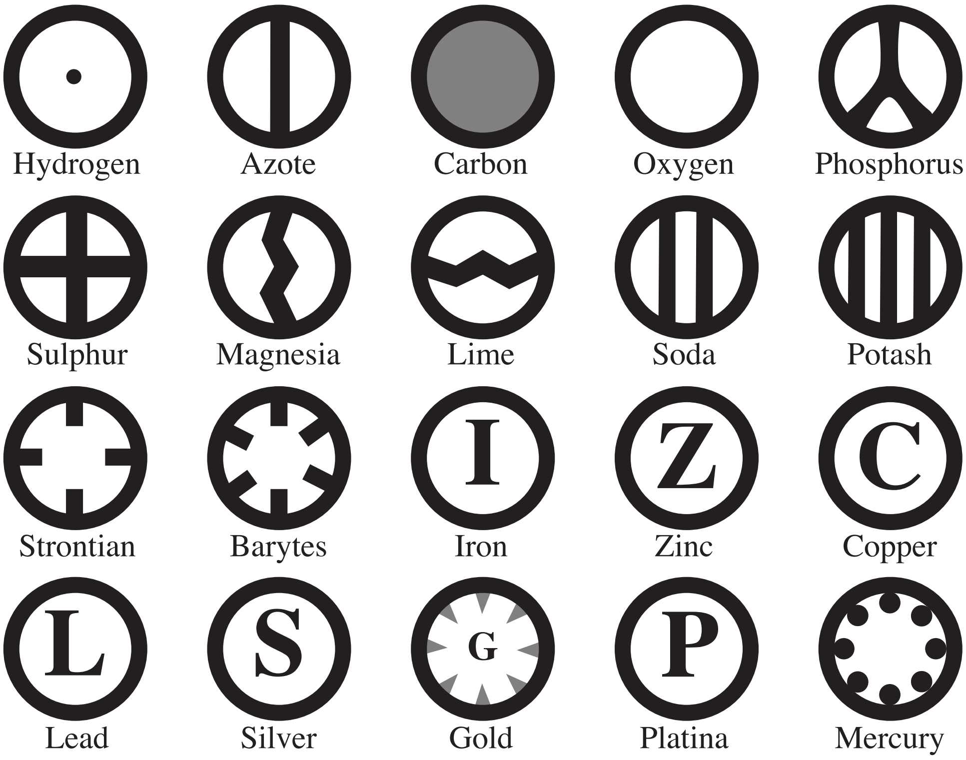
Question 32 continues on page 30

QUESTION 32. (Continued) **Marks**

Answer this half-elective in a *new* Elective Answer Book.

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

(a) In 1808 Dalton used the following symbols for his 'atoms'. **2**



'Projects Physics Course 5: Models of the Atom', Holton et al, Project Physics 1970.
Courtesy Horwitz Publications Pty Ltd.

(i) Describe ONE feature of Dalton's atoms.

(ii) What is ONE piece of experimental evidence that led Dalton to propose his atomic theory?

QUESTION 32. (Continued) **Marks**

(b) Townsend's experiment to determine the basic unit of charge involved a number of steps and deductions: **2**

- a known quantity of charge was used to electrify water droplets in a cloud chamber;
- the droplets fell under gravity at the same uniform rate;
- because they fell at the same rate, the droplets were the same size;
- from their rate of fall, Townsend deduced the volume of each drop;
- from the total volume of the collected water, and the volume of each drop, Townsend deduced the number of drops collected;
- from this information, and making one assumption, Townsend deduced the charge carried by each drop.

(i) What was the assumption Townsend would have had to make about the charge on each water droplet?

(ii) How was the basic unit of charge deduced?

(c) In discovering isotopes, J. J. Thomson created a special piece of apparatus. One key feature of this apparatus was a *velocity filter*. The velocity filter combined the use of an electromagnet, a pair of electric plates, and a screen with a hole in it. **$2\frac{1}{2}$**

(i) Draw a labelled diagram showing the arrangement of the main parts of the velocity filter.

(ii) Describe how the velocity filter was adjusted.

(iii) Explain why the velocity filter was needed.

(d) Rutherford's model of the atom was produced after much experimental work using scattering of radioactive emissions. **3**

(i) Draw a labelled diagram showing the features of Rutherford's model of the atom.

(ii) What experimental evidence did Rutherford's model satisfy that Thomson's model did not?

Question 32 continues on page 32

QUESTION 32. (Continued) **Marks**

(e) When hot hydrogen vapour is viewed through a spectrometer, four distinct bright lines of the Balmer Series can be seen. **3**

The wavelengths of these lines are given in the table below.

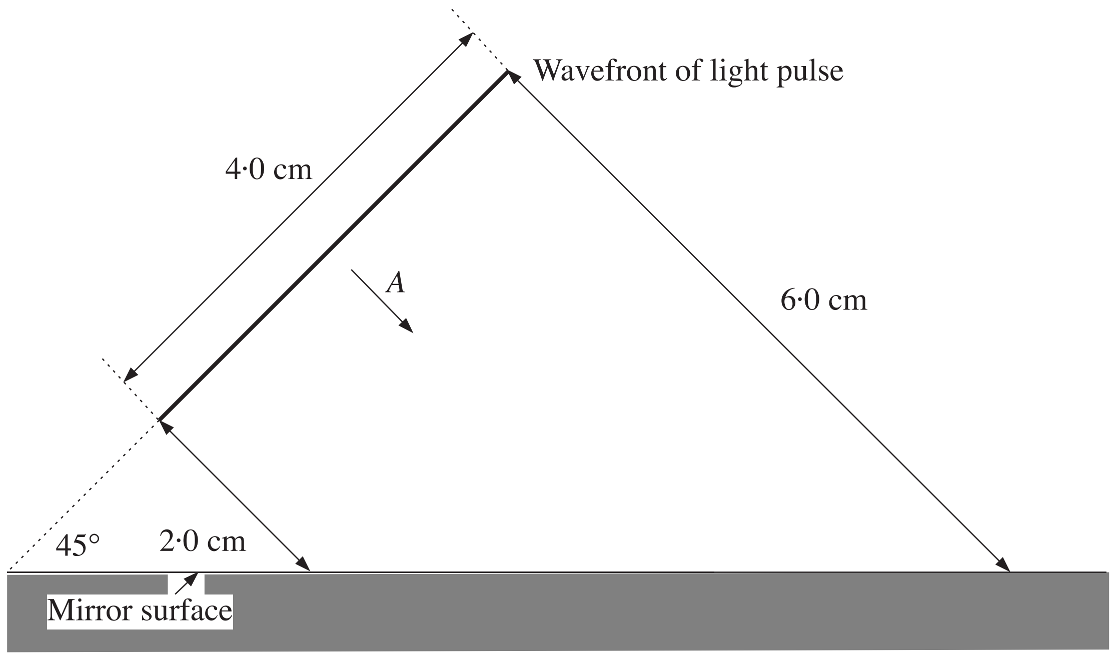
Balmer Series
$6{\cdot}563 \times 10^{-7}$ m
$4{\cdot}861 \times 10^{-7}$ m
$4{\cdot}340 \times 10^{-7}$ m
$4{\cdot}102 \times 10^{-7}$ m

(i) By referring to the Bohr model of the atom, describe how these lines are formed.

