BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1999

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 either blue or black pen 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

Instructions for answering multiple-choice questions

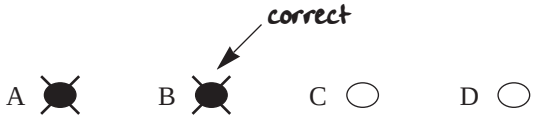
- Complete your answers in either blue or black pen.
- Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ~~correct~~ and drawing an arrow as follows.



1 An air traffic controller observes two aeroplanes travelling horizontally. She measures the velocity of the first plane as 200 m s^{-1} north and the velocity of the second plane as 150 m s^{-1} east.

The velocity of the first aeroplane, relative to the second, is closest to

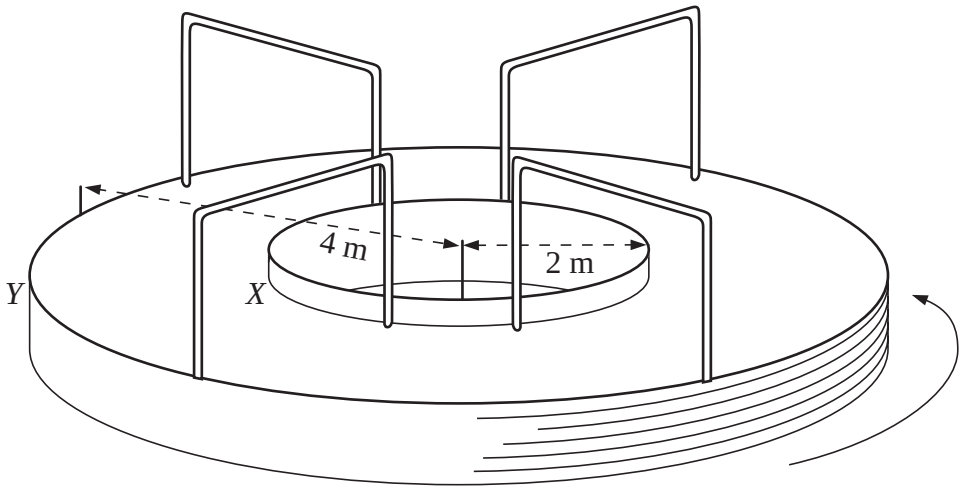
(A) 250 m s^{-1} N37°E

(B) 250 m s^{-1} N37°W

(C) 350 m s^{-1} N37°E

(D) 350 m s^{-1} N37°W

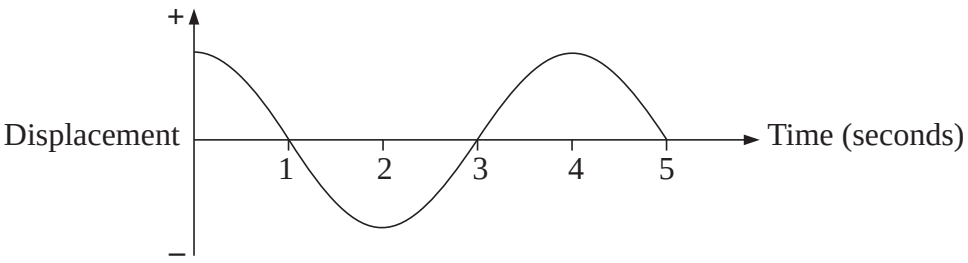
2 A merry-go-round may be represented as shown in the diagram. *X* is a point on the inner edge and *Y* is a point on the outer edge.



When the merry-go-round is spinning, which pair of the following ratios is correct?

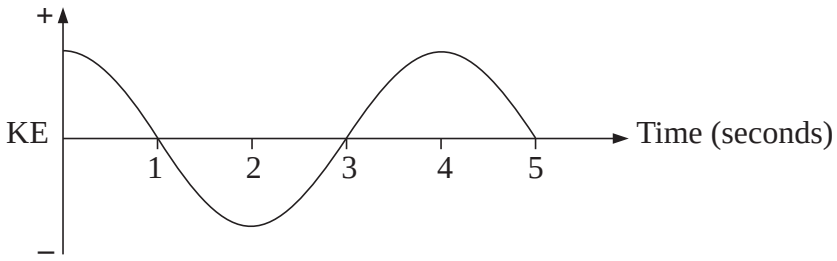
	$\frac{\textit{Angular velocity of X}}{\textit{Angular velocity of Y}}$	$\frac{\textit{Linear velocity of X}}{\textit{Linear velocity of Y}}$
(A)	1 : 1	1 : 1
(B)	1 : 1	1 : 2
(C)	1 : 2	1 : 2
(D)	1 : 2	1 : 1

3 The following graph shows how the displacement of an object changes with time as it undergoes simple harmonic motion.

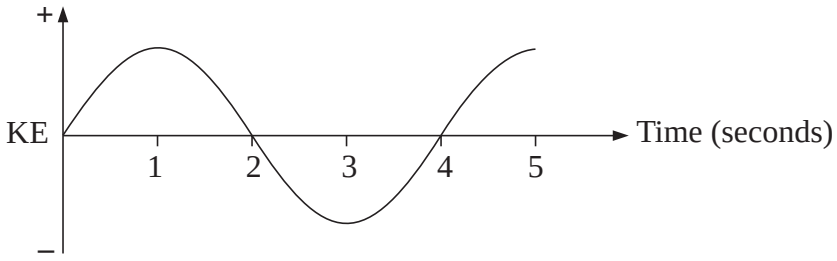


Which one of the following graphs correctly shows how the kinetic energy (KE) of the object varies with time?

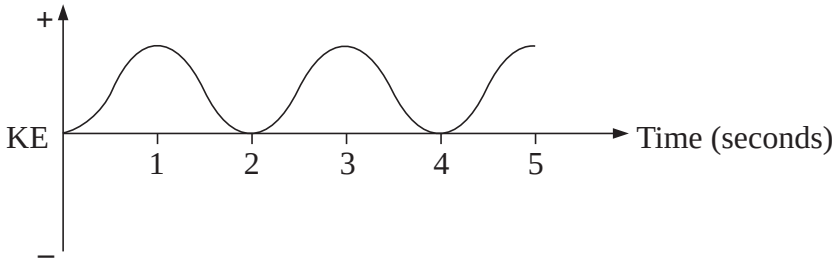
(A)



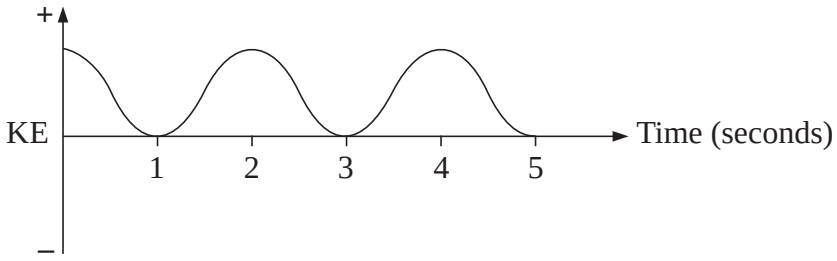
(B)



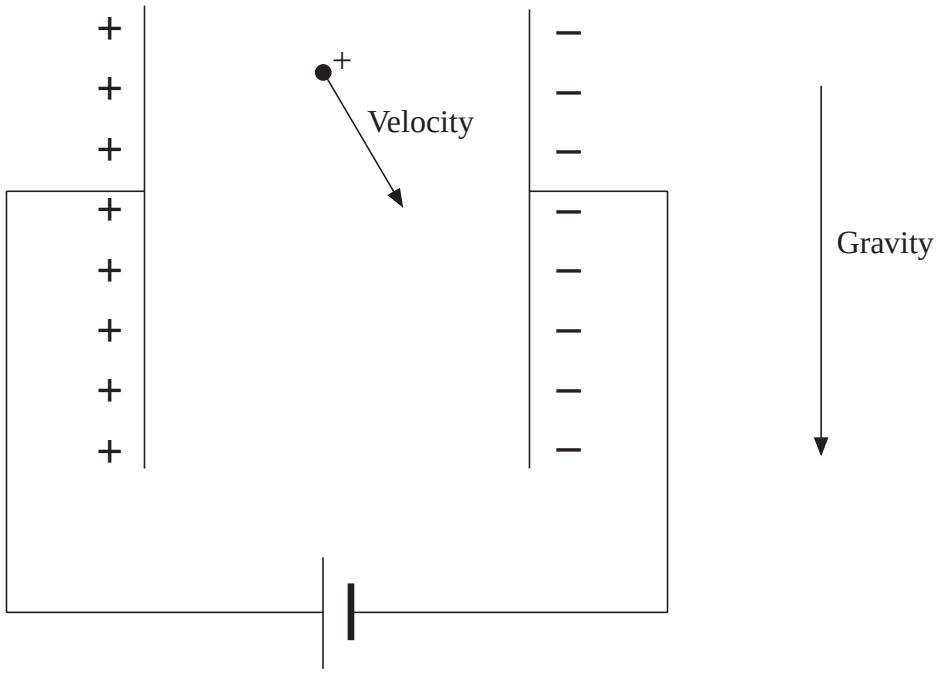
(C)



(D)



4 A small positively charged sphere is projected into the region between two vertical charged parallel plates as shown. Air resistance can be ignored.



While the sphere remains in the region of the uniform electric field between the charged plates, the *vertical component* of its acceleration will be

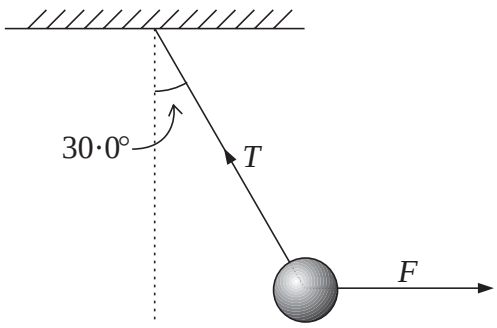
(A) less than the acceleration due to gravity.

(B) equal to the acceleration due to gravity.

(C) greater than the acceleration due to gravity.

(D) dependent on the mass of the sphere.

5 An object of weight 10·0 N is attached to a string. It is held aside by a horizontal force F to make an angle of 30·0° to the vertical as shown in the diagram.



