SYDNEY GRAMMAR SCHOOL

2017

FORM V
ANNUAL EXAMINATION

Physics

Friday 1st September 8.40AM

Working Time: 2 hours

General Instructions

- Working time – 2 hours
- Board-approved calculators may be used
- Write using black pen only
- Draw diagrams using pencil
- A Data Sheet, Formula Sheet and Periodic Table are provided at the back of this paper
- Write your name at the top of the Multiple Choice Answer Sheet & pages 9, 15, 21 and 27 of Part B
- Hand in your Multiple Choice Sheet and all of Part B in one bundle (do not staple together)

Total marks (96)

This paper has two parts: Part A and Part B.

Part A
Total marks **(18)**
- Attempt ALL Questions
- Allow about 20 minutes for this Part

Part B
Total marks **(78)**
- Attempt ALL Questions
- Allow about 1 hour 40 minutes for this Part

CHECKLIST	
Each boy should have the following:	
1 Question Paper	
1 Multiple Choice Answer Sheet	

1 – PCK	3 – MTK	5 – DGB	7 – MRW
2 – SRW	4 – AAH	6 – PCK	

EXAMINERS:
MRW/AAH/PCK/DGB

Part A

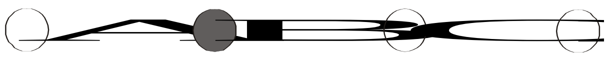
Total marks (18)
Attempt ALL Questions
Allow about 20 minutes for this Part

Use the multiple-choice Answer Sheet.

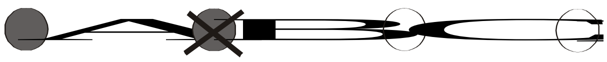
Select the alternative A, B, C or D that best answers the question. Fill the response circle completely.

Sample 2 + 4 =

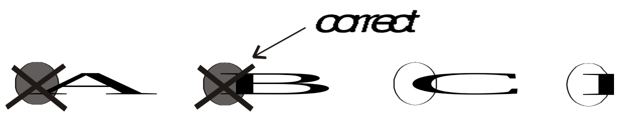
(A) 2 (B) 6 (C) 8 (D) 9



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 this by writing the word *correct* and drawing an arrow as follows.



1 Which of the following represents the correct present and future stages in the life-cycle of the Sun?

	Current stage	*Future stage*
(A)	Supernova	Planetary Nebula
(B)	Supergiant	White Dwarf
(C)	Main Sequence	White Dwarf
(D)	Main Sequence	Black Hole

2 Potassium-42 is an unstable nucleus that undergoes beta-negative decay to form:

(A) Chlorine-38.
(B) Potassium-41.
(C) Calcium-42.
(D) Scandium-46.

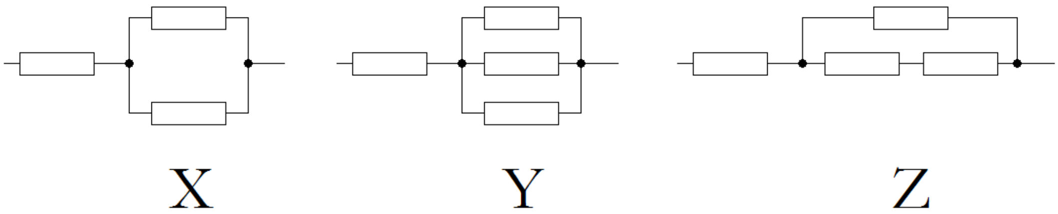
3 The isotope Pu-239 has a half-life of 24,100 years. If there was a 5 kg mass of Pu-239 when Toba, a super-volcano that almost wiped humanity off the surface of the Earth erupted 72,300 years ago, how much of this mass would still be Pu-239 today?

(A) 556 g
(B) 625 g
(C) 833 g
(D) 1667 g

4 A coffee cup immersion heater utilises a heating coil with a resistance of 8.5 Ω. Determine the power dissipated by this heater when operated at 240 V.

(A) 3.3 W
(B) 28.2 W
(C) 2040.0 W
(D) 6776.4 W

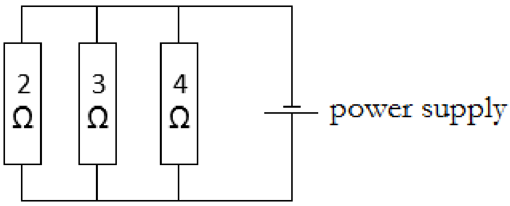
5 Three groups of resistors (X, Y and Z) are shown below. All resistors used in the groups are identical and have the same resistance.



Which statement about the total resistance of each group is correct?

(A) Resistance of X > Resistance of Y > Resistance of Z
(B) Resistance of Y > Resistance of X > Resistance of Z
(C) Resistance of Z > Resistance of X > Resistance of Y
(D) Resistance of X > Resistance of Z > Resistance of Y

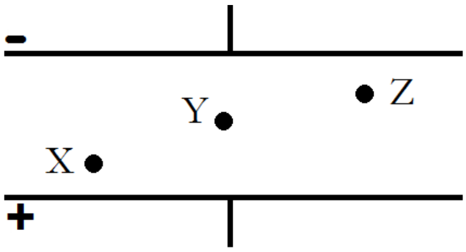
6 The electrical circuit below contains 3 resistors (2 Ω, 3 Ω and 4 Ω) connected in parallel to a direct current power supply.



Which statement about this circuit is correct?

(A) If a 2 A current flows through the 2 Ω resistor, then a 3 A current must flow through the 3 Ω resistor.
(B) If a 2 A current flows through the 2 Ω resistor, then a 4 A current must flow through the 4 Ω resistor.
(C) If a 2 A current flows through the 2 Ω resistor, then a 1 A current must flow through the 4 Ω resistor.
(D) If a 2 A current flows through the 4 Ω resistor, then a 3 A current must flow through the 3 Ω resistor.

7 The diagram below shows two oppositely charged parallel plates creating an electric field *E*. Three identical, positive charges are placed simultaneously and respectively at points X, Y and Z.



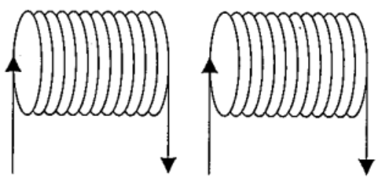
Which statement about the force acting on each of the charges due to the electric field is correct?

(A) The force on the charge at X is the largest.
(B) The force on the charge at Z is less than the force on the charge at Y.
(C) The force on the charge at Y is larger than the force on the charge at X.
(D) All three charges have the same force acting on them.

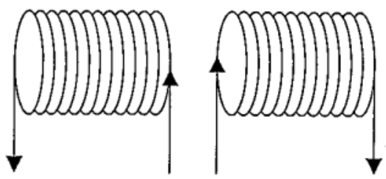
8 The diagram below shows two bar magnets placed next to each other.

Which pair of solenoids below would produce a similar magnetic field to that of the two bar magnets above?

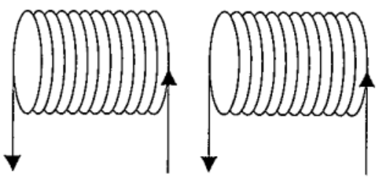
(A)



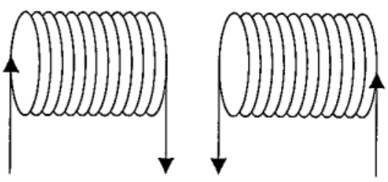
(B)



(C)



(D)



9 In a household, a 100 W light bulb shines for 3.5 hours. Calculate the energy dissipated by the light bulb.

(A) 2.86×10^{1} J
(B) 3.50×10^{2} J
(C) 2.10×10^{4} J
(D) 1.26×10^{6} J

10 A car travels a total distance of 200 km on an expressway. It travels the first 90 km at an average speed of 80 $km{\cdot}h^{-1}$.
What is the average speed required for the remaining part of the journey, if the car is to reach the destination in a total time of 2 hours?

(A) 110 $km{\cdot}h^{-1}$
(B) 120 $km{\cdot}h^{-1}$
(C) 122 $km{\cdot}h^{-1}$
(D) 126 $km{\cdot}h^{-1}$

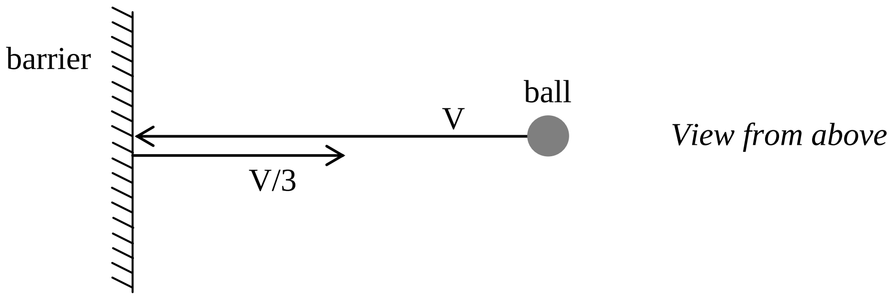
11 The acceleration due to gravity for an object in free fall on Planet X is one-seventh that on Earth.
In an experiment on Earth, it takes 0.64 seconds for a stone to fall a distance of 2 m from rest.
What is the time taken for the same object to fall the same distance from rest on Planet X?

(A) 0.24 s
(B) 1.69 s
(C) 4.48 s
(D) 10.94 s

12 A car initially travelling at 8 $m{\cdot}s^{-1}$ accelerates to 22 $m{\cdot}s^{-1}$ over 350 m. Calculate the magnitude of the corresponding acceleration.

(A) 0.02 $m{\cdot}s^{-2}$
(B) 0.60 $m{\cdot}s^{-2}$
(C) 0.78 $m{\cdot}s^{-2}$
(D) 1.20 $m{\cdot}s^{-2}$

13 A billiard ball travelling on a horizontal surface at a speed of V collides with a barrier and comes off with a speed of V/3 as shown in the following diagram.

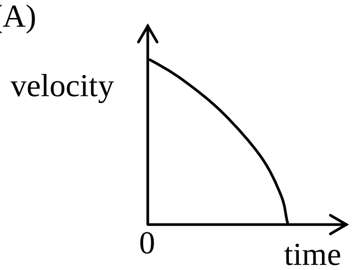


The kinetic energy of the ball before the collision is E. The kinetic energy **lost** by the ball during the collision is:

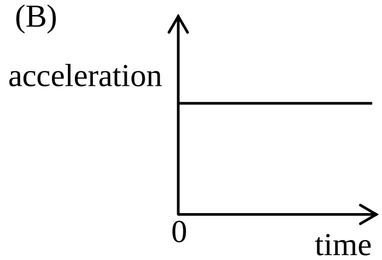
(A) E / 9
(B) E / 3
(C) 2E / 3
(D) 8E / 9

14 Which of the following graphs best represents the motion of a bus that is travelling along a straight road with a speed that is uniformly increasing with time?