(ii) Using the Rydberg equation, show how any ONE of the above spectral lines can be predicted.

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

(a) The diagram below shows the 4·0 cm wide wavefront for a pulse of light travelling towards a mirror surface. Arrow *A* shows the direction in which the wavefront is travelling. The distances of the ends of the pulse from the mirror are shown at a particular instant in time. **3**



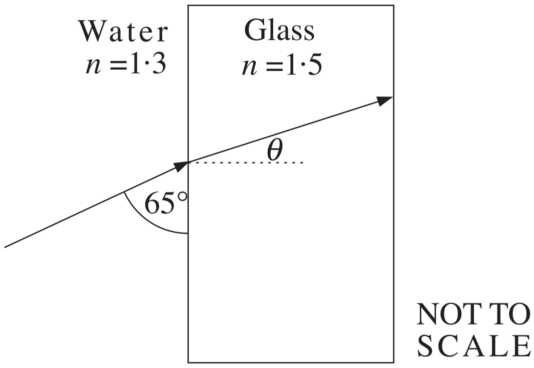
(i) How far will the wavefront travel in $1{\cdot}0 \times 10^{-10}$ seconds?

(ii) Redraw the mirror surface in your Answer Book. On your diagram, show the position of the wavefront $1{\cdot}0 \times 10^{-10}$ seconds after the position shown in the diagram above. Use arrows on your diagram to indicate the direction in which the wavefront is travelling.

Question 33 continues on page 34

QUESTION 33. (Continued) **Marks**

(b) A ray of light travels through water (refractive index = 1·3) and is incident on a rectangular glass prism (refractive index = 1·5) as shown below. **2**



Calculate:

(i) the speed of the light in the glass prism;

(ii) the value of the angle θ.

QUESTION 33. (Continued) **Marks**

(c) When monochromatic light is directed towards an opaque object that has a sharp edge, a pattern of light results. Figure 1 shows the variation in light intensity in the pattern, and Figure 2 shows what the pattern looks like. **3**

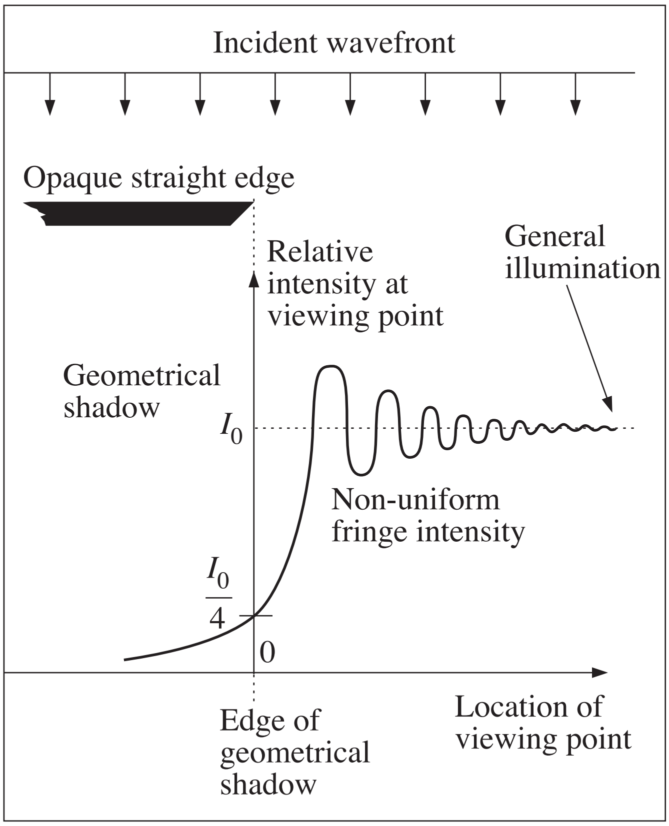


FIG. 1

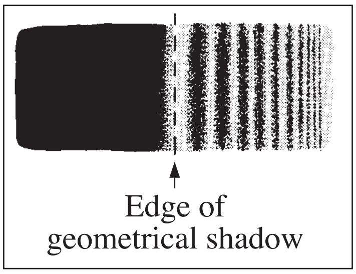


FIG. 2

'Essential Pre-university Physics', Whelan & Hodgson, John Murray 1971, p244-5.

(i) Explain why the fringes have non-uniform intensity, as shown in Figure 1.

(ii) Why is light seen in the geometrical shadow region?

(d) A double slit is illuminated by blue light of wavelength 450 nm. The separation of the slits is $1{\cdot}5 \times 10^{-5}$ m. A pattern of maxima and minima appears on a screen placed at a distance of 1·0 m. **3**

(i) Calculate the angular separation of the TWO first-order minima for the blue light.

(ii) If the blue light was replaced with green light, would the linear separation of the TWO first-order minima increase or decrease? Justify your answer.

Question 33 continues on page 36

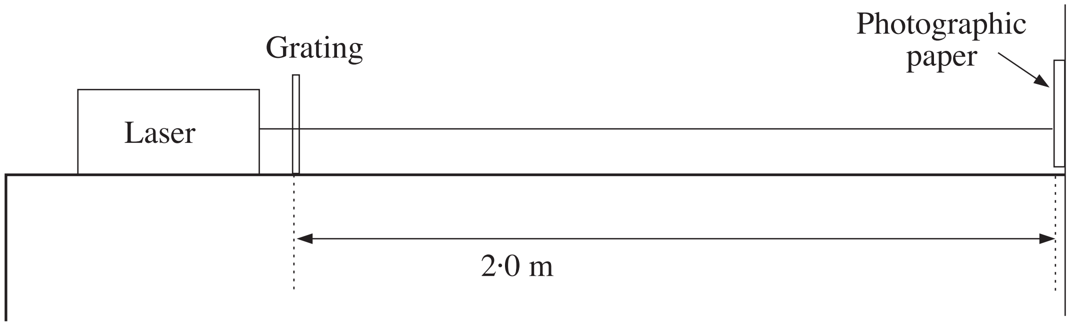
QUESTION 33. (Continued) **Marks**

(e) White light can be separated into its component colours using a glass prism or a diffraction grating. **2**

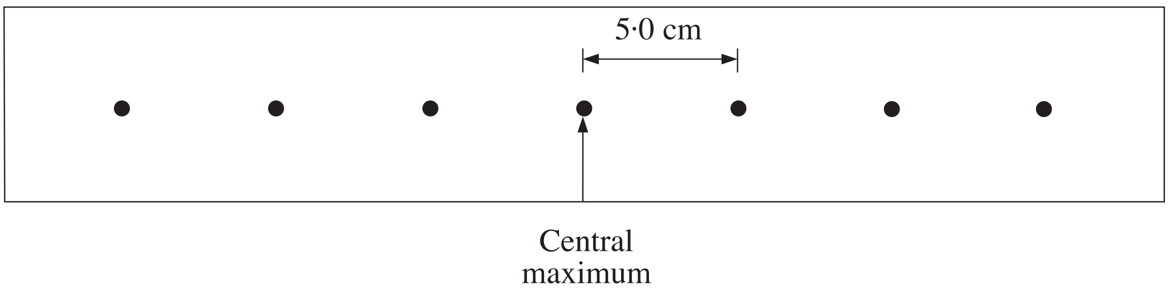
(i) Briefly explain why white light is dispersed by a glass prism.