The magnitude of the tension T in the string is

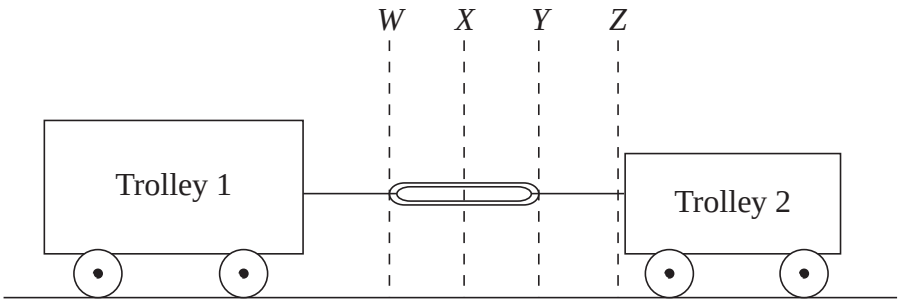
(A) 8·66 N

(B) 10·0 N

(C) 11·5 N

(D) 20·0 N

6 Two frictionless trolleys are pulled apart so that an elastic band connecting them is stretched. Trolley 1 has a mass three times greater than the mass of trolley 2. Position X is the midpoint of the separation between the trolleys.



The trolleys are then released simultaneously.

The position where they are most likely to collide is

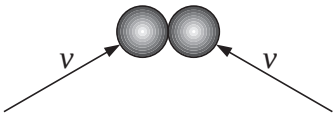
(A) position W.

(B) position X.

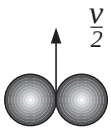
(C) position Y.

(D) position Z.

7 Two objects with equal mass, travelling with equal speed v, collide as shown in the diagram.



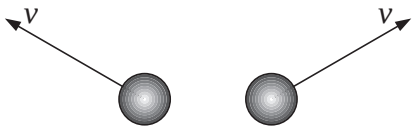
Which one of the following diagrams represents a possible outcome of the collision if momentum is conserved but kinetic energy is not conserved?

(A) 

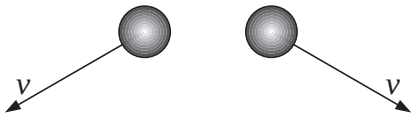
The objects stick together and move as shown.

(B) 

The objects stick together and remain at rest.

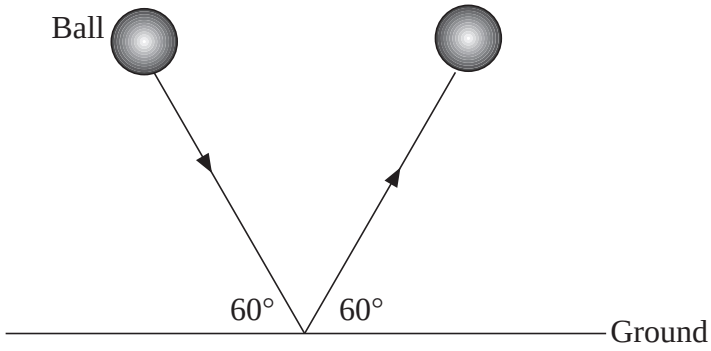
(C) 

The objects move apart as shown.

(D) 

The objects move apart as shown.

8 A ball is bounced on the ground as shown in the diagram.



The change in momentum of the *ground* is

(A) half the magnitude of the change in momentum of the ball.

(B) twice the magnitude of the change in momentum of the ball.

(C) the same magnitude as the change in momentum of the ball, and in the same direction.

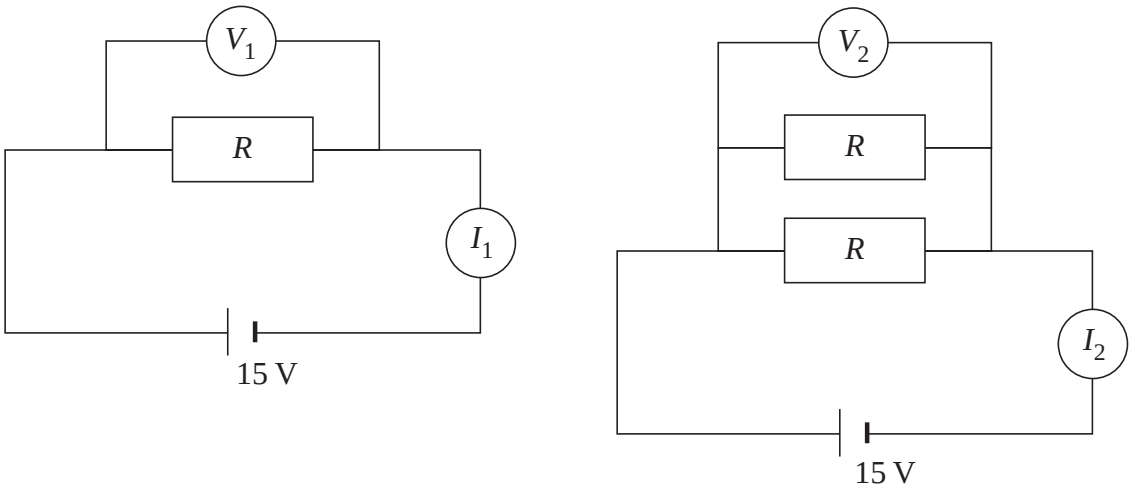
(D) the same magnitude as the change in momentum of the ball, and in the opposite direction.

9 Ten party lights, each rated at 10 watts, are connected in series in a circuit with a 240 volt power supply.

The potential difference across, and current through, each globe in the circuit are closest to

	Potential difference (V)	*Current* (A)
(A)	240	2·4
(B)	240	0·42
(C)	24	2·4
(D)	24	0·42

10 The following diagrams represent two simple circuits. *R* represents identical resistors in each circuit.



V_1 and V_2 are readings from ideal voltmeters. I_1 and I_2 are readings from ideal ammeters.

Which of the following statements is true?

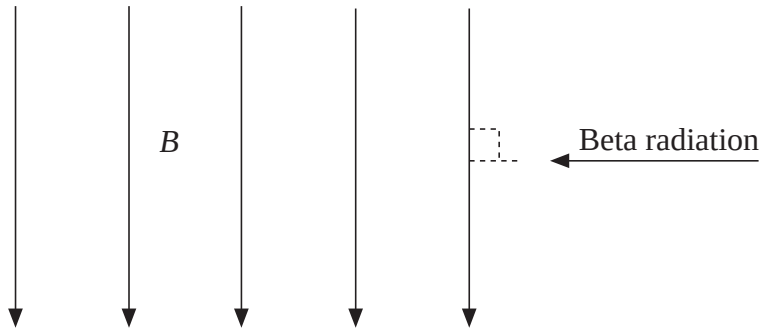
(A) $V_2 = V_1$ and $I_2 > I_1$

(B) $V_2 = V_1$ and $I_2 < I_1$

(C) $V_2 > V_1$ and $I_2 > I_1$

(D) $V_2 > V_1$ and $I_2 < I_1$

11 A narrow beam of beta radiation is injected into a region in which a uniform magnetic field is directed vertically downward. The path of the beta radiation is initially perpendicular to the direction of the magnetic field.



When the beta radiation enters the field it will

(A) remain undeflected.

(B) be deflected out of the page.

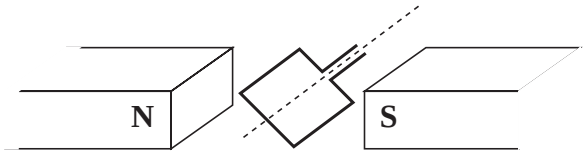
(C) be deflected into the page.

(D) be deflected up the page.

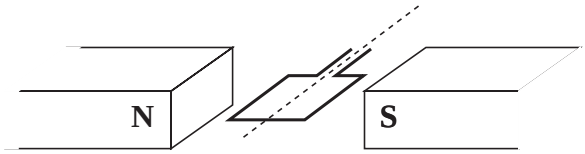
12 A coil of wire is in a uniform magnetic field between two magnets. The coil of wire is rotated about an axis.

In which of the following diagrams is the magnetic flux through the coil greatest?

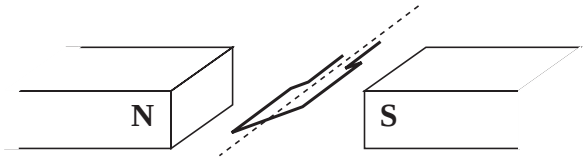
(A)



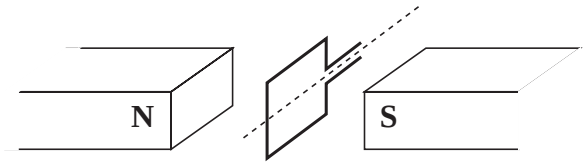
(B)



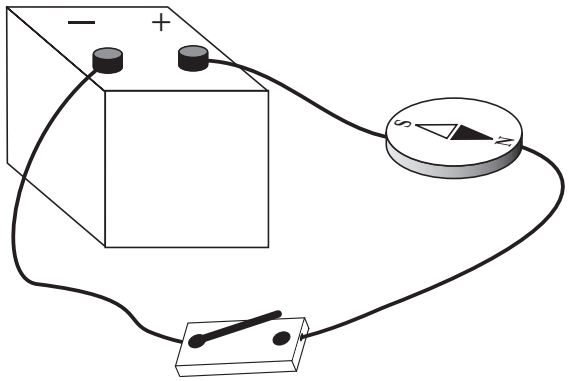
(C)



(D)

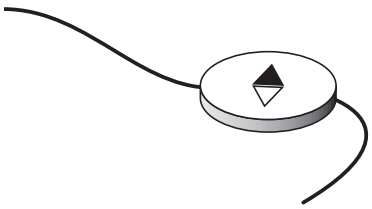


13 A battery and a switch are connected in a circuit. A compass is placed on top of one of the wires as shown.

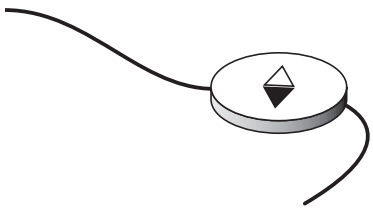


Which one of the following diagrams best represents the direction in which the compass will point when the switch is closed?