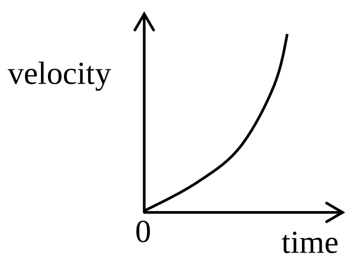
(A)



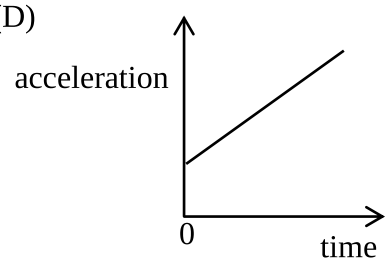
(B)



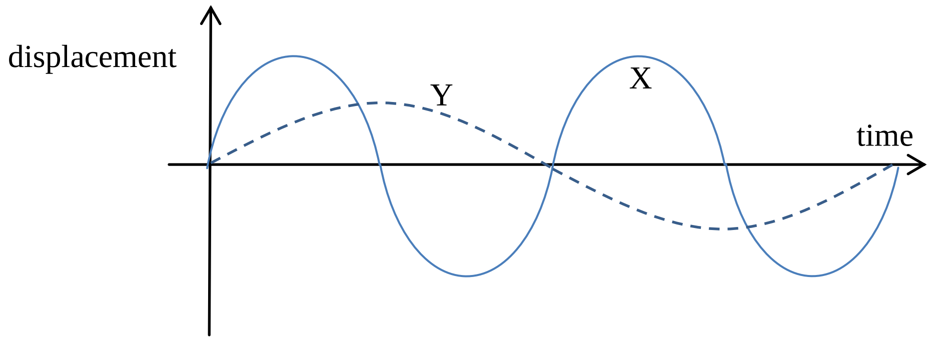
(C)



(D)



15 The diagram below shows two sound waves.



Which of the statements below correctly describes the two sounds heard?

(A) X is louder than Y, and X has a higher pitch than Y.
(B) X is louder than Y, and X has a lower pitch than Y.
(C) X is quieter than Y, and X has a lower pitch than Y.
(D) X is quieter than Y, and X has a higher pitch than Y.

16 The average intensity of sunlight falling on the Earth's outer atmosphere is 1.36×10^3 W.m^{-2}. Jupiter is five times further from the Sun than Earth. The average intensity of sunlight falling on Jupiter's outer atmosphere is:

(A) 3.40×10^4 W·m^{-2}
(B) 4.80×10^3 W·m^{-2}
(C) 2.72×10^2 W·m^{-2}
(D) 5.44×10^1 W·m^{-2}

17 Which of the following lists the components of the electromagnetic spectrum in order of increasing wavelength?

(A) Ultra-violet, infra-red, radio, visible
(B) Radio, infra-red, visible, ultra-violet
(C) Ultra-violet, visible, infra-red, radio
(D) Radio, ultra-violet, visible, infra-red

18 An airport security X-ray machine emits X-rays with a frequency of 4.8×10^{19} Hz. The wavelength of these X-rays is:

(A) 2.1×10^{-20} m
(B) 6.3×10^{-12} m
(C) 2.3×10^0 m
(D) 1.6×10^{11} m

End of Part A

Class

Name

Part B

Total marks (78)
Attempt ALL Questions
Allow about 1 hour and 40 minutes for this Part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 19 (3 marks) **Marks**

An Astronomical Unit (AU) is defined as the average distance between the Earth and the Sun, i.e. $d_{Earth\text{-}Sun} = 1.00$ AU.
It is used as a convenient unit when measuring distances within the Solar System.

Ceres is a dwarf planet in the asteroid belt that is at a distance of 2.77 AU from the Sun. Determine how long it takes Ceres to orbit once around the Sun. **3**

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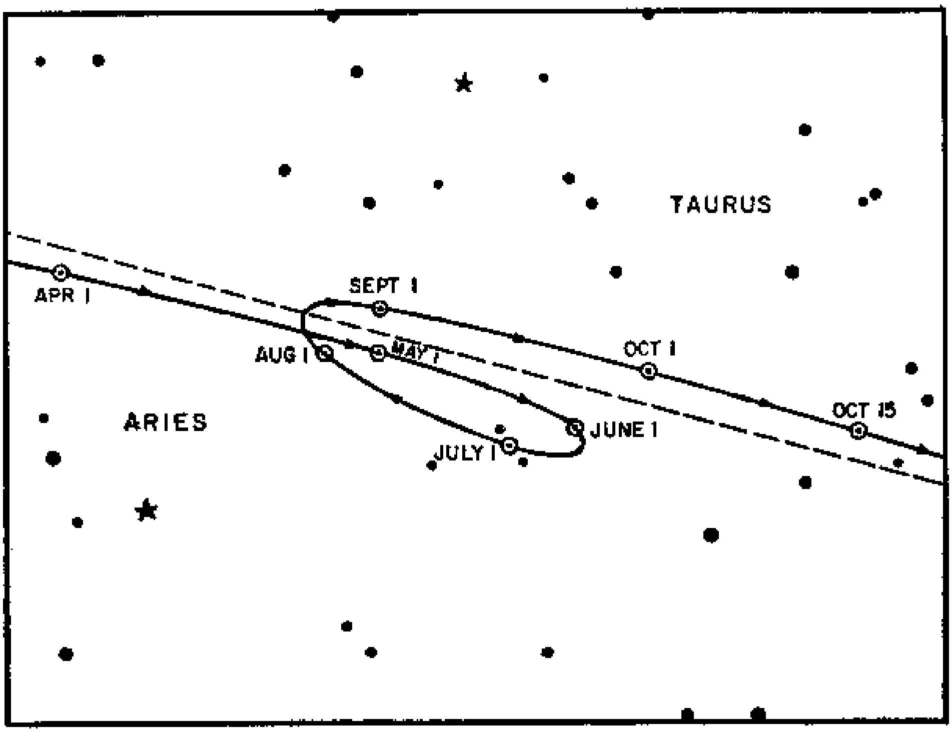
Question 20 (3 marks) **Marks**

(a) The following diagram shows the positions for the planet Mars at various dates throughout the year.



Outline how the geocentric model explained this retrograde motion.

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(b) Identify **two** pieces of evidence that were observable after the invention of the telescope that supported the heliocentric model. **2**

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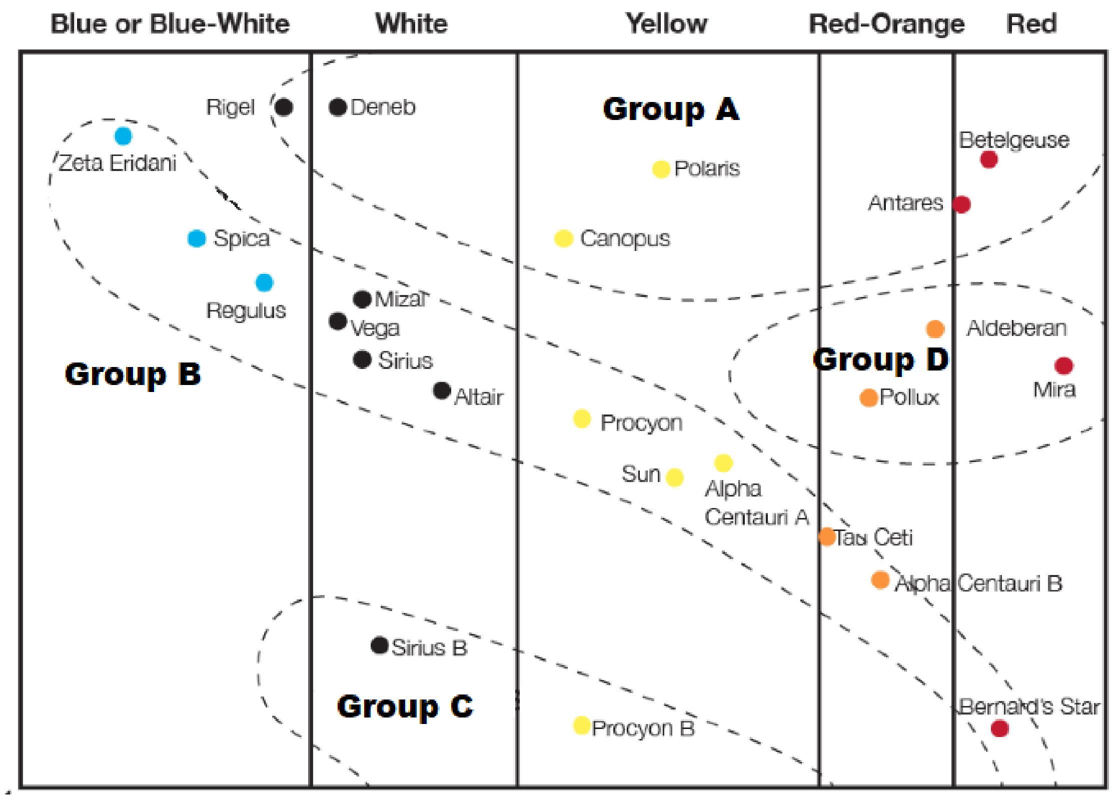
Question 21 (4 marks) **Marks**

Below is a Hertzsprung-Russell diagram for stars found in the Milky Way.



(a) Which star has the highest surface temperature? **1**

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(b) Which white dwarf is the most luminous? **1**

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(c) Identify Group B. **1**

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(d) Identify Group D. **1**

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Question 22 (4 marks)

(a) Determine the half-life of Nitrogen-16 if a 200.0 g sample of this isotope decays to 12.5 g in 28.5 s.

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(b) In a particular transmutation, Francium-211 decays into Astatine-207. Write a complete nuclear decay equation to represent this nuclear reaction.

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Question 23 (3 marks)

Complete the following table to compare the physical properties of two different types of radioactivity.