(ii) A diffraction grating produces more than one spectrum, whereas only one spectrum is produced by a glass prism. Briefly describe *another difference* between the spectra produced by the grating and prism.

(f) Laser light of wavelength 633 nm was directed through a diffraction grating onto a wall in a dark room as shown below. **2**



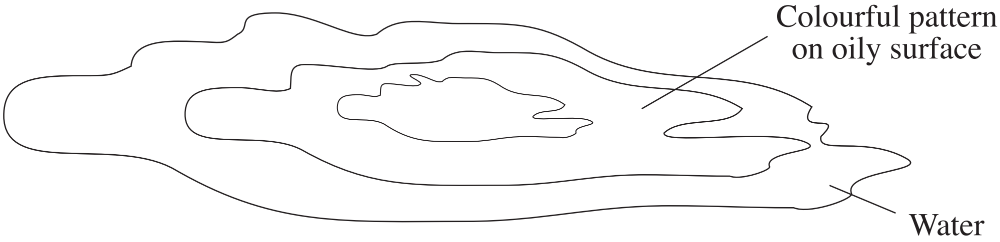
A piece of photographic paper was used to record the following pattern of dots produced on the wall.



If the grating was 2·0 m from the paper on the wall, determine the spacing of lines in the diffraction grating.

QUESTION 33. (Continued) **Marks**

(g) Colourful patterns often appear on oil found on wet road surfaces and driveways. **5**



(i) Draw a magnified side-on view showing the oil/water surface. Show the path of light that could produce any one of the colours seen.

(ii) Explain how any one of the colours is produced.

(iii) Explain why several colours are usually seen in the pattern.

(iv) Calculate the least thickness of oil (refractive index = 1·2) on the surface of water (refractive index = 1·3), that would produce a bright reflection of monochromatic light of wavelength $5{\cdot}9 \times 10^{-7}$ m incident at 90° to the surface.

Question 33 continues on page 38

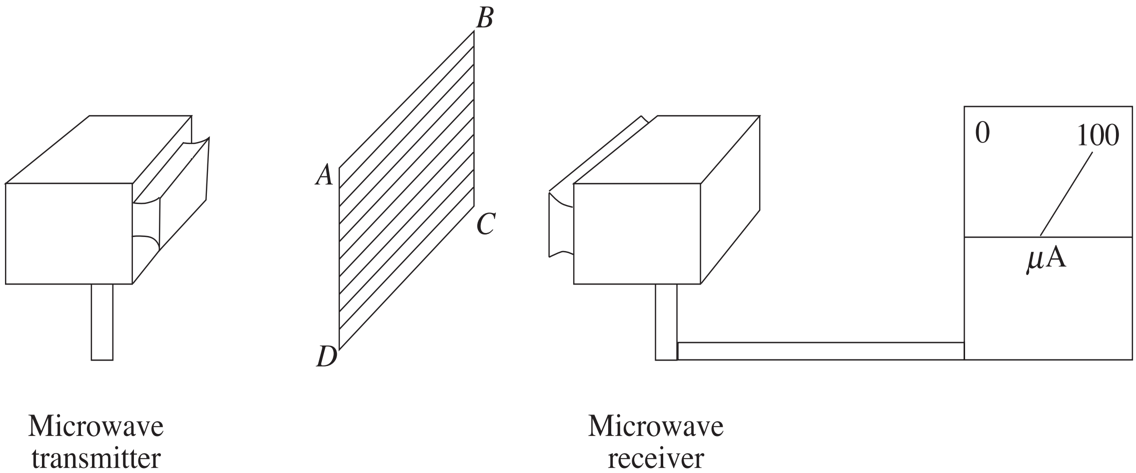
QUESTION 33. (Continued) **Marks**

(h) Both microwaves and visible light are parts of the electromagnetic spectrum and display the same wave properties. **3**

A microwave transmitter produces plane-polarised waves.

(i) Explain what is meant by the term ‘plane-polarised’.

A wire grid is placed in front of the transmitter as shown below. It is rotated in the plane *ABCD*. A maximum value of 100 μA is obtained on the meter when the wires are horizontal, and a zero reading is obtained when the wires are vertical.



(ii) Determine the smallest angle to the vertical to which the grid can be rotated, to produce a reading of 75 μA on the meter.

(iii) If the wire grid were to be rotated through a full 360°, how often would a reading of 75 μA occur?

(i) The following Doppler Effect equation gives the relationship between an observed frequency of light (f_o) and its frequency as measured at its source (f_s) for sources travelling at speeds close to that of light. **2**

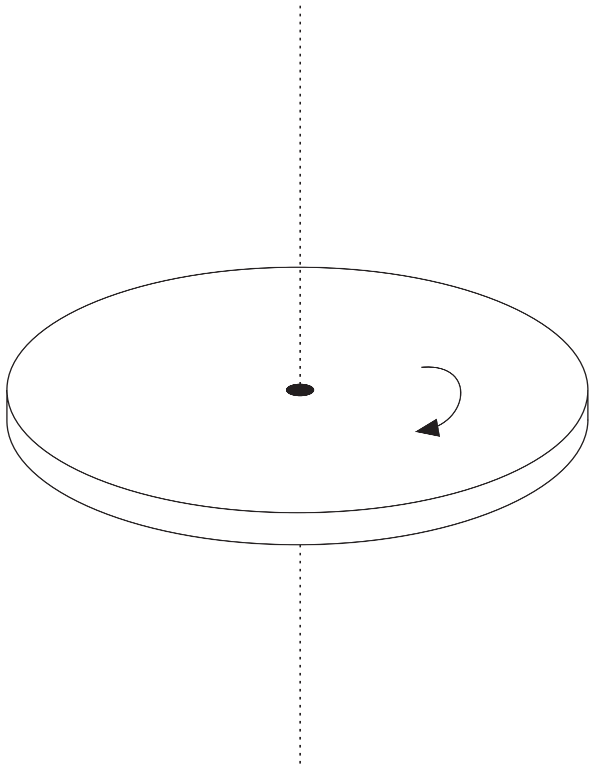
$$f_o = f_s\left(\frac{1 \pm \frac{v}{c}}{\sqrt{1-\frac{v^2}{c^2}}}\right)$$ where v = relative speed of source, and c = speed of light.

A science fiction novelist described a futuristic spacecraft that could travel at a constant speed of $2{\cdot}7 \times 10^8$ m s^{-1}. When travelling away from Earth at this speed the spacecraft sent messages back to Earth using a laser that emitted light of wavelength $6{\cdot}3 \times 10^{-7}$ m (as measured in the spacecraft).

Determine the frequency of the laser light when it reached the Earth.

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

(a) A disk with moment of inertia 0·27 kg m^2 is rotating about an axis through its centre with an angular velocity of 16 rad s^{-1}. An opposing uniform force of 2·2 N is applied at a distance of 50 cm from the centre of the disk and brings it to rest. **3**



(i) How long will it take the disk to come to rest?

(ii) Through what angle (in radians) does the disk turn from the instant the force is applied until the disk comes to rest?