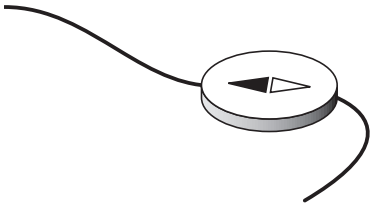
(A)



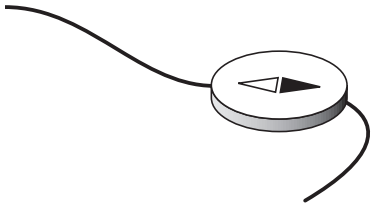
(B)



(C)



(D)



14 A wine glass is shown below.

When a vibrating tuning fork is held a short distance from the open end of the wine glass a loud sound is heard coming from the wine glass.

This effect is due to

(A) diffraction.

(B) dispersion.

(C) refraction.

(D) resonance.

15 Two loudspeakers are placed 10 m apart and are directed towards each other. Each speaker broadcasts at $3{\cdot}4 \times 10^3$ Hz to form a standing wave along a line joining the two speakers. A small microphone is placed midway between the speakers on the line joining them and then moved along the line.

The microphone would detect

(A) a constant high intensity at all points along the line.

(B) zero intensity at all points along the line.

(C) consecutive antinodes spaced 5·0 cm apart.

(D) consecutive antinodes spaced 10·0 cm apart.

PART B

Questions 16–25 are worth 3 marks each.

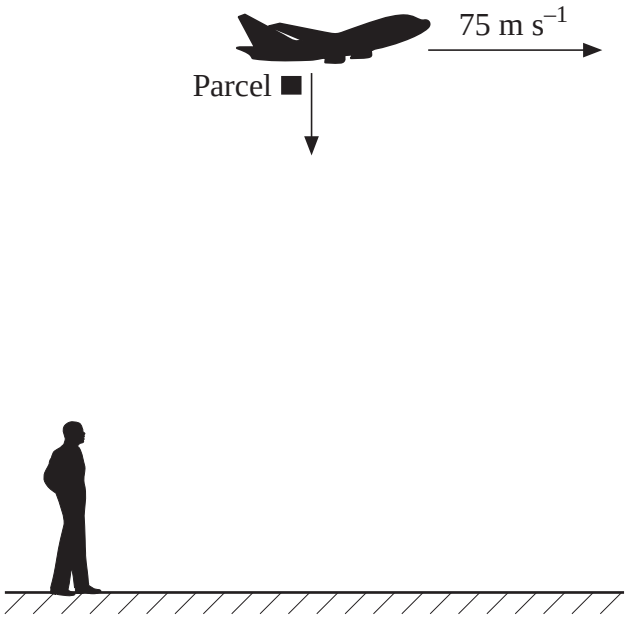
Answer this Part in the Part B Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

16 A parcel is dropped from a plane flying overhead with a constant horizontal velocity of 75 m s^{-1} east.

A person on the ground observes the parcel, which takes 20 seconds to reach the ground.



NOT TO SCALE

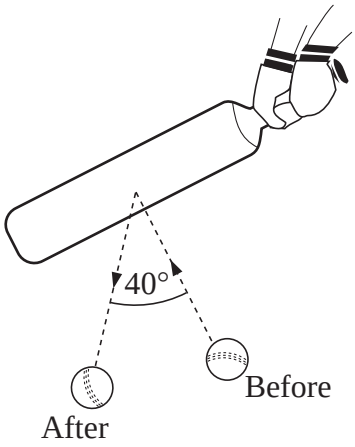
(a) Describe in words the motion of the parcel relative to:

(i) the plane;

(ii) the person on the ground.

(b) How high above the ground was the plane when the parcel was dropped? (Ignore air resistance.)

17 A cricket ball is hit by the player as shown below.



The cricket ball has an initial *horizontal* velocity of 5·0 m s^{-1} north. After being hit, it has a *horizontal* velocity of 8·0 m s^{-1} S40°W.

(a) What is the change in the *horizontal* velocity of the ball?

A fielder is running at 6·0 m s^{-1} at right angles to the direction of the ball after it has been hit.

(b) What is the magnitude of the *horizontal* velocity of the ball relative to the fielder after it has been hit?

18 A girl of mass 40·0 kg slides at a constant speed down a slippery dip inclined at 22° to the horizontal.

A scaled vector diagram representing the weight (*W*) of the girl and the normal force (*N*) is provided in your Part B Answer Book.

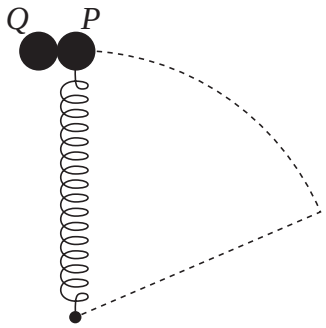
(a) (i) Complete the vector diagram showing the magnitude and direction of the force of friction (*F*).

(ii) Determine the magnitude of the force of friction.

(b) Suppose the girl accelerated down the incline at 1·84 m s^{-2} instead of moving at constant speed, because of a decrease in friction.

Calculate the magnitude of the change in friction.

19 A spherical object *P* of mass 0·25 kg is attached to the end of a stretched, lightweight spring. *P* moves in a horizontal circle of radius 0·25 m with a speed of 2·0 m s^{-1} on a frictionless table as shown below.



At some point the mass *P* collides elastically with an identical mass *Q* placed at rest on the table. Mass *Q* is free to move.

(a) Calculate the centripetal force on *P* before the collision.

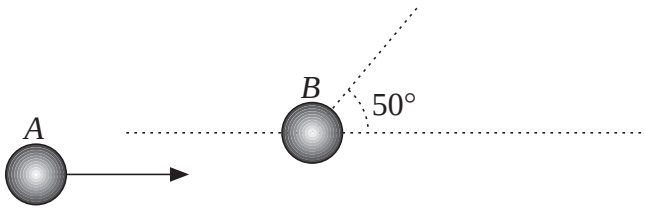
(b) Describe in words the motion, after the collision, of:

(i) *P*;

(ii) *Q*.

20 Two smooth balls each of mass 150 g are on a table. Ball *A*, moving at 0·50 m s^{-1}, strikes a glancing blow to ball *B* which is initially stationary.

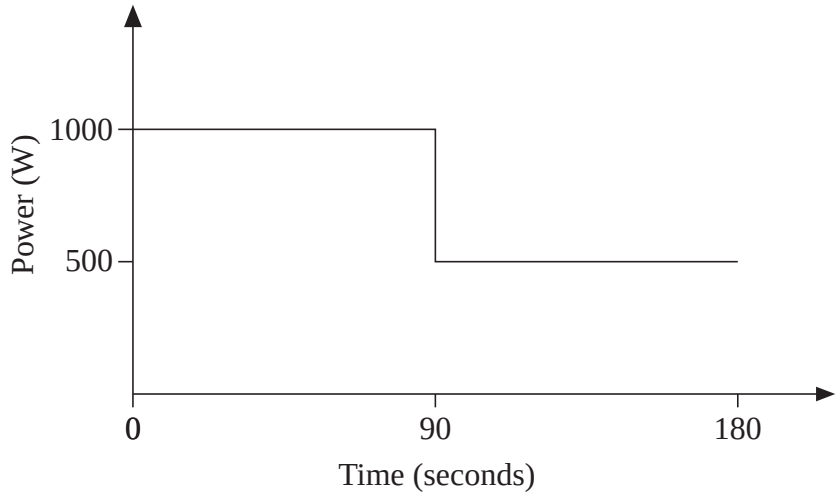
The collision is elastic. After the collision, ball *B* moves off at 0·32 m s^{-1} at an angle of 50° to the original direction of ball *A*.



(a) Calculate the initial momentum of ball *A*.

(b) What is the velocity of ball *A* after the collision?

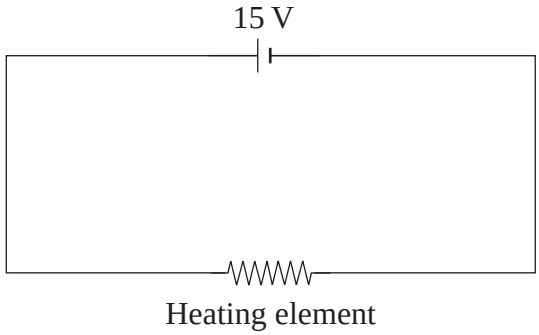
21 An electrical appliance runs off a 240 V supply. A graph of power versus time for this appliance is shown below.



(a) Use the graph to determine the energy dissipated by the appliance in the first 180 seconds.

(b) What is the resistance of the appliance when its power consumption is 1000 W?

22 A power supply is connected to a heating element as shown in the following diagram. The potential difference at the power supply terminals is 15 volts.



(a) Write down a unit, equivalent to the volt, in terms of the unit of electric charge and the unit of energy.

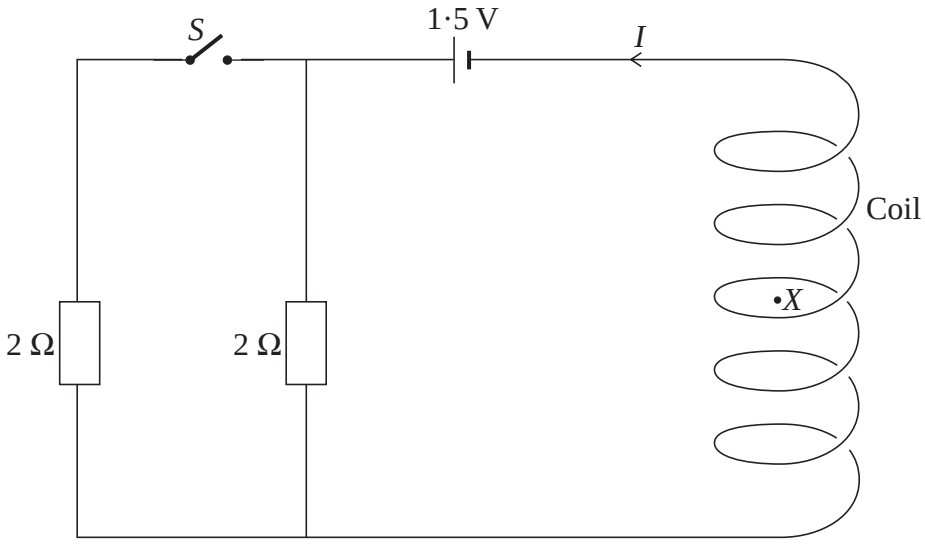
(b) A total of $5{\cdot}0 \times 10^{20}$ electrons pass any point in the heating element circuit in 40 seconds. Calculate the amount of energy dissipated in the circuit.