3

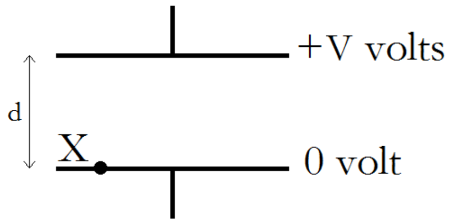
Type of radiation	Relative charge	Relative penetrating power	Relative ionising power
	0		very low
		very low	

Question 24 (3 marks) **Marks**

The diagram below shows two parallel plates with an unknown potential difference $+V$ between them. The plates are separated by a distance $d = 1.0 \times 10^{-3}$ m.

An electron is released from rest at point X on the neutral plate and collides with the positive plate (i.e. top plate) at a speed $v = 2.9 \times 10^{6}$ m·s^{-1}.

Neglect the effect of gravity.



Determine the potential difference V applied between the plates. **3**

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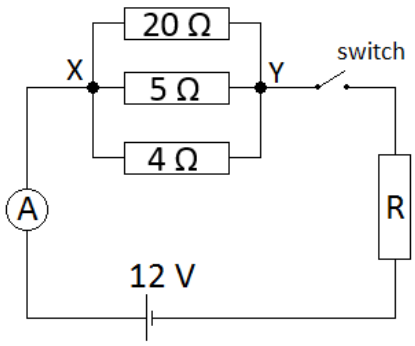
Class

Name

Question 25 (5 marks)

Consider the circuit below:



When the switch is closed, the ammeter reads 4 A.

(a) Determine the resistance *R*. **3**

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(b) Determine the potential difference V_{XY} between the points X and Y. **1**

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(c) Determine the current flowing through the 20 Ω resistor. **1**

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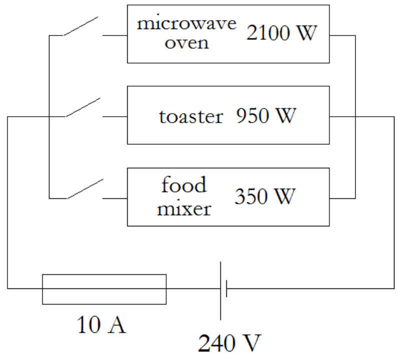
Question 26 (5 marks) **Marks**

A kitchen has the following three appliances connected in parallel to a 240 V power supply in series with a 10 A fuse: a 350 W food mixer, a 950 W toaster, and a 2100 W microwave oven.



(a) Determine which of these appliances can be operated at the same time without breaking the fuse. *Show all working*. **3**

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(b) Explain how fuses or other electrical devices protect against electrical dangers. **2**

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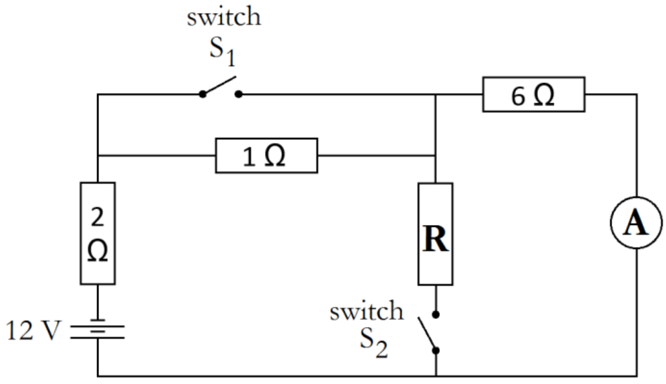
Question 27 (5 marks) **Marks**

The ammeter in the circuit below shows the **same** reading when switches S_1 and S_2 are both open **and** when they are both closed.



Calculate:

(a) the reading on the ammeter. **2**

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(b) the value of resistance R. **3**

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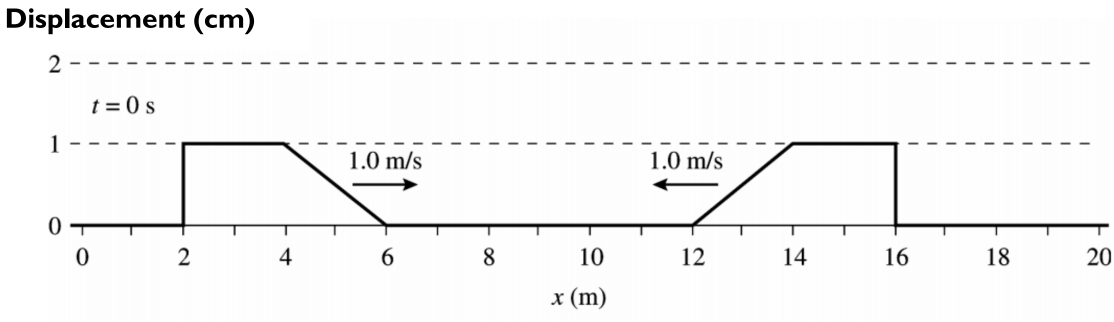
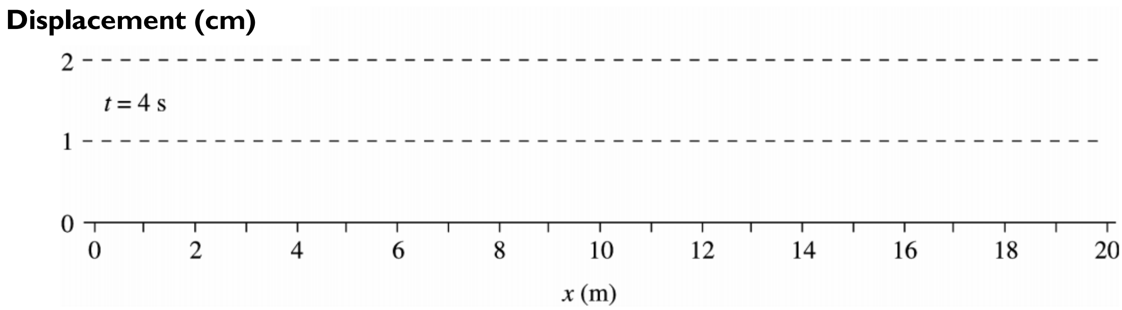
Question 28 (2 marks) **Marks**

The picture below shows two wave pulses approaching each other on a stretched string at time t = 0 s. Both pulses have a speed of 1.0 m·s^{-1}.

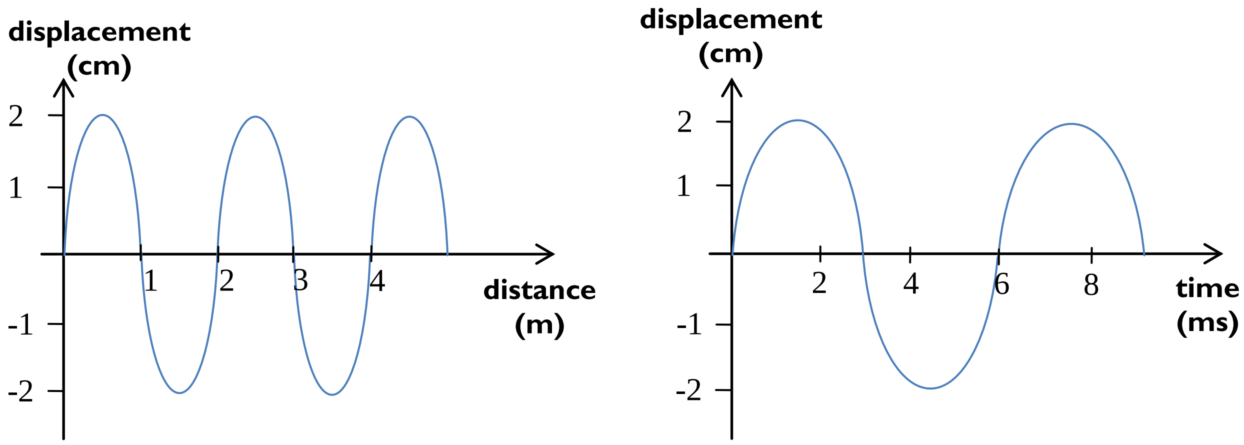


Draw the shape of the string due to the two pulses at t = 4 s on the empty graph below. **2**



Question 29 (5 marks) **Marks**

The diagrams below represent the same wave.



For the wave shown, determine:

(a) its amplitude. **1**

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(b) its wavelength. **1**

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(c) its period. **1**

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(d) its frequency. **1**

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(e) its speed. **1**

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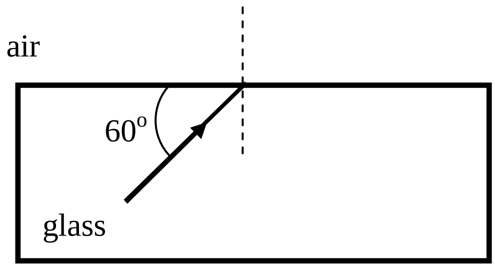
Class

Name

Question 30 (5 marks) **Marks**

The diagram below shows light passing from a glass block, with a refractive index of 1.52, into air.



(a) Calculate the angle of refraction of the light. **2**

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(b) Calculate the critical angle of the glass. **1**

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(c) The glass block is now immersed in an unknown transparent fluid. Determine the refractive index of the unknown fluid in order for the critical angle of this new interface to be 60°. **2**

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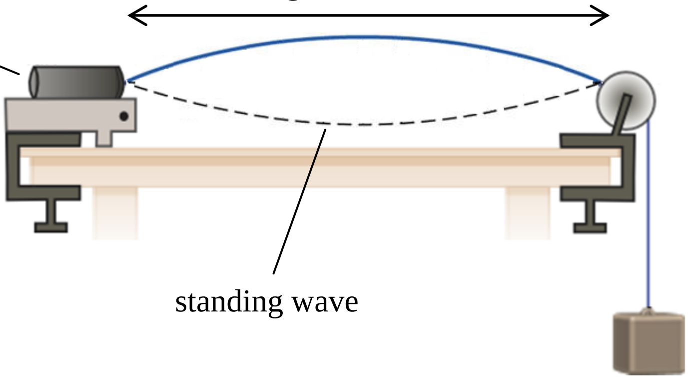
Question 31 (4 marks)

A pupil performs an experiment on the production of standing waves on guitar strings. He sets up the following equipment.



The mass, *M*, hanging from the string keeps the tension in the string equal to Mg.

The pupil adjusts the frequency of the mechanical oscillator until he creates a standing wave, with a wavelength equal to double the length of the string, *L*, which he holds constant at 1.00 m.

The pupil's teacher tells him that the frequency, *f*, required to produce this standing wave is given by the following equation:

$$f^2 = \frac{Mg}{4\mu L} \qquad \boxed{\text{Equation 1}}$$

where μ is known as the *linear density* of the string, and is equal to the mass of a one metre length of the string.