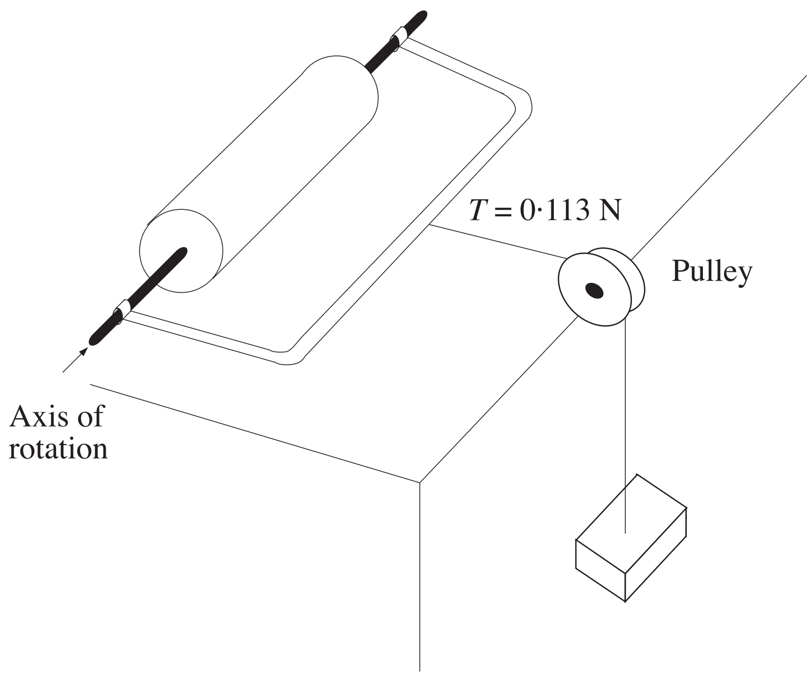
Question 34 continues on page 40

QUESTION 34. (Continued) **Marks**

(b) A string is attached to a cylinder as shown in the diagram below. Both the string and the handle are of negligible mass, and the pulley is frictionless. **4**

The cylinder has a mass of 0·100 kg and radius 3·50 cm, and is free to rotate ($I = \frac{1}{2}mr^2$).

A mass is hung on the end of the string, producing a tension of 0·113 N that causes the cylinder to roll from rest, without slipping, along the rough table surface.



The cylinder has an angular acceleration about its axis of 21·5 rad s^{-2}.

(i) Calculate the magnitude of the torque applied to the cylinder about that axis.

(ii) Calculate the magnitude of the friction, F_f (assumed constant), exerted on the cylinder.

(iii) Determine the total kinetic energy of the cylinder 1·00 second after it begins rolling.

QUESTION 34. (Continued) **Marks**

(c) The moment of inertia of a bicycle wheel was determined with the apparatus shown below. **5**

DUE TO COPYRIGHT RESTRICTIONS THIS IMAGE COULD NOT BE REPRODUCED.

The slotted masses were released from rest and were found to fall a distance of 0·50 m in 1·20 s. The radius of the wheel was 0·35 m and its mass 0·80 kg. The friction of the axle was negligible.

(i) Calculate the magnitude of the acceleration of the slotted masses.

(ii) Determine the tension in the string as the slotted masses were falling.

(iii) Calculate the magnitude of the torque acting on the wheel.

(iv) Determine the moment of inertia of the wheel.

(v) The moment of inertia of the wheel could be predicted using the formula $I = mr^2$. Will this value be larger, the same, or smaller than that deduced from the experiment? Give a reason for your answer.

Question 34 continues on page 42

QUESTION 34. (Continued) **Marks**

(d) The parallel-axis theorem can be used for calculating moments of inertia about axes that are not axes of symmetry. **2**

(i) State the parallel-axis theorem.

(ii) The moment of inertia of a uniform ball about an axis through its centre is given by $\frac{2}{5}Mr^2$, where M is the mass of the ball and r its radius. What is the moment of inertia of the ball about its point of contact with the ground as it rolls along the ground?

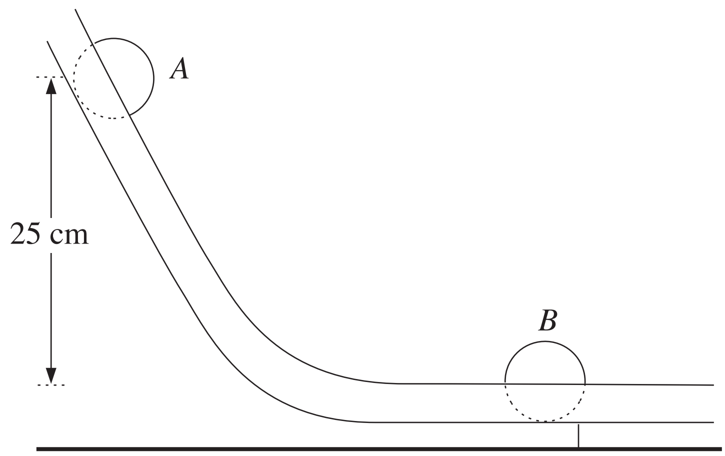
(e) An ice skater has his arms fully extended outward and is spinning with an angular velocity of 1·2 rad s^{-1}. He brings his arms close to his body and his angular velocity increases. **3**

(i) Without making calculations, explain why this change happens.

(ii) Given that his moment of inertia changes from 37 kg m^2 to 4·7 kg m^2, calculate the magnitude of his final angular velocity.

(f) A sphere has a mass of 150 g and a radius of 7·5 cm. The moment of inertia for a sphere is found by the expression $I = \frac{2}{5}Mr^2$. **4**

The sphere is released from rest at position A. It rolls a vertical distance of 25 cm without slipping, down a wide-grooved track as shown in the following diagram.



For the sphere, calculate:

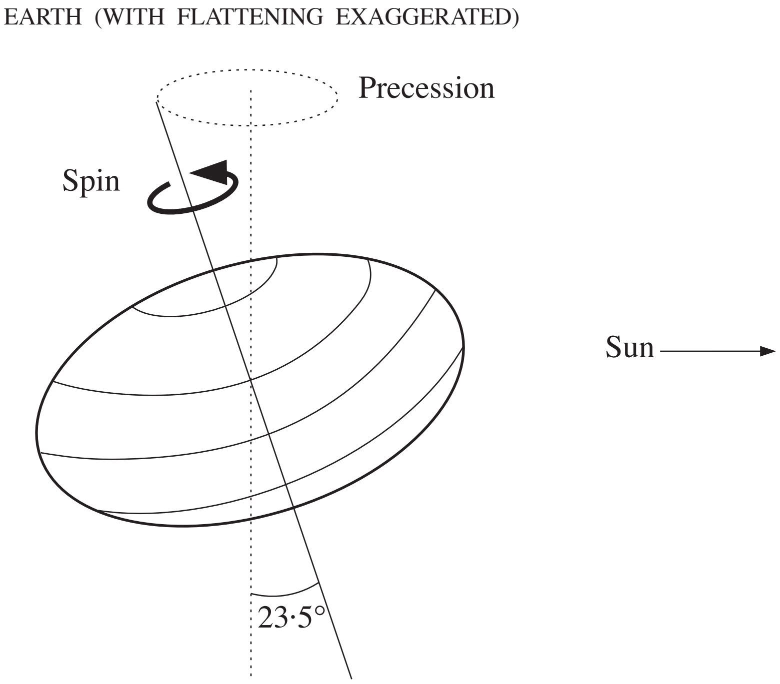
(i) the total kinetic energy at position B;

(ii) the angular velocity at position B;

(iii) the percentage of its total kinetic energy that is rotational kinetic energy.