(c) The power supply is now changed so that 8·0 coulombs of charge flows into the heating element in 2·0 seconds.

(i) Calculate the current flowing into the element.

(ii) Compare this value to the current flowing out of the element.

23 This question refers to the following diagram.



Two resistors are connected into a circuit with a cell, a coil and a switch *S*. Assume that the resistance of the coil is negligible.

In the diagram, switch *S* is shown open.

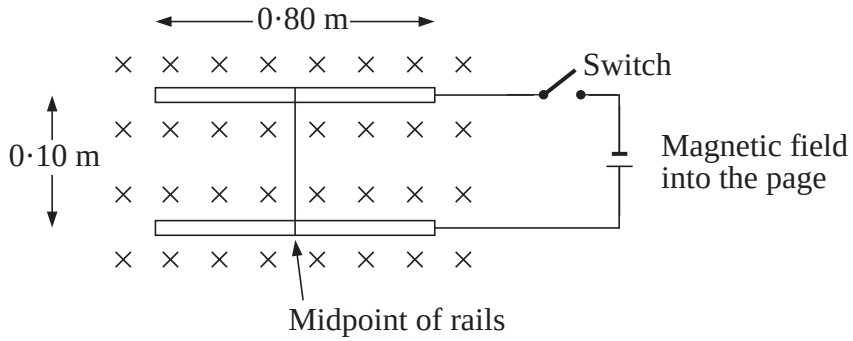
(a) On the diagram in the Part B Answer Book, draw ONE arrow through point *X*, which is inside the coil, to show the direction of the magnetic field of the coil at that point.

The switch is then closed.

(b) State whether the current *I* flowing in the coil will increase, decrease, or remain unchanged. Explain your answer.

(c) State what change, if any, will occur in the strength of the magnetic field of the coil at point *X*. Explain your answer. (Calculations are not required.)

24 Two conducting parallel rails are situated in a region of a permanent magnetic field and connected to a battery via a switch. A narrow conducting slider is laid across the rails at the midpoint of the rails as shown in the diagram.

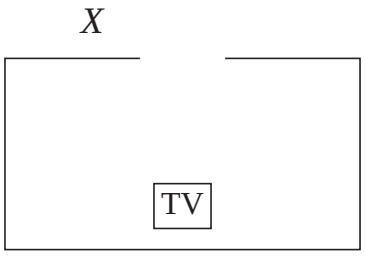


The strength of the magnetic field is 0·50 T and the slider is initially at rest. When the switch is closed a current of 20 A flows through the slider.

(a) Calculate the magnetic force acting on the slider. Give the magnitude and direction.

(b) The mass of the slider is 0·040 kg and the force of friction from the rails is 0·36 N. Calculate the velocity of the slider as it comes off the rails.

25 A television is turned on in a room with an open door.



Sound waves from the television reach a person standing at position *X*, due partially to diffraction.

(a) Explain why the sound waves can reach the person due to diffraction, but light waves do not.

(b) On the diagram in your Part B Answer Book, sketch the pattern of wavefronts caused by the diffraction of sound waves. Assume a single frequency of sound waves for the diffraction pattern.

(c) Sound waves are able to pass through the walls of the room. Compare the speed of sound waves in air and the walls.

PART C

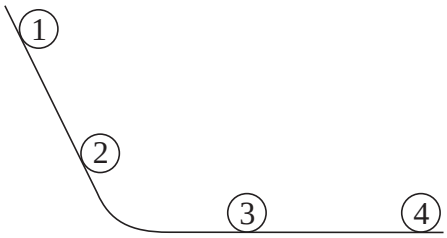
Questions 26–31 are worth 5 marks each.

Answer this Part in the Part C Answer Book.

Show all necessary working.

Marks may be awarded for relevant working.

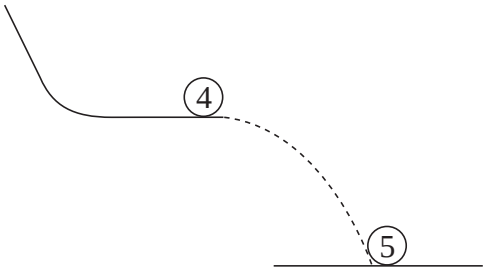
26 A ball is released at position ①. It rolls down an incline and along a flat horizontal section, as illustrated in the diagram.



(a) The ball is in positions ① to ④ at different times in its journey. The instantaneous velocity and acceleration have been drawn for some positions in the table. Complete the table given in the Part C Answer Book for positions ② to ④.

	Position			
	①	②	③	④
Instantaneous velocity	Zero	↘	→	
Acceleration	↘			

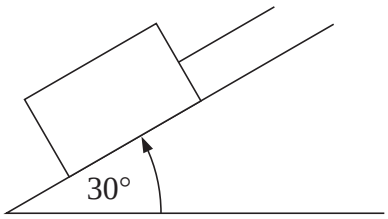
(b) Suppose the ball leaves the ramp at ④ with a speed of 3·0 m s^{-1} and falls to the floor at position ⑤ in 0·50 s as shown.



(i) Calculate the horizontal distance from position ④ to position ⑤.

(ii) Calculate the angle the path of the ball makes with the ground when it strikes at position ⑤.

27 A 3·7 kg box is initially held stationary on a slope at 30° by a lightweight inextensible string. Ignore friction.



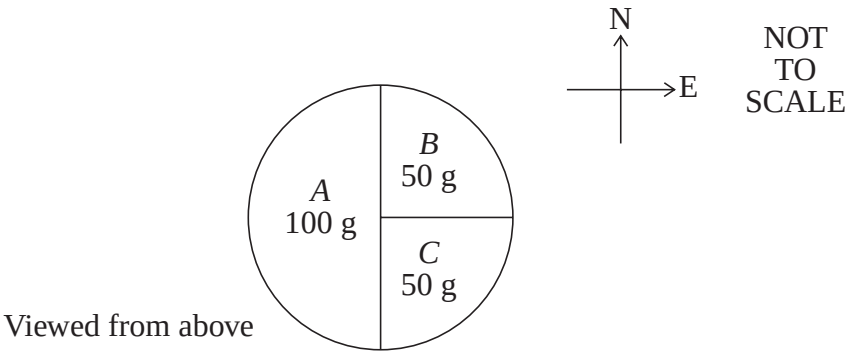
(a) Determine the tension in the string when the box accelerates up the slope with a magnitude of 1·7 m s^{-2}.

(b) Describe the motion of the box when the tension in the string is 16 N. (Show working to support your answer.)

The tension in the string and the angle of the slope can be changed in order to observe the motion of the box under different conditions.

(c) The box accelerates up the slope when the tension in the string is 35 N and the slope is at 30°. If the slope is changed to 50°, must the tension in the string be larger or smaller to keep the same acceleration? Explain your answer.

28 A firework is shot vertically into the air. At the point of its maximum height it is momentarily at rest. At this point it explodes into three fragments as indicated in the diagram.



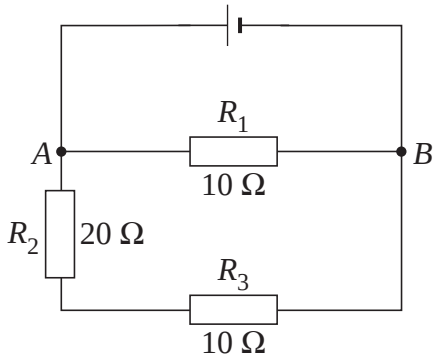
Fragment *A* (mass 100 g) moves west at an initial horizontal velocity of 100 m s^{-1}. Fragment *C* (mass 50 g) moves south at an initial horizontal velocity of 200 m s^{-1}.

(a) Find the velocity of fragment *B* immediately after the explosion.

(b) (i) Calculate the total kinetic energy after the explosion.

(ii) Has kinetic energy been conserved? Explain your answer.

29 Three resistors, R_1, R_2 and R_3, are connected into a circuit with a dc power supply. This is shown in the diagram.



(a) State which of the resistors, if any, are connected:

(i) in series;

(ii) in parallel.

The current through R_2 is 0·50 A.

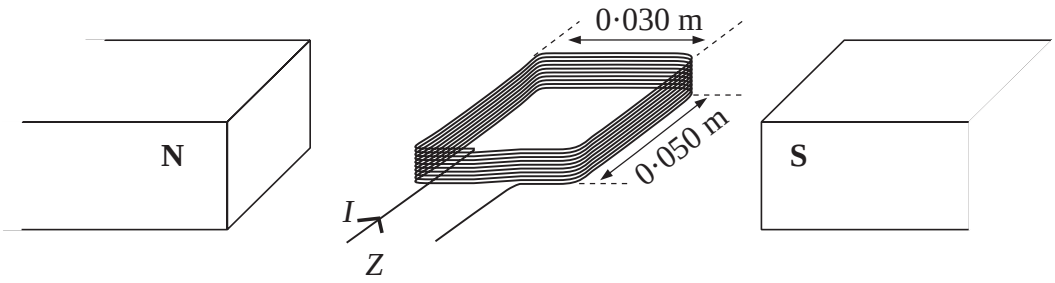
(b) Calculate the voltage of the power supply.

(c) Calculate the current in R_1.

(d) Calculate the effective resistance of the combination of these three resistors.

Please turn over

30 A coil consists of ten turns of insulated copper wire. It is placed between the poles of magnets as shown in the diagram. These magnets may be assumed to create a uniform magnetic field of flux density 0·15 T.



A current of 2·0 A is passed through the coil in the direction shown.