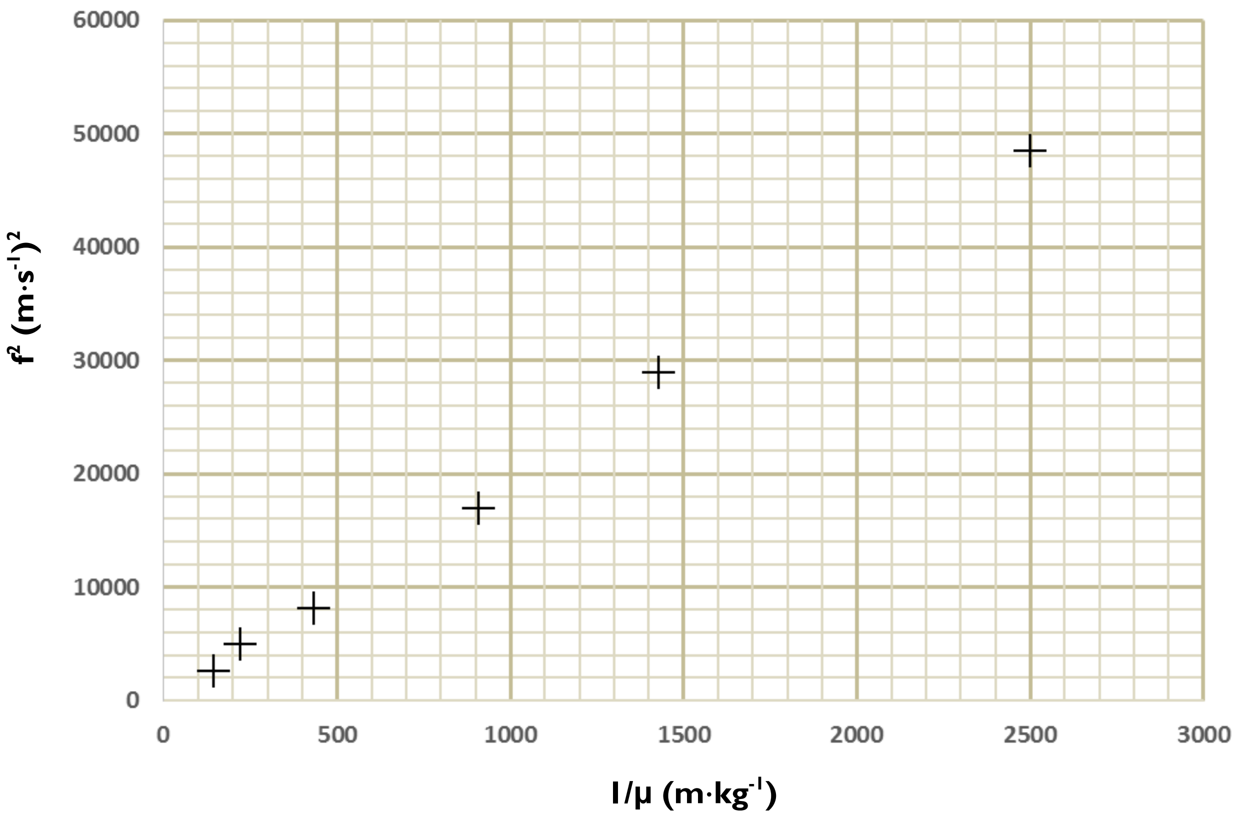
The pupil repeats the experiment for six strings from his guitar, and records his results in the table below:

String (note)	Linear Density μ ($\times 10^{-3}$ kg·m^{-1})	1/μ (m·kg^{-1})	Frequency f (Hz)	f^2 (Hz^2)
E	0.4	2500	220	48400
A	0.7	1429	170	28900
D	1.1	909	130	16900
G	2.3	435	90	8100
B	4.5	222	70	4900
E	6.8	147	50	2500

Question 31 continued on next page.

Question 31 continued.
Marks

The pupil then plotted the graph f^2 versus $1/\mu$ to verify Equation 1:



(a) Write an expression for the mass, *M*, hanging from the string in terms of the gradient of the graph and other variables. **2**

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(b) Draw the line of best fit of the graph above and use its gradient to calculate the value of the hanging mass, *M*. **2**

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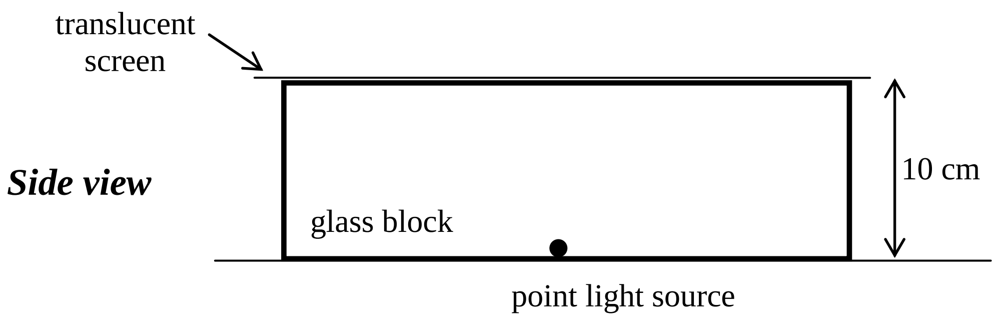
Question 32 (5 marks)

The diagram below shows a glass block with a translucent screen on top of it.



At the base of the glass block is a magenta (i.e. purple) point light source that emits light of two specific wavelengths:

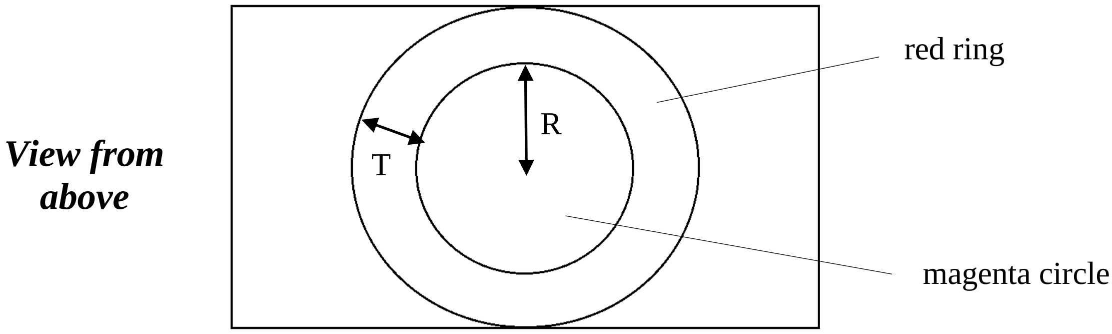
- red light, of wavelength 7.20×10^{-7} m in air,
- blue light, of wavelength 4.50×10^{-7} m in air.

The refractive index of the glass block varies depending on the wavelength of the light.
For a given wavelength in air, λ, the refractive index, n_λ, varies according to the following formula:

$$n_\lambda = \frac{k}{\sqrt[3]{\lambda}} \quad \text{where } k = 1.26 \times 10^{-2}\ \text{m}^{1/3} \text{ for all wavelengths in air}$$

When a thin translucent screen is placed on top of the glass block and viewed from above, the following is observed:

NB – You can ignore the refractive properties of the translucent screen, because it is so thin.



Question 32 continued on next page.

Question 32 continued. **Marks**

(a) Explain this observation. **2**

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(b) Calculate the radius of the magenta circle, R, and the width of the red ring, T. **3**

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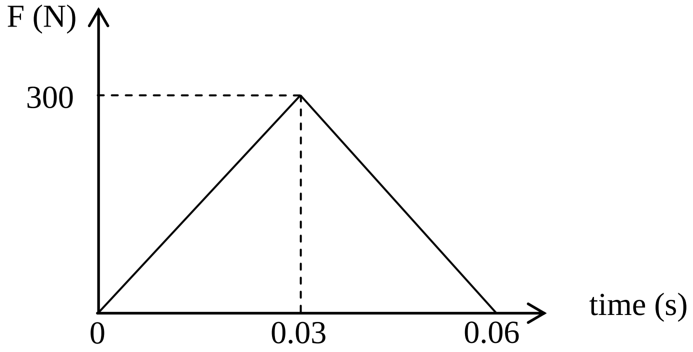
Question 33 (5 marks) **Marks**

Consider the following graph of the force, *F*, of a racquet acting on a tennis ball as a function of time. Initially a tennis ball of mass 0.150 kg had a velocity of 25 $m \cdot s^{-1}$ towards the racquet. As a result of being hit by the racquet, the ball returned directly along the same path.



(a) Calculate the magnitude of the impulse of the force of the racquet which acted on the tennis ball during the 0.06 s. **2**

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(b) Determine the magnitude of the final velocity of the tennis ball. **3**

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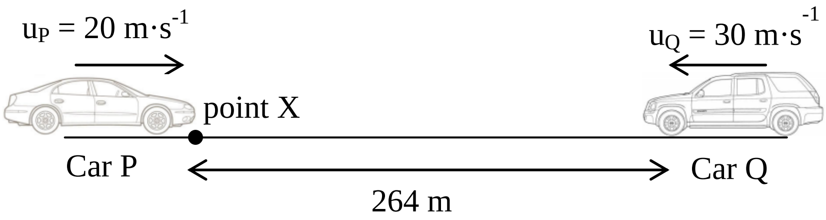
Class

Name

Question 34 (6 marks) **Marks**

Two cars are travelling along a straight road as shown in the diagram below.
At the instant shown, Car P passes point X and the two cars are 264 m apart.
Car P travels at a constant speed of 20 m·s^{-1}.
Car Q is initially travelling at 30 m·s^{-1} and, at the instant shown, starts to decelerate at the constant rate of 2 m·s^{-2}.