QUESTION 34. (Continued) **Marks**

(g) The Earth is not a perfect sphere. It is flattened at the poles and bulges at the equator. It spins on its axis with a tilt of 23·5° to the plane of its orbit around the Sun. The Earth's axis precesses around the perpendicular to the plane of its orbit, as shown in the diagram below, with a period of 26 000 years. **4**



(i) Why does the Earth precess?

(ii) What is the direction of the torque vector acting on the Earth, in terms of the above diagram?

(iii) If all the ice at the poles melted, causing the equatorial bulge of the oceans to increase, would the precession increase or decrease? Justify your answer by considering what would happen to the angular momentum and torque vectors.

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

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

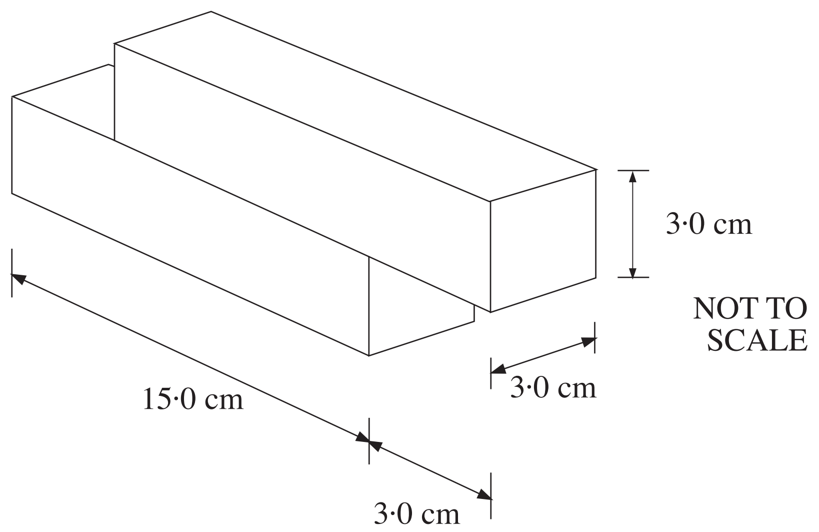
Answer each half-elective in a *separate* Elective Answer Book.

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

(a) Why are most door handles positioned as far from the hinged side of the door as possible? **1**

(b) Two uniform blocks of wood, with dimensions $3{\cdot}0\text{ cm} \times 3{\cdot}0\text{ cm} \times 15{\cdot}0\text{ cm}$, each weighs 0·70 N. **$1\frac{1}{2}$**

As shown below, one block sits on top of the other, with a 3·0 cm overhang.



Find the centre of mass for this system.

QUESTION 35. (Continued) **Marks**

(c) The following experiment is proposed to demonstrate the elasticity of metals. Two pieces of wire are cut so they are *each* exactly 5·0 m long. One is of steel with a diameter of 1·5 mm, while the other is of copper. Each wire is to be loaded with a mass of 125 kg. It is intended that the extensions of the wires be the same when they are loaded. **5**

	Steel	*Copper*
Young's modulus ($N\ m^{-2}$)	$2{\cdot}1 \times 10^{11}$	$1{\cdot}3 \times 10^{11}$
Yield strength ($N\ m^{-2}$)	$4{\cdot}8 \times 10^{8}$	$3{\cdot}4 \times 10^{8}$
Ultimate tensile strength ($N\ m^{-2}$)	$6{\cdot}4 \times 10^{8}$	$3{\cdot}5 \times 10^{8}$

(i) Assuming elastic behaviour, what should be the diameter of the copper wire so that it would have the same extension as the steel wire?

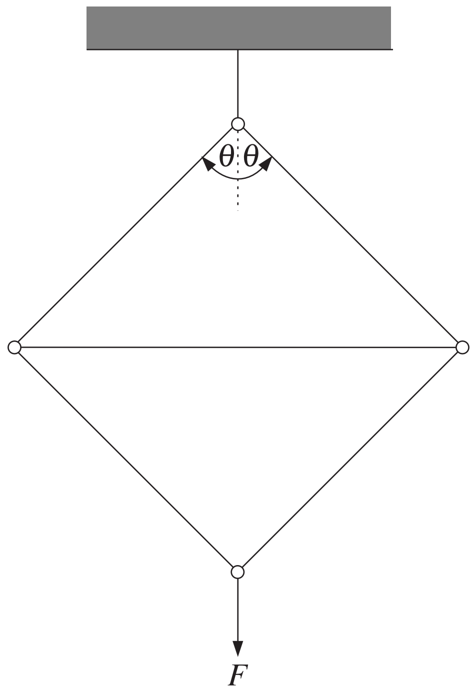
(ii) What would be the predicted extension of the wires under the 125 kg load?

(iii) By considering the copper wire, explain whether or not the experiment would work as planned.

Question 35 continues on page 46

QUESTION 35. (Continued) **Marks**

(d) As shown in the sketch below, a pin-jointed frame is made up of four sides of equal length, with a diagonal member joining one pair of opposite vertices. The frame is suspended by one vertex from a rigid support, and loaded with a force F, from the opposite vertex. All members are thin-walled, aluminium tubes with the same diameter. **5**



(i) Explain whether the diagonal member is in tension or compression.

(ii) If the force exerted by the diagonal member on the joints at its ends is denoted by B, calculate B in terms of F and θ.

(iii) If the angle θ is 60°, explain what is the likely mechanism by which the frame will fail as the load F is increased. Assume that the joints do not fail.

QUESTION 35. (Continued) **Marks**

Answer this half-elective in a *new* Elective Answer Book.

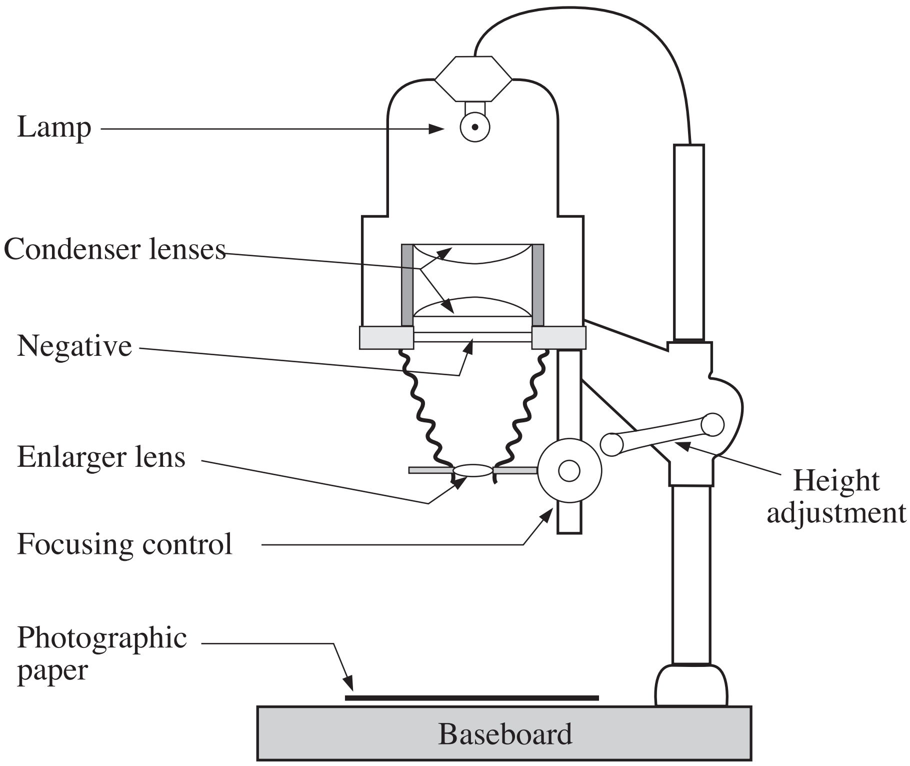
B. Half-elective: Optical Instruments ($12\frac{1}{2}$ marks)

(a) A person who is 170 cm tall stands upright in front of a vertical plane mirror. The person's eyes are 160 cm above the floor.