(a) Calculate the torque that acts on the coil when it is in the position shown in the diagram.

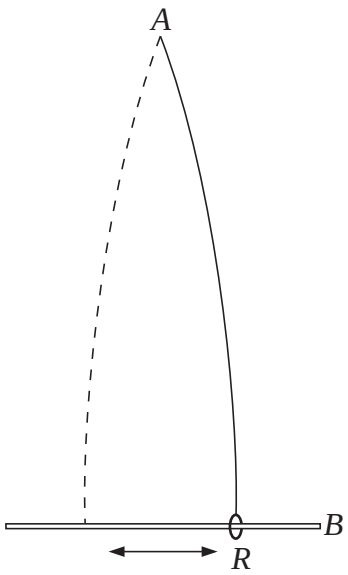
(b) In what direction will the coil start to turn as seen from position *Z*?

(c) A device is placed at *Z* to allow current to be supplied to the coil so that the coil rotates continuously.

(i) Name the device.

(ii) Explain how it works.

31 A lightweight string is connected between a solid support *A* and a ring *R*. The ring is free to move on a smooth horizontal rigid bar *B* perpendicular to the string. The length of the string is 0·90 m.



The ring is made to vibrate along the bar. When the frequency of vibration of the ring is 65 Hz, the string vibrates in its fundamental mode.

(a) Explain the similarity between the standing waves in this string and the standing waves in air in a tube closed at one end.

(b) Calculate the wavelength of the standing wave associated with the fundamental mode of resonance of the string.

(c) Draw a diagram to illustrate the vibration of the string in its first overtone (third harmonic).

(d) Calculate the frequency of vibration of the iron ring that would cause the string to vibrate in its first overtone (third harmonic).

(e) Calculate the distance from the solid support *A* to the closest antinode while the string is vibrating in its first overtone.

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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 this half-elective in a SEPARATE Elective Answer Book.

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

(a) Aristotle firmly believed that the heavens must be spherical. **4**

> 'The heaven, moreover, must be a sphere, for this is the only form worthy of its essence . . .'

However, he was less certain about the nature of the Earth.

> 'It remains to discuss the Earth where it is situated, whether it is at rest or moves, and what is its form.'

(i) The question of the position of the Earth led to two opposing models—heliocentric and geocentric.

1. What is meant by *geocentric model*?

2. Give ONE reason why this model was accepted.

(ii) Kepler was able to further improve our understanding of the 'nature of the Earth' through the development of his three laws.

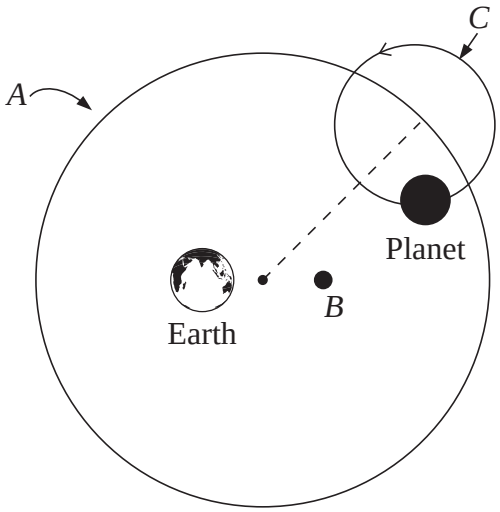
1. State either Kepler's first or second law.

2. Give ONE piece of observational evidence that supports this law.

Question 32 A continues on page 27

QUESTION 32 (Continued) **Marks**

(b) A model put forward by Ptolemy to explain the motion of planets had the following features: **3 1/2**



(i) Name the parts of the model labelled *A*, *B* and *C*.

Ptolemy was able to explain the variation in apparent speed of a planet's motion in the sky.

(ii) What was the function of *C* in the explanation?

(iii) What was the function of *B* in the explanation?

(c) Newton's law of universal gravitation can be expressed mathematically as **5**

$$F = \frac{Gm_1m_2}{r^2}.$$

(i) With the aid of a clearly labelled diagram, show the meaning of the symbols used in this equation.

(ii) The acceleration due to gravity at the surface of the Earth and at the surface of Saturn are approximately the same. The mass of Saturn is approximately 100 times that of the Earth. What is the ratio of the radius of Saturn to the radius of the Earth?

(iii) The parallax of Mars was measured in 1673, from which the radius of the Earth's orbit was deduced.

Using this information and other observations, explain how the radii of the orbits of all the planets were deduced. (Hint: Use Kepler's third law.)

Question 32 continues on page 28

QUESTION 32 (Continued) **Marks**

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

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

(a) The corpuscular and wave models of light are proposed to explain the properties of light. Two properties of light are: **$2\frac{1}{2}$**

- refraction;
- reflection.

(i) Choose ONE of these properties and explain it in terms of the:

1 corpuscular model;

2 wave model.

(ii) The modern theory of light recognises the dual properties of light. Name ONE property of light other than reflection or refraction that is better explained by the wave theory of light.

(b) In 1801, Young used light from a single slit to illuminate a pair of closely spaced slits. The pattern of light from the two slits was observed on a distant screen. **3**

(i) Describe the pattern that Young observed on the screen.

(ii) Describe the pattern predicted by the corpuscular model of light.

(iii) Fresnel extended the work of Young. Outline the improvements made by Fresnel.

Question 32 B continues on page 29

QUESTION 32 (Continued) **Marks**

(c) (i) What is the quantum model of light? **3**

(ii) What contribution did Planck make to the quantum model of light?

(iii) Explain how Einstein further developed the quantum model of light.

(d) Monochromatic light of wavelength 650 nm is incident on a clean sodium surface of work function $3{\cdot}7 \times 10^{-19}$ J. **4**

(i) Determine the energy of a photon of this light.

(ii) Would the photoelectric effect be evident in this sample? Explain your answer.

(iii) The intensity of this light is now increased. How does this affect the emission of electrons from the sodium surface? Explain your answer.

Question 32 continues on page 30

QUESTION 32 (Continued) **Marks**

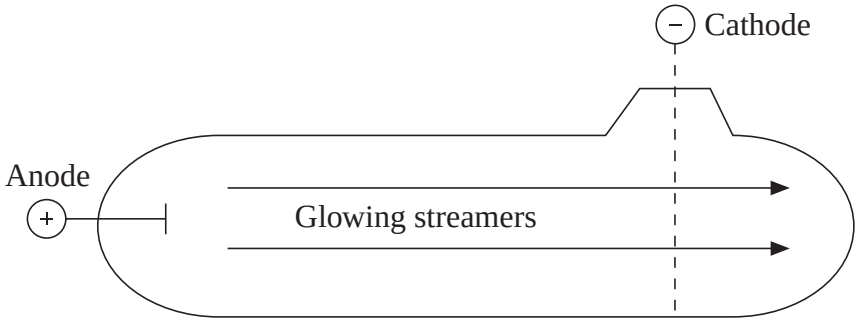
Answer this half-elective in a SEPARATE Elective Answer Book.

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

(a) Experiments with gas discharge tubes led to a greater understanding of the atom. **$3\frac{1}{2}$**

(i) What was Heinrich Geissler's contribution to the development of gas discharge tubes?

(ii) In the mid-1880s experiments on the discharge of gases at low pressures were carried out using a tube containing a cathode with holes as shown:



Glowing streamers were noted coming out from the anode, travelling in the direction shown.

1 What name was given to these *glowing streamers*?

2 Thomson later gathered further evidence on the nature of these streamers and compared them to electrons.

Give ONE piece of evidence that Thomson used to determine the nature of these streamers. How did the streamers compare with electrons?

(b) In about 1903, models for the atom were proposed by Lenard and Thomson. **5**

(i) Draw a labelled diagram to illustrate the features of Thomson's model.

(ii) How did Thomson's model differ from that proposed by Lenard.

(iii) Briefly outline ONE experimental investigation that led to the rejection of the Thomson model.

Question 32 C continues on page 31

QUESTION 32 (Continued) **Marks**

(c) Neils Bohr in 1913 proposed a model of the hydrogen atom that successfully explained the formation of observable lines in the spectrum. **4**

(i) Outline Bohr's model of the atom. Explain how it accounted for spectral lines. A diagram may assist in your answer.

(ii) Using the Rydberg equation, calculate the wavelength of green light in the spectrum of hydrogen for the transition from the fourth to the second energy level.

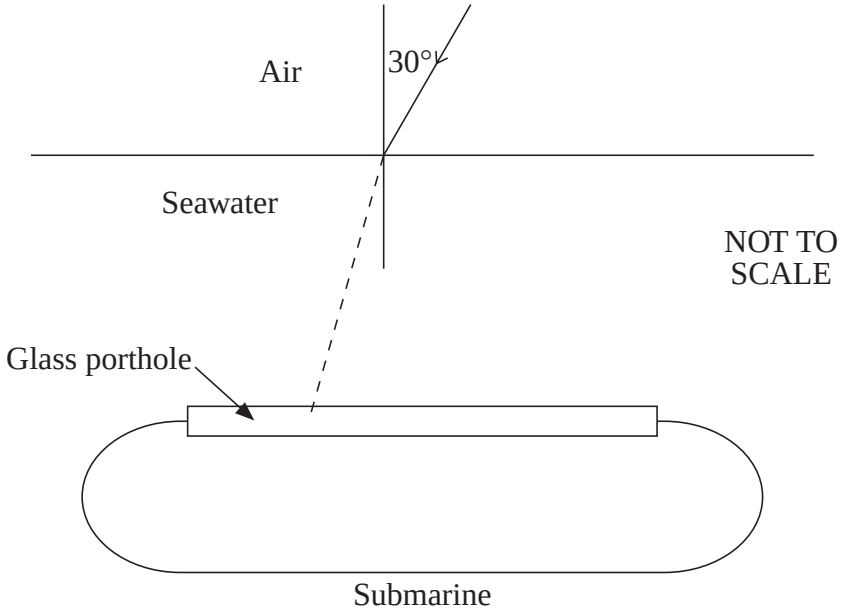
End of question

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

(a) Draw a diagram to show how Huygens' principle can be used to explain reflection at a plane interface between air and glass. Label your diagram fully. **2**

(b) Explain the function of the prism and the telescope in a prism spectrometer. **2**

(c) A ray of light passes from air (refractive index of 1·0) into seawater at an angle as shown, before passing into a glass porthole of a submarine. Seawater has a refractive index of 1·4 and the glass porthole has a refractive index of 1·6. **3**



(i) Calculate the relative refractive index for light passing from the seawater into the glass.