(a) Determine the time that elapses before the cars meet. **3**

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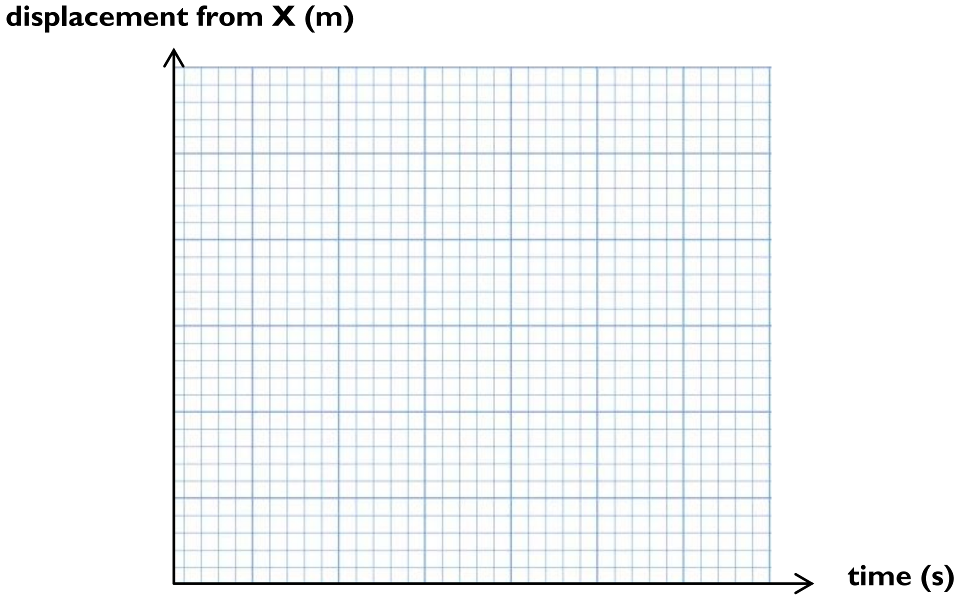
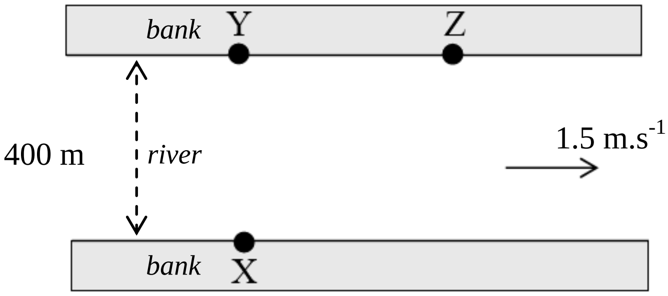
(b) On the same set of axes below, sketch displacement versus time graphs to show the positions of each car relative to the point X shown on the diagram. Take t = 0 s as the time when car P passes X and continue the graphs until the cars meet. **3**



Question 35 (7 marks) **Marks**

Two swimmers (A and B) at point X on one side of a river are in a race where the finishing line is at point Y directly opposite. The river is 400 metres wide and has a current of 1.5 m·s^{-1}, as shown in the following diagram.



They both dive in at the same time and swim across the river. In still water, both swimmers move at 2 m·s^{-1}.

Swimmer A directs himself so that his resultant motion is in the direction XY, while Swimmer B always swims with his body perpendicular to the current and lands at point Z. He then runs to point Y with a speed of 8 m·s^{-1}.

(a) Draw two vector diagrams to determine the respective resultant speed of Swimmer A and Swimmer B **when in the water**. **4**

Swimmer A in water	*Swimmer B in water*
Resultant speed of Swimmer A: v_A =	Resultant speed of Swimmer B: v_B =

Question 35 continued on next page.

Question 35 continued

Marks

(b) Determine which swimmer reaches Point Y first by calculating the time taken by each swimmer to finish the race. **3**

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Question 36 (4 marks) **Marks**

An unknown mass, *m*, has a fixed but unknown velocity, *u*.

To determine these two unknown values, the unknown mass is allowed to collide *elastically* and separately with two stationary masses A and B ($m_A = 2.4$ kg and $m_B = 6.8$ kg).

As shown in the diagrams below, when the unknown mass collides with A, A recoils with a kinetic energy of 13.2 J. When the unknown mass collides with B, B recoils with a kinetic energy of 8.7 J.

Determine the unknown mass, *m*, and its unknown velocity, *u*. **4**
Show all working.

End of Part B

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Physics

Data Sheet

Charge on the electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	330 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Radius of Earth, R_E	6.4×10^{6} m
Speed of light, c	3.00×10^{8} m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2×10^{-7} N A^{-2}
Universal gravitational constant, G	6.7×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck's constant, h	6.626×10^{-34} J s
Rydberg's constant, R (hydrogen)	1.097×10^{7} m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	4.18×10^{3} J kg^{-1} K^{-1}
Coulomb's constant, k	9.0×10^{9} Nm^{2}C^{-2}

FORMULAE SHEET FORM V ONLY

$$v_{av} = \frac{\Delta r}{\Delta t}$$

$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{v-u}{t}$$

$$v = u + at$$

$$v^2 = u^2 + 2ar$$

$$r = ut + \frac{1}{2}at^2$$

$$\sum F = ma$$

$$F = \frac{mv^2}{r}$$

$$E_k = \frac{1}{2}mv^2$$

$$E_p = mgh$$

$$W = Fr$$

$$p = mv$$

$$\Delta p = F_n t$$

$$F = mg$$

$$E = \frac{F}{q}$$

$$E = \frac{V}{d}$$

$$F = \frac{kQ_1Q_2}{d^2}$$

$$I = \frac{Q}{t}$$

$$R = \frac{V}{I}$$

$$P = VI$$

$$Energy = VIt$$

$$v = f\lambda$$

$$f = \frac{1}{T}$$

$$I \propto \frac{1}{d^2}$$

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

$$n\lambda = d\sin\theta$$

$$n\lambda = \frac{dx}{L}$$

$$E_p = -\frac{Gm_1m_2}{r}$$

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

$$F = \frac{Gm_1m_2}{d^2}$$

$$E = mc^2$$

FORMULAE SHEET

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

$$F = BIl\sin\theta$$

$$\tau = Fd$$

$$\tau = nBIA\cos\theta$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

$$d = \frac{1}{P}$$

$$M = m - 5\log\left(\frac{d}{10}\right)$$

$$\frac{I_A}{I_B} = 100^{(m_B - m_A)/5}$$

$$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$$

$$F = qvB\sin\theta$$

$$E = \frac{V}{d}$$

$$E = hf$$

$$c = f\lambda$$

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

$$\lambda = \frac{h}{mv}$$

$$A_0 = \frac{V_{out}}{V_{in}}$$

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

$$Z = \rho v$$

$$\frac{I_r}{I_0} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$

Surface area of a sphere of radius $R = 4\pi R^2$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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 47.87 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 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 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 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc 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 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	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 Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	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 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np 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

Elements with atomic numbers 112 and above have been reported but not fully authenticated.
Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

Class

Name

CRIB

Physics
Part A
ANSWER SHEET

2017
FORM V
ANNUAL EXAMINATION

General Instructions

- Write your class and name in the space provided.
- Attempt all questions 1 – 18.
- Use a black pen.
- Select the alternative A, B, C, or D that best answers the question.
- Fill in the response circle completely.

	A	B	C	D	Correct answer
1.	1 %	2 %	97 %	-	C
2.	-	2 %	98 %	-	C
3.	-	95 %	-	5 %	B
4.	-	0 %	2 %	98 %	D
5.	1 %	5 %	87 %	7 %	C
6.	1 %	-	97 %	2 %	C
7.	6 %	1 %	6 %	87 %	D
8.	3 %	16 %	-	81 %	D
9.	3 %	19 %	-	78 %	D
10.	1 %	1 %	4 %	94 %	D
11.	-	92 %	7 %	1 %	B
12.	-	98 %	-	2 %	B
13.	35 %	2 %	8 %	55 %	D
14.	-	94 %	4 %	2 %	B
15.	99 %	-	-	1 %	A
16.	4 %	1 %	4 %	91 %	D
17.	1 %	8 %	90 %	1 %	C
18.	2 %	97 %	-	1 %	B

1 Which of the following represents the correct present and future stages in the life-cycle of the Sun?

	Current stage	*Future stage*
(A)	Supernova	Planetary Nebula
(B)	Supergiant	White Dwarf
(C)	Main Sequence	White Dwarf
(D)	Main Sequence	Black Hole

2 Potassium-42 is an unstable nucleus that undergoes beta-negative decay to form:

(A) Chlorine-38.
(B) Potassium-41.
(C) Calcium-42.
(D) Scandium-46.

$${}^{42}_{19}K \longrightarrow {}^{42}_{20}Ca + {}^{0}_{-1}\beta$$

(β- decays increase the atomic number by 1 and leave the mass number unchanged)

3 The isotope Pu-239 has a half-life of 24,100 years. If there was a 5 kg mass of Pu-239 when Toba, a super-volcano that almost wiped humanity off the surface of the Earth erupted 72,300 years ago, how much of this mass would still be Pu-239 today?

(A) 556 g
(B) 625 g
(C) 833 g
(D) 1667 g

$72300 = \underline{\underline{3}} \times 24100 = 3$ half-lives

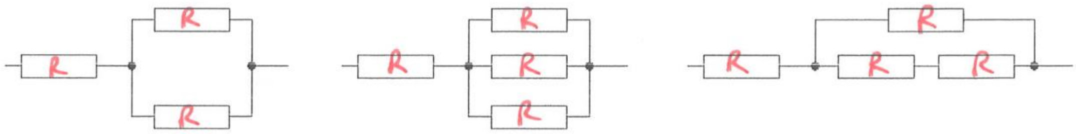
$\Rightarrow$ new amount $= \frac{1}{2^3} \times 5000 = 625\,g$

4 A coffee cup immersion heater utilises a heating coil with a resistance of 8.5 Ω. Determine the power dissipated by this heater when operated at 240 V.

(A) 3.3 W
(B) 28.2 W
(C) 2040.0 W
(D) 6776.4 W

$$P = \frac{V^2}{R} = \frac{240^2}{8.5} = 6776.4\,W$$

5 Three groups of resistors (X, Y and Z) are shown below. All resistors used in the groups are identical and have the same resistance.



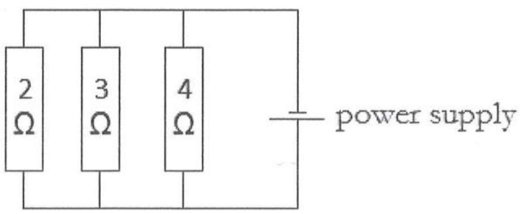
$R_x = \frac{3R}{2}$ X $R_y = \frac{4R}{3}$ Y $R_z = \frac{5R}{3}$ Z

Which statement about the total resistance of each group is correct?

(A) Resistance of X > Resistance of Y > Resistance of Z
(B) Resistance of Y > Resistance of X > Resistance of Z
(C) Resistance of Z > Resistance of X > Resistance of Y
(D) Resistance of X > Resistance of Z > Resistance of Y

6 The electrical circuit below contains 3 resistors (2 Ω, 3 Ω and 4 Ω) connected in parallel to a direct current power supply.

parallel circuit so V is the same for the 3 resistors ($V_2 = V_3 = V_4$)



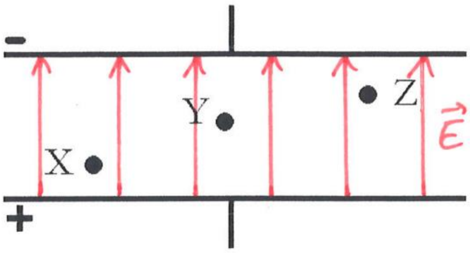
Which statement about this circuit is correct?