(i) In your Answer Book, draw a carefully-labelled ray diagram showing how a full head-to-toe image can be seen in the mirror. **3**

(ii) What is the least length that the mirror can have for the full image to be seen?

(b) A photographic enlarger is shown below. It shines light from a lamp through a film negative so that an enlarged image of the negative falls on a baseboard. Photographic paper can be placed on the baseboard. **5**



'Sight & light', McGuire & Linthwaite, STAV 1990 p57.

(i) Name another optical instrument that has the same optical components as the enlarger.

(ii) Why must the negative not be placed further than twice the focal length above the enlarger lens?

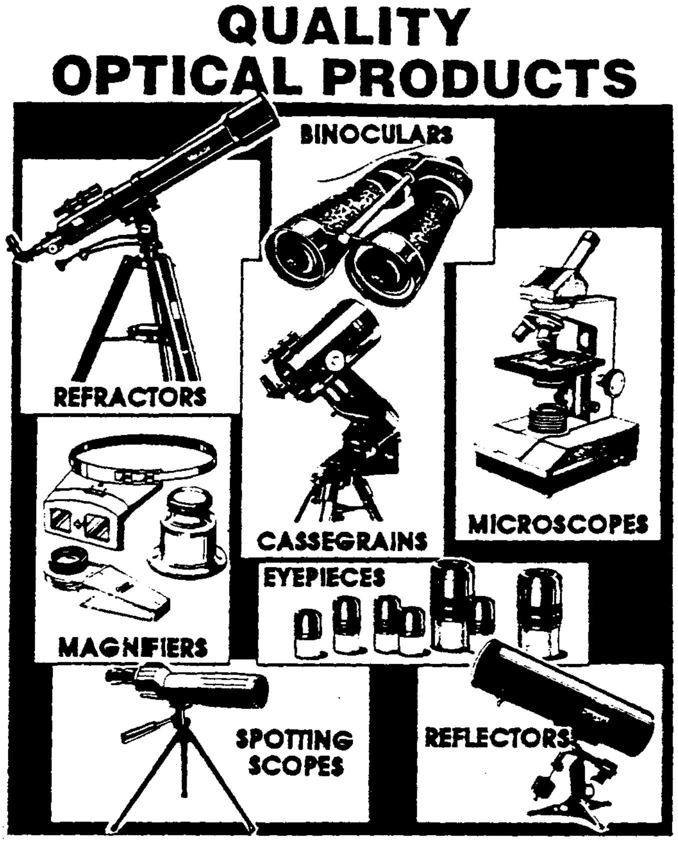
(iii) A negative is 30 mm across and it is placed 60 mm above a simple, convex enlarger lens of focal length 35 mm. Draw, to scale, a ray diagram to show how far the enlarger lens should be suspended above the photographic paper to produce a sharp image.

(iv) Determine the magnification of the image in part (iii).

Question 35 continues on page 48

QUESTION 35. (Continued) **Marks**

(c) Study the advertisement below. **$4\frac{1}{2}$**



Reproduced courtesy York Optical Co.

(i) Of the items pictured, which TWO rely on mirrors for magnification?

(ii) The binoculars use pairs of prisms. Give ONE reason for this.

(iii) Describe ONE optical *improvement* of the reflector telescope over the refractor.

(iv) State ONE advantage of the Cassegrain telescope over the Newtonian reflector.

QUESTION 35. (Continued) **Marks**

Answer this half-elective in a *new* Elective Answer Book.

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

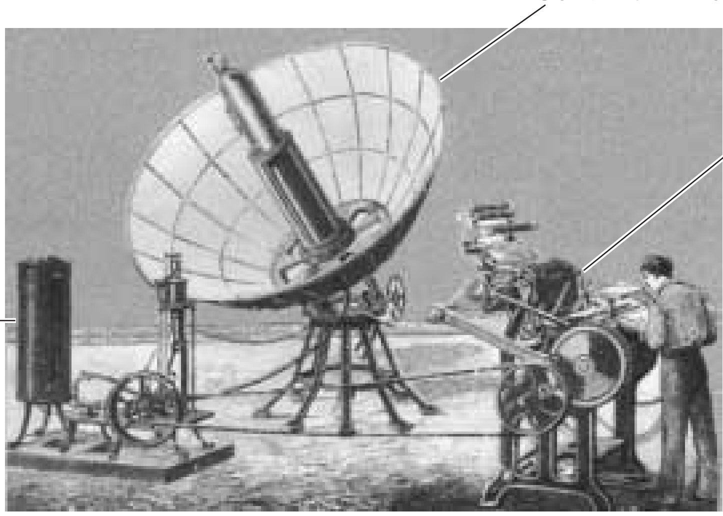
(a) In one year the state of New South Wales burnt 21·7 million tonnes of coal to produce 48 700 gigawatt-hours of electrical energy in power stations. The stations ran at an efficiency of 35%. (1 gigawatt = 10^9 watts) **3**

(i) How many joules of energy are in 48 700 gigawatt-hours?

(ii) How many joules of heat energy were wasted?

(iii) What happened to this wasted heat?

(b) A solar printing press was demonstrated in 1882. Sunlight shone on a 3·5 m diameter concave mirror and this was focused on a steam boiler. **$2\frac{1}{2}$**



Mary Evans Picture Library.

(i) If during the demonstration of the invention the average power reaching the Earth from the Sun was 800 W m^{-2}, calculate the maximum amount of energy available to the printing press in 5 hours.

(ii) State ONE way the inventor could measure how much energy was absorbed by the steam engine.

(iii) In the present day, what other method could be used to operate a solar printing press without using steam power?

Question 35 continues on page 50

QUESTION 35. (Continued) **Marks**

(c) THREE energy sources are: **5**

- Nuclear fission
- Nuclear fusion
- Gravitational energy.

(i) Briefly state ONE important advantage of *each* source over the other two.

(ii) Choose ONE of the above energy sources, and outline the physical processes involved in its conversion to electricity.

(d) Many houses now use a low-voltage motorised fan to extract damp air from sub-floor areas. A 12 V adaptor connects the fan to a standard power point. The motor draws 0·50 A. **2**

(i) If the fan is always on, how much energy will it use in one year?

(ii) Given a cost of 13 cents per kilowatt hour, calculate its cost per year.