(ii) At what angle does the light ray refract when passing into the glass porthole if the porthole is parallel to the surface of the seawater as shown.

(d) Soda glass and Pyrex glass are both used to make laboratory glassware. One way to distinguish between the two types of glass is to immerse both in a solution of refractive index matching that of the Pyrex glass but not the soda glass. **2**

Explain how this procedure enables you to distinguish between the two types of glass.

Question 33 continues on page 33

QUESTION 33 (Continued) **Marks**

(e) In a single-slit experiment, monochromatic light falls on a narrow slit and forms a pattern on a screen beyond the slit. The width of the slit can be varied, while the slit remains at a constant distance from the screen. **3**

Compare the pattern formed on the screen when the width of the slit is much smaller than the wavelength of the incident light, with the pattern formed when the width is much greater than the wavelength.

(f) A lens of refractive index 1·50 is coated with a thin film of magnesium fluoride of refractive index 1·38 to reduce reflection from the surface. **2**

Determine the minimum thickness for a coating that will maximise transmission at a wavelength of 550 nm.

(g) In a Young's double-slit experiment an interference pattern is formed on a screen 1·20 m from the slits. Explain what will happen to the separation between the interference fringes if the screen is moved closer to the slits. **2**

(h) A monochromatic light source is incident normally on two diffraction gratings *X* and *Y*. **2**

The slit spacing of grating *X* is 1·86 μm and a first order line at $\theta = 19{\cdot}4°$ is obtained. The slit spacing of grating *Y* is not known but a first order line for the same light occurs at $\theta = 22{\cdot}1°$. What is the slit spacing of grating *Y*?

(i) (i) Describe a simple way to distinguish a pair of polarising sunglasses from a non-polarising pair. **5**

(ii) Using a diagram, explain how polarising sunglasses aid vision in cases where sunlight is reflected from a horizontal surface, such as water.

(iii) A beam of plane-polarised light is incident at right angles on a polarising filter. The polarising axis of the filter is rotated at 40° with respect to the plane of polarisation of the incident light.

If the intensity of light passing through the filter is *I*, calculate the intensity of the incident plane-polarised light.

Question 33 continues on page 34

QUESTION 33 (Continued) **Marks**

(j) A spectral line of frequency $6{\cdot}00 \times 10^{14}$ Hz is found in the spectrum of a gas on Earth. The same line has a frequency of $1{\cdot}71 \times 10^{14}$ Hz when found in the spectrum of a galaxy. **2**

(i) Determine the velocity of the galaxy using the Doppler effect equation:

$$f_o = f_s \left[\frac{1 + \frac{v}{c}}{\sqrt{1 - \frac{v^2}{c^2}}} \right]$$

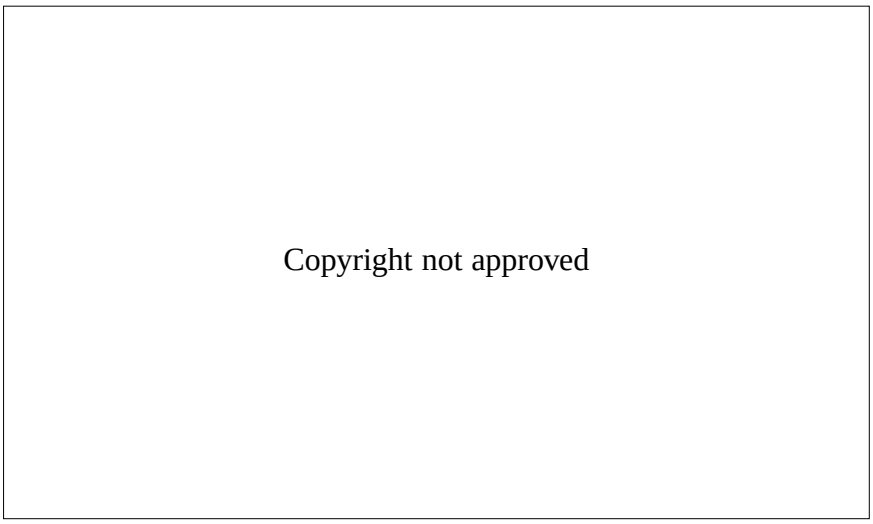
where v = relative speed of source
c = speed of light
f_o = observed frequency of light
f_s = source frequency.

(ii) Explain why the movement of the galaxy is sometimes described as a *red shift*.

End of question

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

(a) A satellite is being launched from the cargo bay of a space shuttle. The satellite may be considered to be a uniform cylinder of mass 200 kg and radius 1·2 m ($I = \frac{1}{2} MR^2$). **5**



When it is deployed, the satellite is set spinning about its long axis at 20 r.p.m. This rotation is established in 15 seconds from rest by a mechanism attached to the shuttle.

(i) Calculate the moment of inertia of the satellite.

(ii) Calculate the magnitude of the angular acceleration of the satellite during the deployment.

(iii) Calculate the magnitude of the torque provided by the mechanism on board the space shuttle.

(iv) Describe any change in the motion of the shuttle as a result of the deployment of the satellite. Explain your answer.

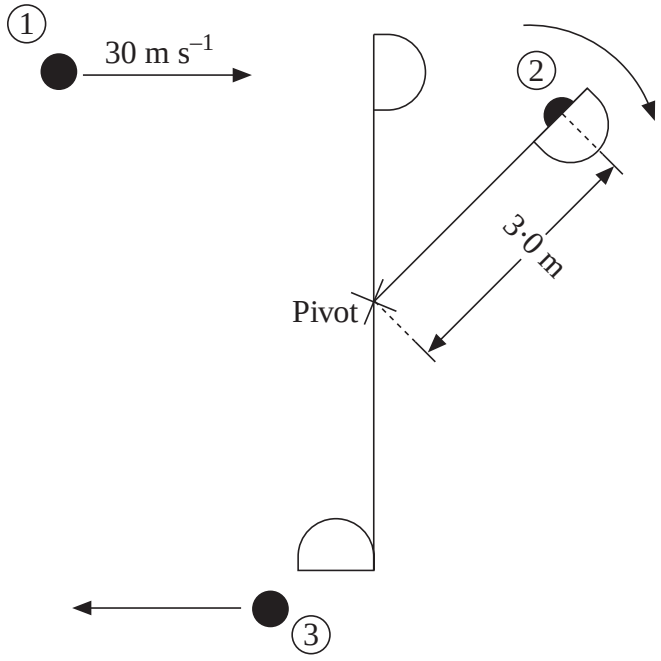
Question 34 continues on page 36

QUESTION 34 (Continued) **Marks**

(b) A ball of mass 0·15 kg may be considered to be a point mass. It travels with uniform velocity of 30 m s^{-1} towards a lightweight cup, which is connected to a pivot by a lightweight rod. The centre of the cup is 3·0 m from the pivot. **8**

When the ball is caught by the cup, the system of ball, cup and rod rotates about the pivot. The motion of the ball, cup and rod is in a horizontal plane.

Three positions of the ball, cup and rod are shown in the diagram.



(i) What is the linear momentum of the ball at position ①?

(ii) What is the angular momentum of the ball about the pivot when at position ①?

(iii) What is the angular momentum of the ball about the pivot at position ②?

Position ③ shows the position of the ball after the system has rotated 180° from its original position. The ball has been released from the cup by some mechanism and is now travelling in the opposite direction.

(iv) What is the angular momentum of the ball about the pivot?

(v) How long did it take for the system to rotate through 180°?

(vi) What is the rate of change of angular momentum of the ball?

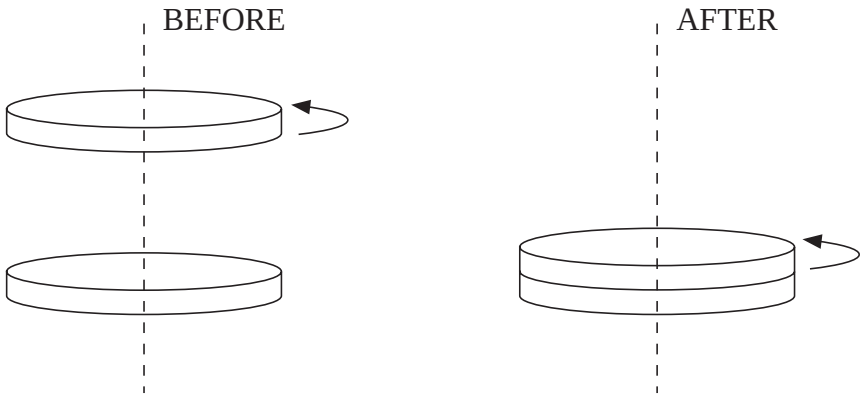
(vii) The only force acting on the system is the centripetal force provided by the tension in the rod.

Show that the value of the torque agrees with the rate of change of angular momentum of the ball that you obtained in part (b) (vi).

Question 34 continues on page 37

QUESTION 34 (Continued) **Marks**

(c) A rotating solid disc has a mass $M = 1{\cdot}6$ kg, radius $R = 0{\cdot}20$ m and angular velocity 2π rad s^{-1}. It drops onto an identical stationary disc so that they share a common axis of rotation after the collision. **5**



The moment of inertia of a disc is $\frac{1}{2}MR^2$.

(i) Calculate the angular velocity of the combined discs after the collision.

(ii) What fraction of the initial kinetic energy is lost in the collision? Show your working.

(iii) Account for the loss of kinetic energy.

(d) A solid sphere, a solid cylinder and a hollow cylinder, all of the same mass and radius, are released from rest on a rough inclined plane. The moments of inertia are $\frac{2}{5}MR^2$, $\frac{1}{2}MR^2$ and MR^2 for the sphere, solid and hollow cylinders respectively about the centres of mass. **5**

(i) State the parallel-axis theorem.