(A) If a 2 A current flows through the 2 Ω resistor, then a 3 A current must flow through the 3 Ω resistor.
(B) If a 2 A current flows through the 2 Ω resistor, then a 4 A current must flow through the 4 Ω resistor.
(C) If a 2 A current flows through the 2 Ω resistor, then a 1 A current must flow through the 4 Ω resistor.
(D) If a 2 A current flows through the 4 Ω resistor, then a 3 A current must flow through the 3 Ω resistor.

Ohm's Law: $V = IR \Rightarrow$ if V is constant then I and R are inversely proportional

$\Rightarrow$ if 2A in the 2Ω resistor, then half goes through the 4Ω resistor ($4 = 2 \times 2$) $\Rightarrow$ 1 A

7 The diagram below shows two oppositely charged parallel plates creating an electric field E. Three identical, positive charges are placed simultaneously and respectively at points X, Y and Z.



Which statement about the force acting on each of the charges due to the electric field is correct?

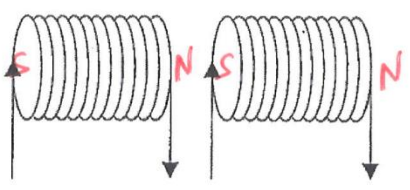
(A) The force on the charge at X is the largest.
(B) The force on the charge at Z is less than the force on the charge at Y.
(C) The force on the charge at Y is larger than the force on the charge at X.
(D) All three charges have the same force acting on them.

$\vec{F}_{electric} = q\vec{E}$ and here, q is the same for the 3 particles and $E = \frac{V}{d}$ is constant (and the same for the 3 particles) $\Rightarrow F_{elec}$ = same (uniform field) for the 3 particles

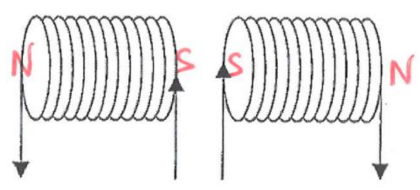
8 The diagram below shows two bar magnets placed next to each other.

Which pair of solenoids below would produce a similar magnetic field to that of the two bar magnets above?

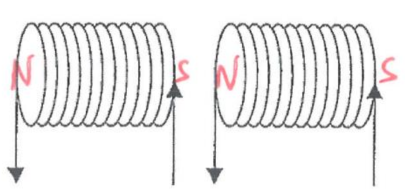
(A)



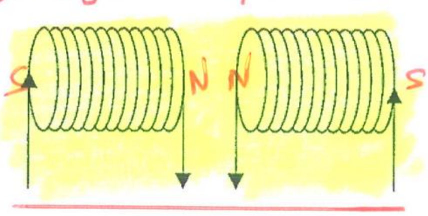
(B)



(C)



(D) Right Hand Grip Rule for solenoids



9 In a household, a 100 W light bulb shines for 3.5 hours. Calculate the energy dissipated by the light bulb.

(A) 2.86×10^1 J
(B) 3.50×10^2 J
(C) 2.10×10^4 J
(D) 1.26×10^6 J

$E = Pt = 100\,W \times 3.5 \times 60 \times 60\,s$

$\Rightarrow E = 1260000\,J$

10 A car travels a total distance of 200 km on an expressway. It travels the first 90 km at an average speed of 80 km·h^{-1}. $\rightarrow t_1$
What is the average speed required for the remaining part of the journey, if the car is to reach the destination in a total time of 2 hours?

(A) 110 km·h^{-1}
(B) 120 km·h^{-1}
(C) 122 km·h^{-1}
(D) 126 km·h^{-1}

• $t_1 = \frac{d_1}{v_1} = \frac{90}{80} = 1.125\,h \Rightarrow t_2 = t - t_1 = 2 - 1.125$

$\Rightarrow t_2 = 0.875\,h$

• $v_2 = \frac{d_2}{t_2} = \frac{110\,km}{0.875\,h}$

90 110
t_1 t_2 2h

$\Rightarrow v_2 = 126\,km/h$

11 The acceleration due to gravity for an object in free fall on Planet X is one-seventh that on Earth. $\left(g_X = \frac{g_E}{7}\right)$ $(t_E = t_X)$
In an experiment on Earth, it takes 0.64 seconds for a stone to fall a distance of 2 m from rest. $(r_E = 2\,m)$
What is the time taken for the same object to fall the same distance from rest on Planet X?

(A) 0.24 s
(B) 1.69 s
(C) 4.48 s
(D) 10.94 s

$r = ut + \frac{1}{2}at^2$ with $u = 0$ here $\Rightarrow t_E = \sqrt{\frac{2r_E}{g_E}}$

$\Rightarrow t_X = \sqrt{\frac{2r_X}{g_X}} = \sqrt{\frac{2r_E}{\frac{g_E}{7}}} = \sqrt{\frac{2r_E \times 7}{g_E}}$

$\Rightarrow t_X = \sqrt{7} \times t_E = \sqrt{7} \times 0.64 = 1.69\,s$

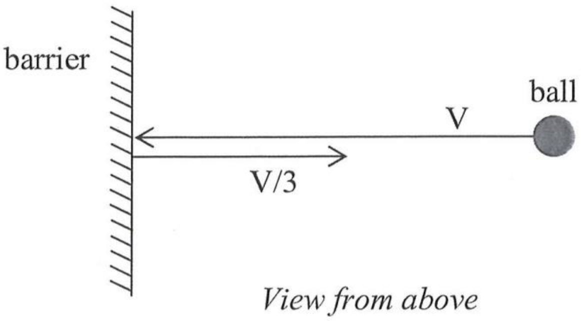
12 A car initially travelling at 8 m·s^{-1} accelerates to 22 m·s^{-1} over 350 m. Calculate the magnitude of the corresponding acceleration.

(A) 0.02 m·s^{-2}
(B) 0.60 m·s^{-2}
(C) 0.78 m·s^{-2}
(D) 1.20 m·s^{-2}

$v^2 = u^2 + 2ar \Rightarrow a = \frac{v^2 - u^2}{2r} = \frac{22^2 - 8^2}{350}$

$\Rightarrow a = 1.20\,m.s^{-2}$

13 A billiard ball travelling on a horizontal surface at a speed of V collides with a barrier and comes off with a speed of V/3 as shown in the following diagram.



View from above

$$\begin{cases} E_{before} = \frac{1}{2} m v_B^2 = \frac{1}{2} m V^2 \\ E_{after} = \frac{1}{2} m v_A^2 = \frac{1}{2} m \left(\frac{V}{3}\right)^2 = \frac{1}{2} \frac{mV^2}{9} \end{cases}$$

$$= \frac{1}{9} E_{before}$$

$$\Rightarrow E_{lost} = \left(1 - \frac{1}{9}\right) E_{before} = \frac{8}{9} E$$

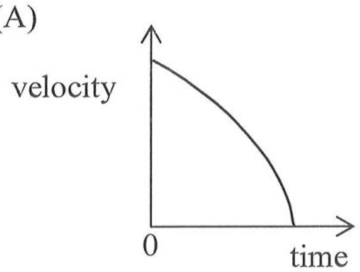
The kinetic energy of the ball before the collision is E. The kinetic energy **lost** by the ball during the collision is:

(A) E / 9
(B) E / 3
(C) 2E / 3
(D) 8E / 9

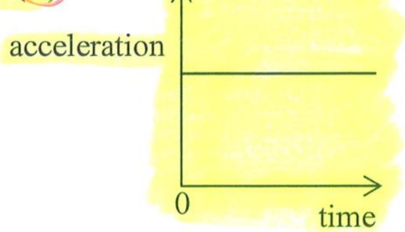
14 Which of the following graphs best represents the motion of a bus that is travelling along a straight road with a speed that is uniformly increasing with time?

a = constant (positive)

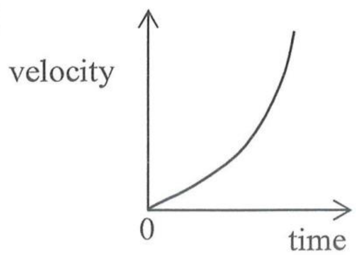
(A)



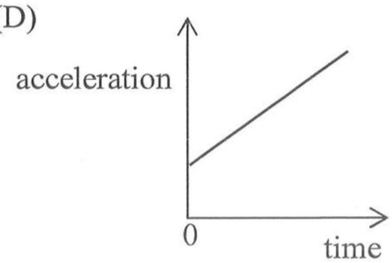
(B)



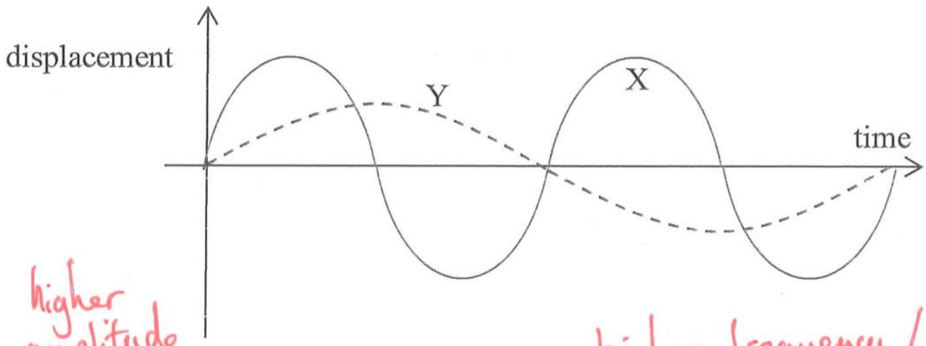
(C)



(D)



15 The diagram below shows two sound waves.



higher amplitude

higher frequency / lower period

Which of the statements below correctly describes the two sounds heard?

(A) X is louder than Y, and X has a higher pitch than Y.
(B) X is louder than Y, and X has a lower pitch than Y.
(C) X is quieter than Y, and X has a lower pitch than Y.
(D) X is quieter than Y, and X has a higher pitch than Y.