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

(a) **5**

Star	*Apparent magnitude*	*Absolute magnitude*
Sun	–26·8	+4·8
Betelgeuse	+0·4	–5·6
Star–*X*	+4·0	–4·2

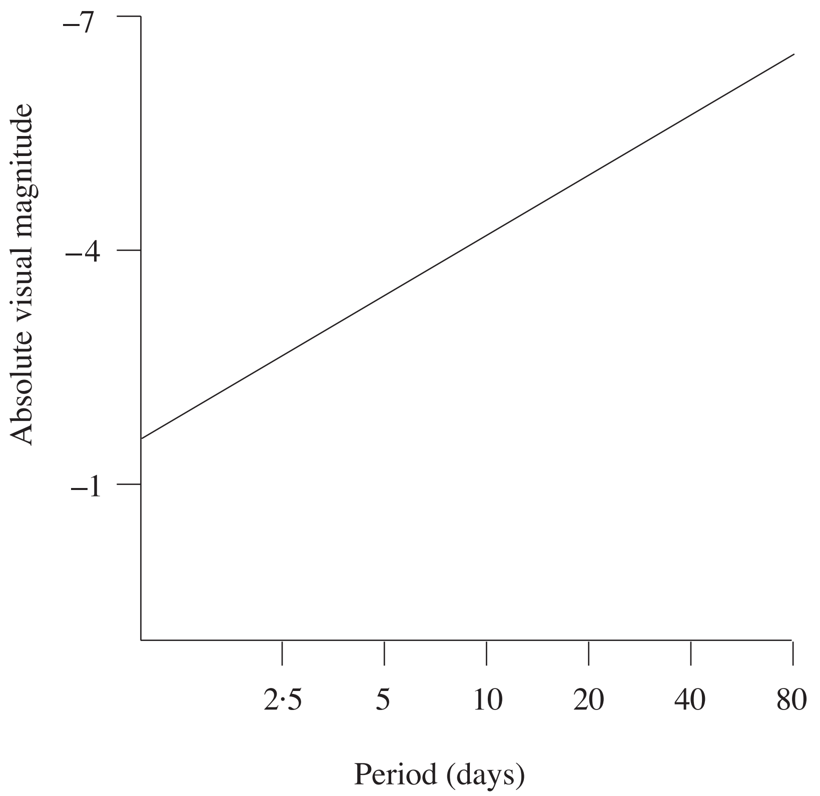
(i) State the difference between *apparent magnitude* and *absolute magnitude*.

(ii) What is the value of the ratio $\dfrac{\text{apparent brightness of the Sun}}{\text{apparent brightness of Betelgeuse}}$?

(iii) Determine the distance to Star–*X*.

(iv) Star–X is a cepheid variable star. Using the above table and the graph below, draw a light curve to show how the brightness of Star–*X* will vary over a 28-day period.

GRAPH OF THE RELATIONSHIP BETWEEN PERIODS AND ABSOLUTE VISUAL MAGNITUDES OF CEPHEID VARIABLES



HAIP Astronomical Journal vol 65, 1960 p426

Question 36 continues on page 52

QUESTION 36. (Continued) **Marks**

(b) The initial nuclear reaction in all stars is the proton–proton chain. The overall result in the three stages of the proton–proton chain is shown in the following equation. **7**

$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{0}_{1}\mathrm{e}^{+} + 2\nu + \gamma$$

(i) How can astronomers calculate the rate at which this reaction is taking place in the Sun?

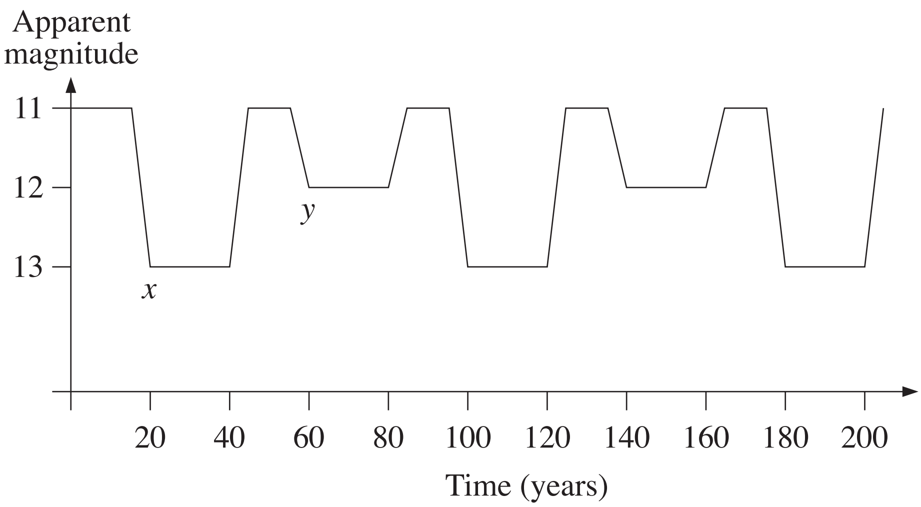
(ii) For the least massive stars on the main sequence, why is the proton–proton chain reaction the only nuclear reaction?

Imagine that a fundamental change occurred in the Sun to 'switch off' fusion reactions in the core.

(iii) In terms of the forces present in the Sun, explain how this would affect its size.

(iv) A change to the size of the Sun should occur in about 5 billion years. Describe this change and explain briefly what will cause it.

(c) The light curve shown below is from a binary star system. At x, the much smaller star is totally eclipsed. **3**



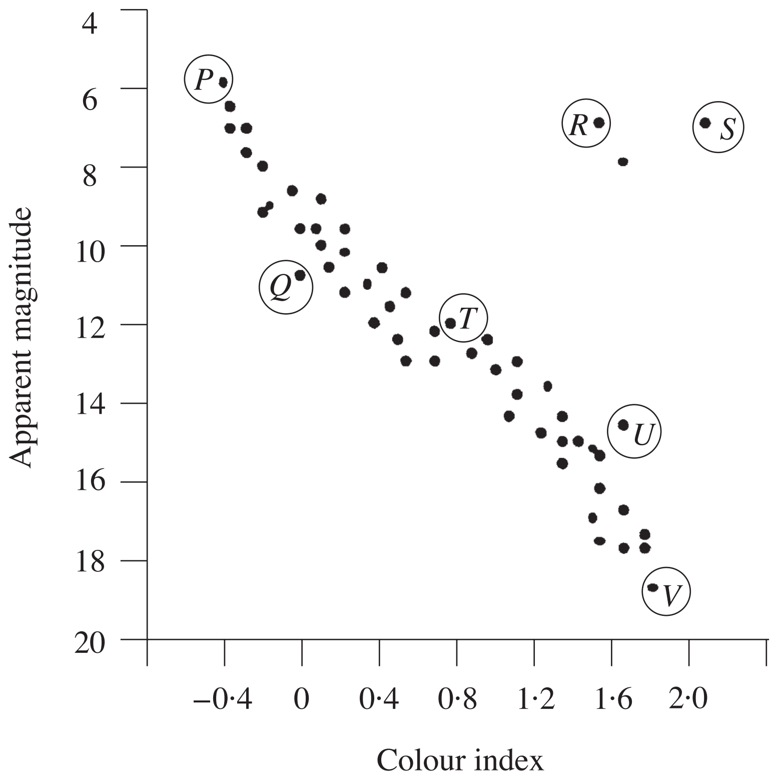
(i) Explain what information is needed to determine if this system is a visual binary.

(ii) What is happening at y?

(iii) Explain why most binary systems do not display a varying light curve.