(ii) Use the parallel-axis theorem to calculate the moment of inertia of each object about its point of contact with the rough plane.

Assuming that the gravitational torque on each object is the same:

(iii) what is the ratio of the largest to smallest angular acceleration about the point of contact of object and plane? Show your working.

If each object travels the same distance down the incline:

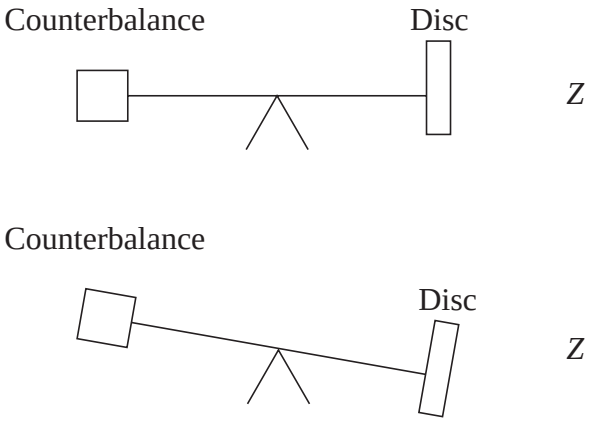
(iv) what is the ratio of the largest to smallest rotational kinetic energy about the point of contact? Show your working.

Question 34 continues on page 38

QUESTION 34 (Continued) **Marks**

(e) A counterbalanced spinning gyroscope is displaced from its horizontal position by a vertically upward bump on the counterbalance, as shown in the diagram. Thereafter, there is no external torque on the gyroscope. **2**

The disc is seen spinning clockwise when viewed from position *Z*.



(i) Draw an angular momentum vector diagram to show the initial and displaced spin angular momenta of the gyroscope.

(ii) Describe the subsequent motion of the gyroscope that results from the bump.

End of question

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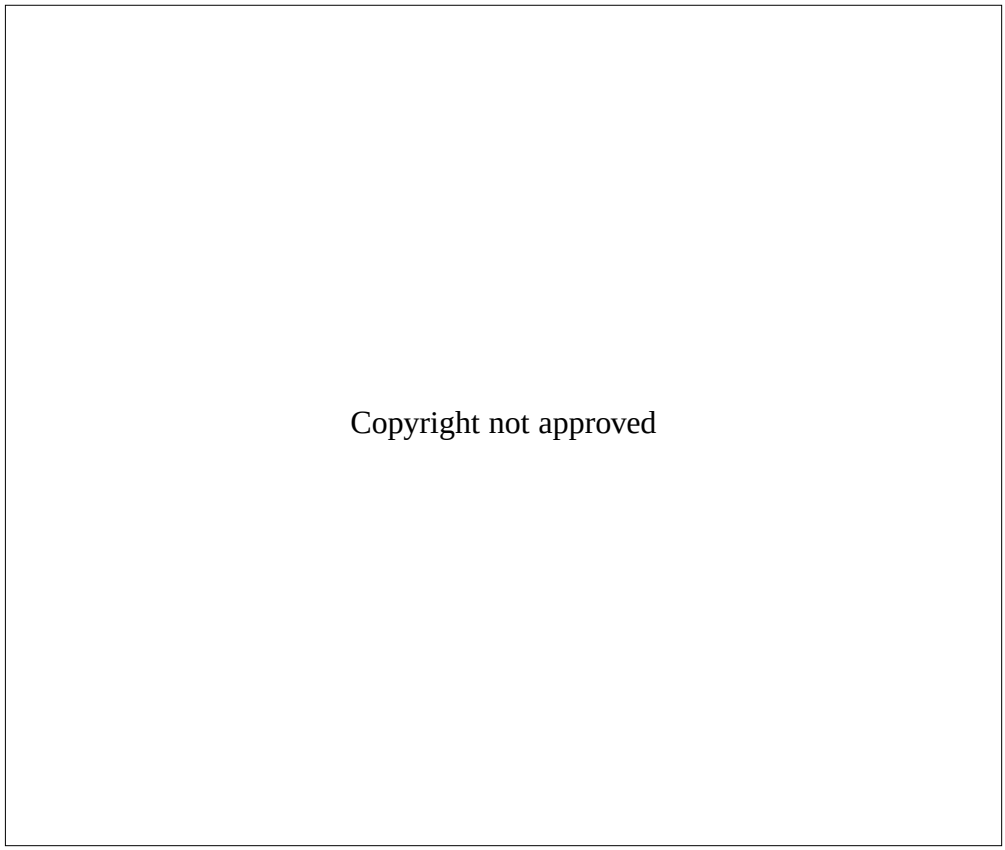
QUESTION 35 Physics in Technology (25 marks) **Marks**

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) A worker exerts two forces on the handle of a shovel as shown in the diagram. **2**

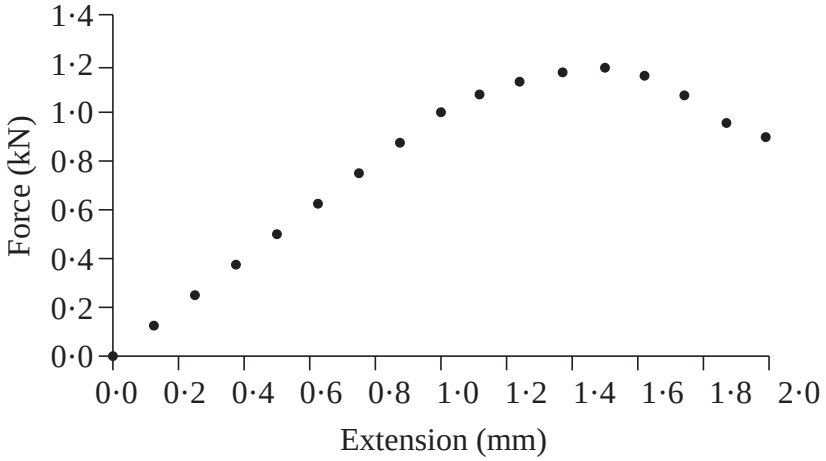


Calculate the moment of each force about point *A*.

Question 35 A continues on page 41

QUESTION 35 (Continued) **Marks**

(b) A steel ribbon is subjected to a variable tensile force and the extension of the ribbon is measured. The graph shows the data measured. The ribbon dimensions are: length 1·00 m; width 5·00 mm and thickness 1·00 mm. **5**



(i) What does the shape of the graph show about the response of the steel ribbon to a variable tensile force?

(ii) Using the graph, calculate the Young's modulus of the steel.

(iii) What is the value of the tensile force that corresponds to the elastic limit of steel?

(c) The diagram represents a rigid framework which is vertical. A load *P* of 1000 N is applied vertically at the joint *B*. **3**

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(i) What function does the stay *AC* provide?

(ii) Is the stay *AC* in compression or tension?

(iii) The stay *AC* is now removed and a linear element is installed between *B* and *D*. Given the choice of a bar or tube of the same cross-sectional area, which would you choose for the linear element? Justify your choice.

Question 35 A continues on page 42

QUESTION 35 (Continued) **Marks**

(d) In your study of this elective, you used your understanding of forces in structures and the behaviour of materials to design and build either a practical structure, or a model of one, to given specifications. **$2\frac{1}{2}$**

(i) Describe your practical structure or model and its purpose.

(ii) Discuss briefly the performance of your structure in terms of either stability or load-bearing characteristics.

Question 35 continues on page 43

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) The image produced by a concave mirror of focal length 4·0 cm is formed at a distance of 12 cm behind the mirror surface and is 8·0 cm high. **$3\frac{1}{2}$**

(i) By calculation or otherwise, find the height of the object and its distance from the mirror surface.

(ii) Describe the image.

(b) A recent series of photographs of a solar eclipse was taken using a reflecting telescope. **4**

The first reflecting telescopes were made by Newton in the late seventeenth century because he was concerned about the problems associated with the use of refracting telescopes.

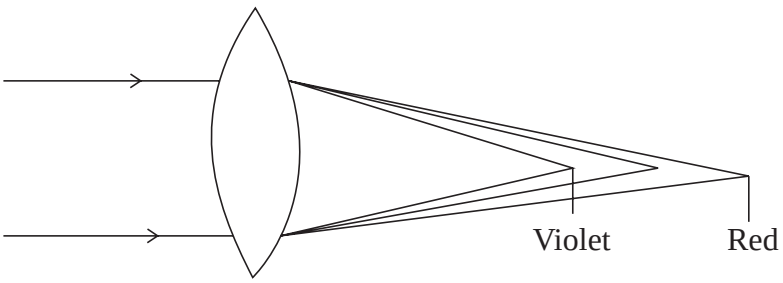
(i) Name ONE problem associated with the use of large refracting telescopes. State how this may be overcome using a reflecting telescope.

(ii) Draw a labelled ray diagram to show how the image is formed by a Newtonian reflecting telescope.

(c) A 1·0 cm high object is placed 6·0 cm from a concave lens of focal length 4·0 cm. **3**

By drawing a conventional ray diagram to scale, show the height and position of the image formed by the lens. Is the image real or virtual? Explain your answer.

(d) White light from a distant source enters a lens as shown. **2**



(i) Name the effect shown and explain its cause.

(ii) How can this effect be reduced in an optical instrument?