16 The average intensity of sunlight falling on the Earth's outer atmosphere is 1.36×10^3 W.m^{-2}. Jupiter is five times further from the Sun than Earth. The average intensity of sunlight falling on Jupiter's outer atmosphere is:

(A) 3.40×10^4 W·m^{-2}
(B) 4.80×10^3 W·m^{-2}
(C) 2.72×10^2 W·m^{-2}
(D) 5.44×10^1 W·m^{-2}

$I_J d_J^2 = I_E d_E^2$ and $d_J = 5 d_E$

$\Rightarrow I_J = I_E \times \frac{d_E^2}{d_J^2} = 1.36 \times 10^3 \times \frac{1}{5^2}$

$\Rightarrow I_J = 54.4$ W.m^{-2}

17 Which of the following lists the components of the electromagnetic spectrum in order of increasing wavelength?

(A) Ultra-violet, infra-red, radio, visible
(B) Radio, infra-red, visible, ultra-violet
(C) Ultra-violet, visible, infra-red, radio
(D) Radio, ultra-violet, visible, infra-red

18 An airport security X-ray machine emits X-rays with a frequency of 4.8×10^{19} Hz. The wavelength of these X-rays is:

(A) 2.1×10^{-20} m
(B) 6.3×10^{-12} m
(C) 2.3×10^{0} m
(D) 1.6×10^{11} m

Wave equation: $c = f\lambda \Rightarrow \lambda = \frac{c}{f}$

$\Rightarrow \lambda = \frac{3.0 \times 10^8}{4.8 \times 10^{19}} = 6.25 \times 10^{-12}$ m

End of Part A

DGB
Class

Name

Part B
Total marks (78)
Attempt ALL Questions
Allow about 1 hour and 40 minutes for this Part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 19 (3 marks) **Marks**

An Astronomical Unit (AU) is defined as the average distance between the Earth and the Sun, i.e. $d_{Earth\text{-}Sun} = 1.00$ AU.
It is used as a convenient unit when measuring distances within the Solar System.

Ceres is a dwarf planet in the asteroid belt that is at a distance of 2.77 AU from the Sun. Determine how long it takes Ceres to orbit once around the Sun. 3

Kepler's Law of Periods: $\frac{R^3}{T^2}$ = constant in our Solar System (1 mark)

$\Rightarrow \frac{R_C^3}{T_C^2} = \frac{R_E^3}{T_E^2} \Rightarrow T_C = T_E\sqrt{\frac{R_C^3}{R_E^3}}$ (1 mark)

OR

$T_E = 1$ year
$R_E = 1$ AU
$R_C = 2.77$ AU

$\Rightarrow T_C = 1 \times \sqrt{\frac{2.77^3}{1^3}}$

$\Rightarrow T_C = \underline{4.61 \text{ years}}$ (1 mark)

$T_E = 365.25$ days
$R_E = 1$ AU
$R_C = 2.77$ AU

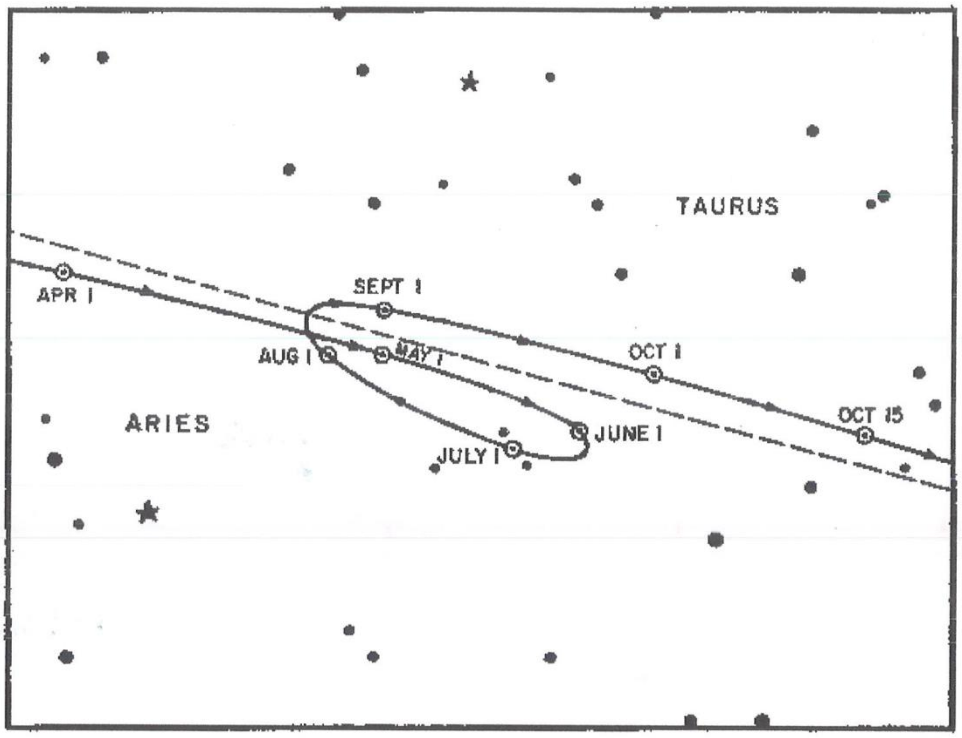
$\Rightarrow T_C = 365.25 \times \sqrt{\frac{2.77^3}{1^3}}$

$\Rightarrow T_C = \underline{1683.9 \text{ days}}$

Marks awarded	*% of boys*
3	78 %
2	7 %
1	7 %

Question 20 (3 marks) **Marks**

(a) The following diagram shows the positions for the planet Mars at various dates throughout the year.



Outline how the geocentric model explained this retrograde motion.

1 mark

By assuming that each planet moved on a small circle (epicycle) that orbited a larger circle (deferent) around the Earth. 1

Marks awarded	*% of boys*
1	94 %

(b) Identify **two** pieces of evidence that were observable after the invention of the telescope that supported the heliocentric model. 2

Marks awarded	*% of boys*
2	91 %
1	5 %

- Phases of Venus

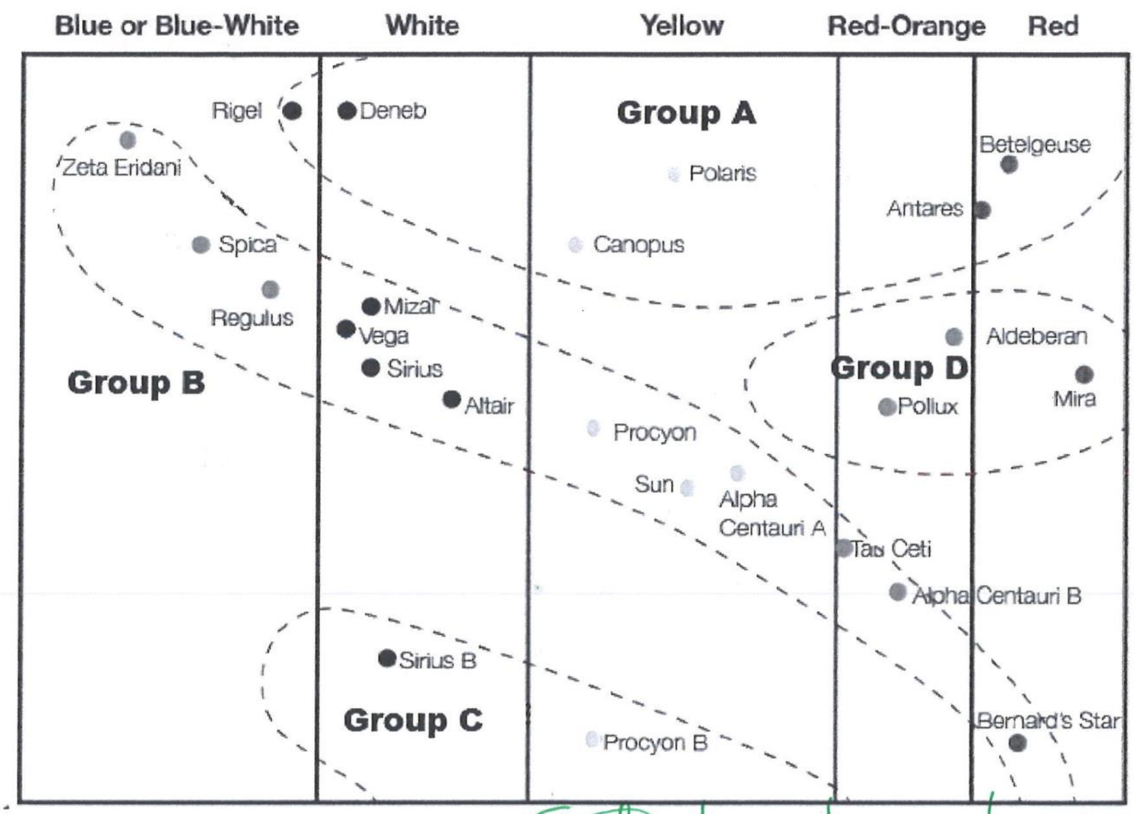
or
- Moons of Jupiter

or
- Rough surface of the Moon

→ 1 mark for each acceptable observation

Question 21 (4 marks) **Marks**

Below is a Hertzsprung-Russell diagram for stars found in the Milky Way.



1 mark for each correct answer

(a) Which star has the highest surface temperature? 1

Zeta Eridani

Marks awarded	% of boys
1	92 %

(b) Which white dwarf is the most luminous? 1

Sirius B

Marks awarded	% of boys
1	95 %

(c) Identify Group B. 1

Main Sequence

Marks awarded	% of boys
1	97 %

(d) Identify Group D. 1

Red Giants

Marks awarded	% of boys
1	97 %

Question 22 (4 marks)

(a) Determine the half-life of Nitrogen-16 if a 200.0 g sample of this isotope decays to 12.5 g in 28.5 s.

1 mark

$2^n = \frac{200}{12.5} = 16 \Rightarrow n = 4$ ∴ 4 half-lives have elapsed **2**

$\Rightarrow t_{1/2} = \frac{28.5}{4} = 7.125$ s ← 1 mark

Marks awarded	*% of boys*
2	79 %
1	12 %

(b) In a particular transmutation, Francium-211 decays into Astatine-207. Write a complete nuclear decay equation to represent this nuclear reaction.