QUESTION 36. (Continued) **Marks**

(d) Look at the Hertzsprung–Russell diagram below for stars in a cluster of unknown distance. **6**



(i) Which of the stars circled is producing the greatest amount of light?

(ii) Which star has the lowest surface temperature?

(iii) It is traditional to draw Hertzsprung–Russell diagrams with absolute magnitude on the vertical axis. In the above diagram, apparent magnitude is used instead. Explain why this does not alter the shape of the main sequence line if star clusters are being graphed.

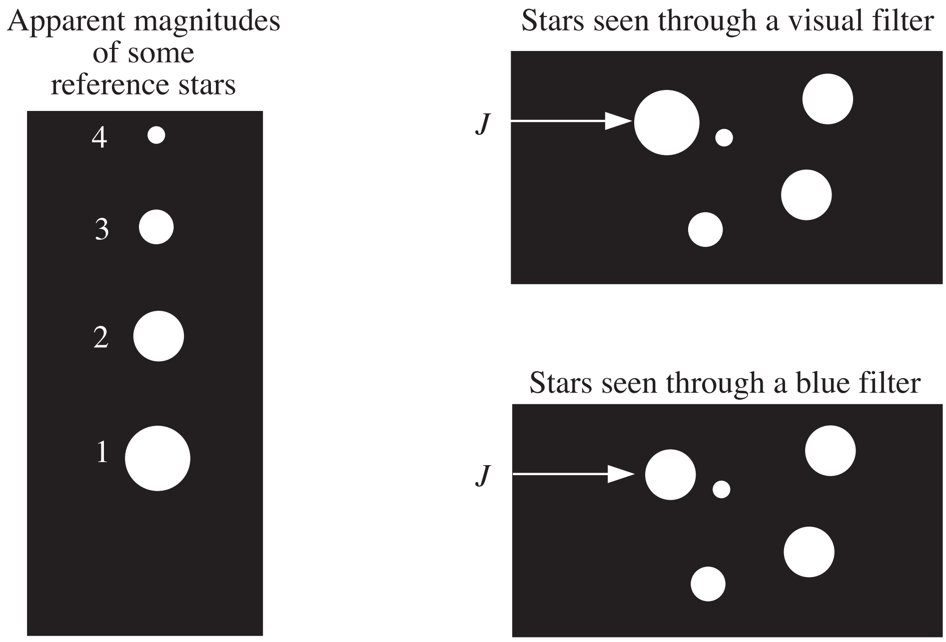
(iv) What is the Hertzsprung–Russell diagram telling us about the age of the cluster shown above? Explain.

(v) Find the distance to the star cluster, given that star *T* has an absolute magnitude of 4·8.

Question 36 continues on page 54

QUESTION 36. (Continued) **Marks**

(e) The simplified diagram below shows photographs of some stars viewed through a visual filter and through a blue filter. **3**

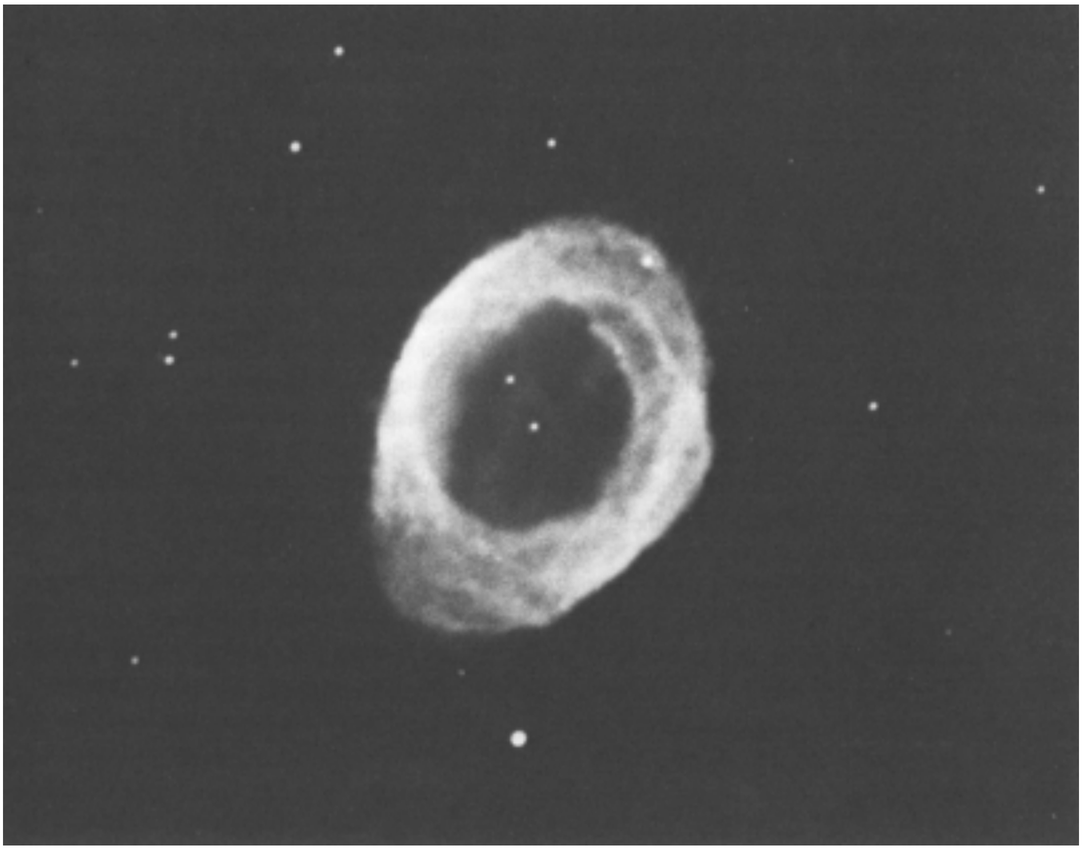


(i) Calculate the colour index of star *J* from the photographs. Show your working.

(ii) Astronomers also study the spectra of stars so that they can determine surface temperatures. Explain why stars with hotter surface temperatures exhibit fewer spectral lines than stars with cooler surfaces.

QUESTION 36. (Continued) **Marks**

(f) Below is a photograph of the Ring Nebula. **1**



Courtesy Palomar Observatory, Mt Palomar, US.

Explain how this nebula could have been formed.

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PHYSICS DATA SHEET

Numerical values of several constants

Avogadro's constant, N_A	$6{\cdot}022 \times 10^{23}$ mol^{-1}
Elementary charge, e	$1{\cdot}602 \times 10^{-19}$ C
Faraday constant, F	96 490 C mol^{-1}
Gas constant, R	8·314 J K^{-1} mol^{-1} 0·0821 L-atm K^{-1} mol^{-1}
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
Volume of 1 mole of ideal gas at 101·3 kPa (1 atm) and at 0°C (273 K) at 25°C (298 K)	 22·41 litre 24·47 litre
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9·8 m s^{-2}
Speed of light, c	$3{\cdot}00 \times 10^{8}$ m s^{-1}
Ampère's constant, $\left(\frac{\mu_0}{2\pi}\right)$	2×10^{-7} N s^2 C^{-2}
Universal gravitational constant, G	$6{\cdot}7 \times 10^{-11}$ 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 931·5 MeV/c^2
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 Atomic Mass	79 Au 197·0 Gold	Symbol of element 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.