Question 35 continues on page 44

QUESTION 35 (Continued) **Marks**

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

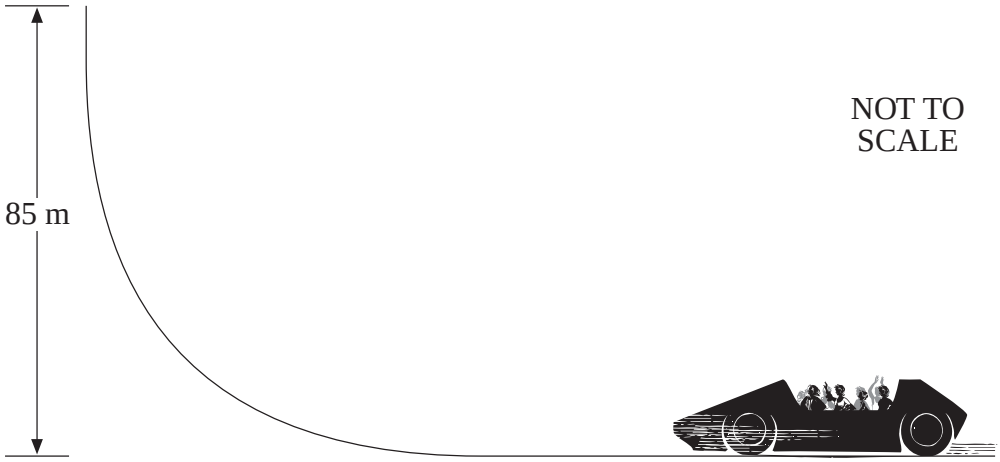
C Half-elective: Transformation of Energy ($12\frac{1}{2}$ marks)

(a) (i) Gravitational, nuclear and solar energy may be converted on a large scale into electrical energy. For each conversion, state ONE fundamental or practical limitation involved in the conversion. **6**

(ii) A hydroelectric power station allows $5{\cdot}0 \times 10^5$ m^3 of water per hour to fall through a height of 150 m. Calculate the maximum power that can be generated in this conversion, if all the gravitational potential energy is converted to electrical energy.

(iii) State ONE reason why this maximum power is never obtained in such a conversion.

(b) A theme-park ride uses an electromagnetic force to accelerate a cart along a metal track that curves from the horizontal to the vertical. **3**



The power supplied to achieve the accelerating force is 2·2 MW for 7·0 seconds.

The cart and its occupants of total mass 8·0 tonnes are accelerated along the track and reach a vertical height of 85 m.

(i) Calculate the electrical energy input during the 7·0 s.

(ii) Calculate the gravitational potential energy of the cart and its occupants at 85 m.

(iii) Calculate the efficiency of the energy transformation for this ride.

Question 35 C continues on page 45

QUESTION 35 (Continued) **Marks**

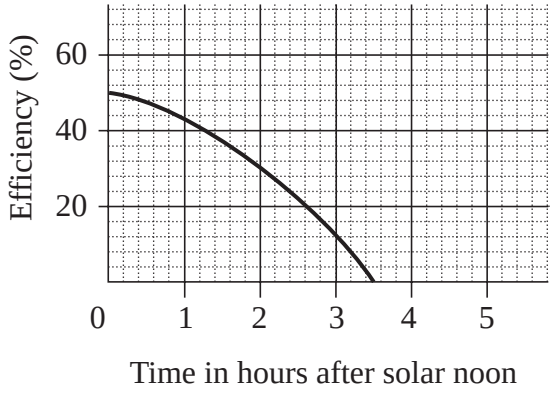
(c) The solar power P_{inc} incident on a solar collector that is directly facing the Sun is given by **3 1/2**

$$P_{inc} = IA \ ,$$

where I is the solar intensity and A is the facing surface area of the collector.

(i) If the solar intensity is 910 W m^{-2} and the collector has an area of 2·8 m^2 facing the Sun, find the solar power incident on the collector.

(ii) The typical efficiency of a single sheet collector versus time after solar noon is shown below.



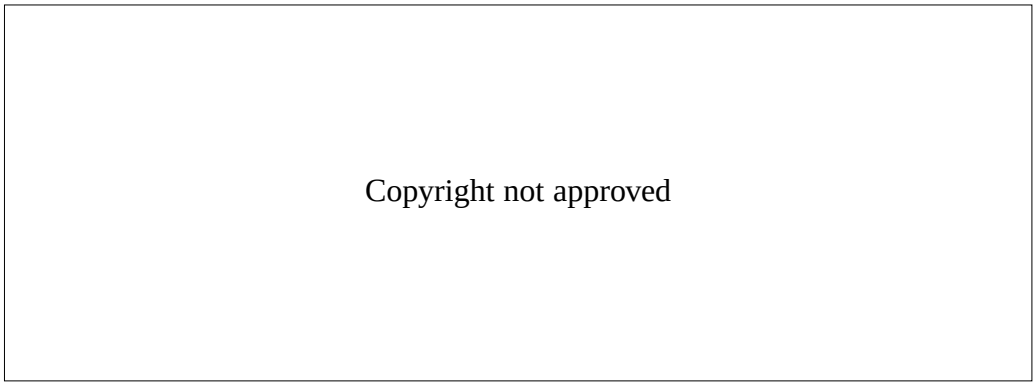
For the solar collector in part (c) (i) determine the power output at exactly two hours after solar noon.

(iii) This power is used to heat 5·0 L of water, which has a density of 1·0 kg L^{-1}. Calculate the temperature rise of the water over a three-minute period.

End of question

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

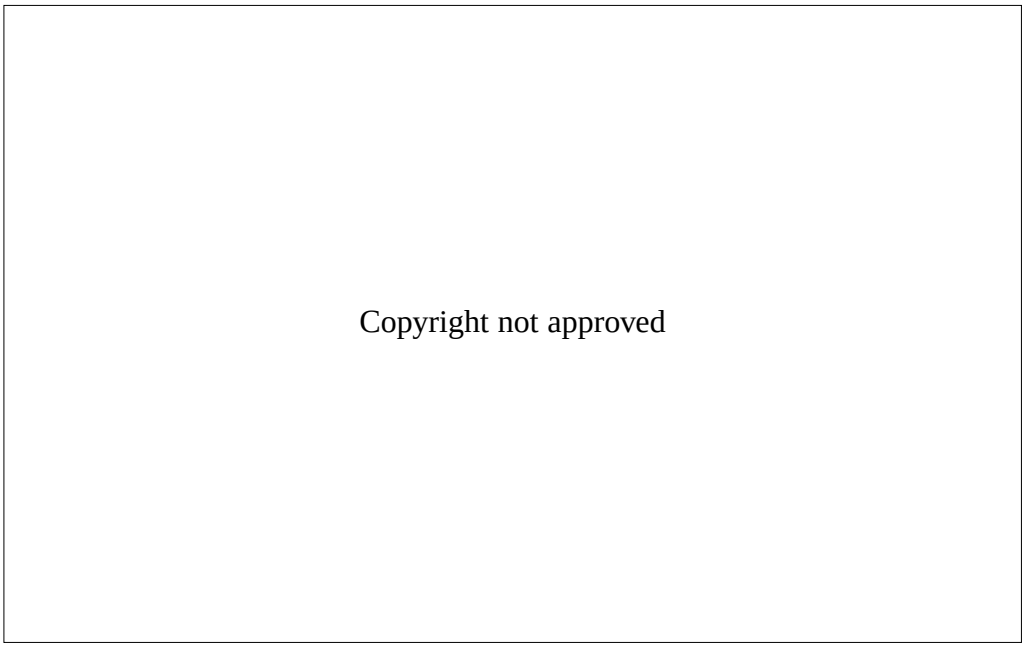
(a) The diagrams show a section of the night sky photographed at the same time using red and blue filters. **2**



(i) At which location (*X*, *Y* or *Z*) is the hottest star most likely to be found? Justify your choice.

(ii) Give ONE difference (apart from temperature and appearance through a filter) between a hot star and a cooler star.

(b) The evolutionary tracks of two stars, *X* and *Y*, are shown in the diagram below. **5**



(i) Briefly explain the initial stage of formation of a star.

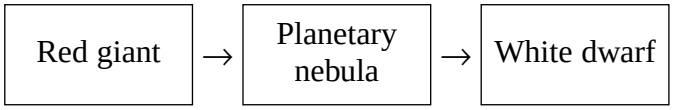
(ii) Which star, *X* or *Y*, has the larger mass? Give a reason for your choice.

(iii) Explain why a star ten times more massive than the Sun stays on the main sequence for a much shorter time than a star of 1 solar mass.

Question 36 continues on page 47

QUESTION 36 (Continued) **Marks**

(iv) The evolution of star *Y* after it leaves the main sequence can be summarised as follows:



Copy and complete the following table in your Answer Book.

Type	*Surface temperature compared to the Sun*	*Luminosity relative to the Sun*
Red giant		
White dwarf		

(c) Adhara is a star of spectral type *B2* and has an absolute magnitude of $-4{\cdot}4$, and an apparent magnitude of $1{\cdot}50$. **3**

(i) Define absolute magnitude.

(ii) Calculate the distance in parsecs to Adhara.

(iii) Give ONE other conclusion about Adhara that can be drawn from the information provided above.

(d) The following description of an object viewed in the night sky was given. **2**

'It is shaped like a ball and consists of tens of thousands of stars, more closely packed towards the centre. A Hertzsprung–Russell diagram for this object has a short main sequence.'

(i) What type of object is being described?

(ii) Name one other characteristic of this type of object.

(e) In the nineteenth century, Joseph Fraunhofer examined the spectrum produced by the Sun, a *G2* star, and noticed dark lines occurring across the spectrum. This type of spectrum is referred to as an absorption spectrum. **2**

(i) Explain how the dark lines are produced.

(ii) Explain why few molecular lines are observed in the spectra of stars.

Question 36 continues on page 48

QUESTION 36 (Continued) **Marks**

(f) A cluster is known to contain a variable star of the δ-Cephei type. This star varies between apparent magnitude 7·4 and 6·6, with a period of 5·3 days. Emission lines in the spectrum of many stars in this cluster are displaced towards the red end of the spectrum, compared to their expected position. **7**

(i) Explain how the distance to this cluster can be estimated.

(ii) Explain any effect that would be noticed in the period of the δ-Cephei type star over 100 years.

(iii) Explain any effect that would be noticed in the average apparent magnitude of the δ-Cephei type star over thousands of years.

(iv) Sketch the light curve of the variable star. Include appropriate labels and scales on the axes of your sketch.

(v) How much brighter is this star at its brightest compared to its faintest?

(g) Energy can be produced in the cores of main sequence stars by two different nuclear processes. **4**

(i) Name the two nuclear processes.

(ii) Describe ONE similarity and ONE difference between these two processes.

(iii) Explain which feature of a star determines which of the two processes will be predominant in that star.

End of paper

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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, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	$2{\cdot}0 \times 10^{-7}$ 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

				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 Of 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												

KEY

Atomic Number — 79 — Symbol of element

Atomic Mass — 197·0 — Name of element (Au — Gold)

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.