1 mark

$^{211}_{87}Fr \longrightarrow {}^{207}_{85}At + {}^{4}_{2}He$ (or $^{4}_{2}\alpha$) **2**

1 mark

Marks awarded	*% of boys*
2	93 %
1	6 %

Question 23 (3 marks)

Complete the following table to compare the physical properties of two different types of radioactivity. **3**

Type of radiation	Relative charge	Relative penetrating power	Relative ionising power
γ	0	high (or very high)	very low
α	+2	very low	high (or very high)

Any mistake: −1

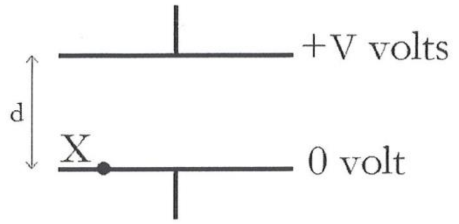
Marks awarded	*% of boys*
3	83 %
2	16 %
1	1 %

Question 24 (3 marks) **Marks**

The diagram below shows two parallel plates with an unknown potential difference $+V$ between them. The plates are separated by a distance $d = 1.0 \times 10^{-3}$ m.

An electron is released from rest at point X on the neutral plate and collides with the positive plate (i.e. top plate) at a speed $v = 2.9 \times 10^{6}$ m·s^{-1}.

Neglect the effect of gravity.



Marks awarded	*% of boys*
3	54 %
2	16 %
1	12 %

Determine the potential difference V applied between the plates. 3

from rest

• Preferred answer: ΔE_k = work done $\Leftrightarrow \frac{1}{2}m(v^2 - \cancel{u^2}) = qV$ 1 mark

$\Rightarrow V = \frac{mv^2}{2q} = \frac{9.109\times10^{-31}\times(2.9\times10^6)^2}{2\times1.6\times10^{-19}} = 23.9\,V$ 1 mark 1 mark

OR

• Alternate answer: N2L $\Rightarrow F_{net} = ma \Leftrightarrow qE = ma \Leftrightarrow q\frac{V}{d} = ma$

$\Rightarrow V = \frac{mad}{q}$ with a such that $v^2 - \cancel{u^2} = 2ad$ 1 mark 1 mark

from rest

$\hookrightarrow a = 4.205\times10^{15}\ m.s^{-2}$

$\Rightarrow V = \frac{9.109\times4.205\times10^{15}\times1.0\times10^{-3}}{1.6\times10^{-19}} = 23.9\,V$ 1 mark

⚠ v (= velocity) and V (= voltage) are 2 different physical quantities

E (= energy) and E (= electric field strength) are also 2 different quantities

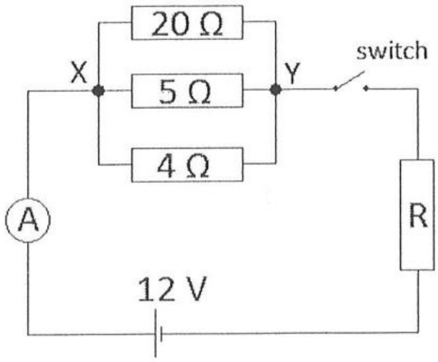
$\Rightarrow$ DO NOT MIX THEM UP IN FORMULAE

Class

Name CRIB (AAM)

Question 25 (5 marks)

Consider the circuit below:



When the switch is closed, the ammeter reads 4 A.

(a) Determine the resistance R. 3

$R_{TOT} = 12/4 = 3\Omega$ (1)

R_{XY} : $\frac{1}{R_{XY}} = \frac{1}{20} + \frac{1}{5} + \frac{1}{4}$ $\rightarrow R_{XY} = 2\Omega$ (1)

$\therefore R = 3 - 2 = 1\Omega$ (1)

(b) Determine the potential difference V_{XY} between the points X and Y. 1

$= 4 \times 2 = 8V$

(1)

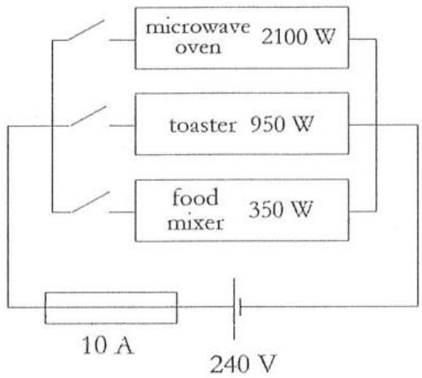
(c) Determine the current flowing through the 20 Ω resistor. 1

$= \frac{8}{20} = 0.4A$

(1)

Question 26 (5 marks) **Marks**

A kitchen has the following three appliances connected in parallel to a 240 V power supply in series with a 10 A fuse: a 350 W food mixer, a 950 W toaster, and a 2100 W microwave oven.



(a) Determine which of these appliances can be operated at the same time without breaking the fuse. *Show all working.* 3

$I_M = \frac{2100}{240} = 8 \cdot 75A.$ ① FOR ANY CURRENT FROM 3.

$I_T = 3 \cdot 96A.$ $I_M = 1 \cdot 46A$ ② FOR ALL 3 CURRENTS

∴ ONLY THE TOASTER + MIXER CAN RUN TOGETHER — ③ WITH WORKINGS

(LOTS OF WAYS TO DO THIS).

(b) Explain how fuses or other electrical devices protect against electrical dangers. 2

① FOR AN OUTLINE OF THE OPERATION OF THE DEVICE

+ ① FOR AN OUTLINE OF HOW IT PREVENTS DANGER. — MUST GIVE AN EXAMPLE OF A DANGER !!

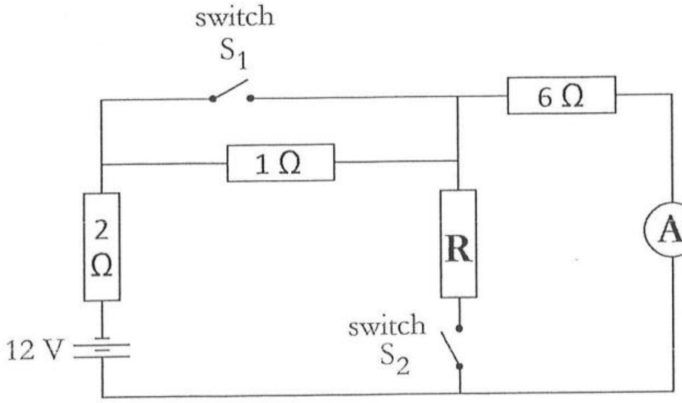
e.g. • FUSE MELTS WHEN THE CURRENT IS TOO LARGE.

• THIS ISOLATES THE DEVICE FROM THE MAINS,

PREVENTING, e.g. FIRES, ELECTRIC SHOCKS, etc.

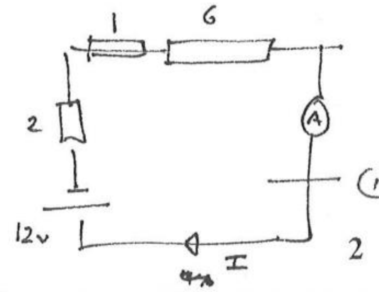
Question 27 (5 marks) **Marks**

The ammeter in the circuit below shows the **same** reading when switches S_1 and S_2 are both open **and** when they are both closed.



Calculate:

when switches are open :

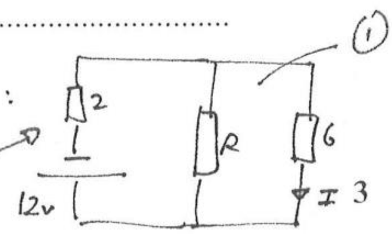


(a) the reading on the ammeter. 2

$I = 12/9 \quad = \underline{1.33\,A}$ — 1

when switches are CLOSED :

or



(b) the value of resistance R. 3

$V_6 = V_R = 6 \times 1{\cdot}33 = 8V.$ — 1

$\therefore V_2 = 4v \quad \therefore I_2 = 2A.$

$\therefore I_R = 0{\cdot}67A. \quad V_R = 8v \longrightarrow \underline{R = 12\Omega}$ — 3

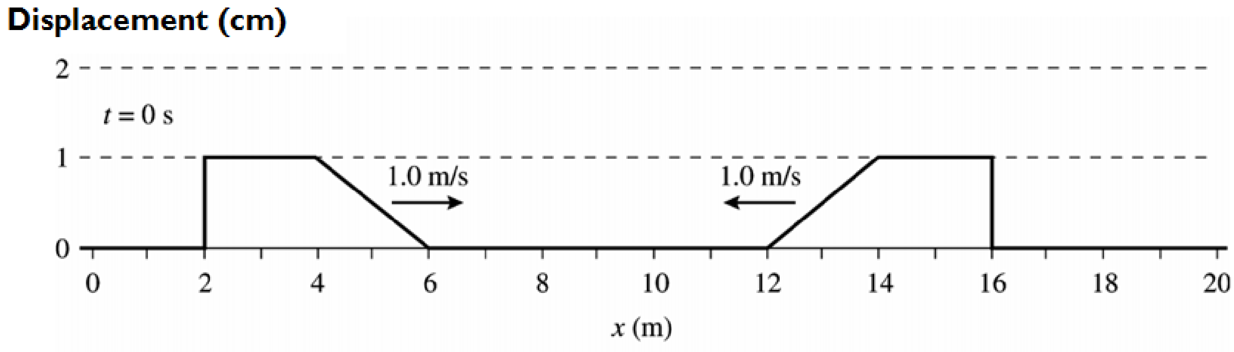
2

(OTHER ROUTES MARKED AS APPROPRIATE)

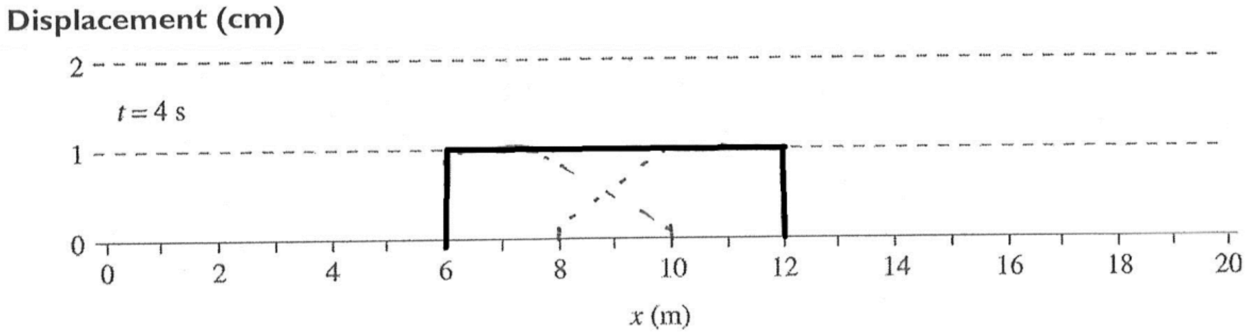
NB IF I COULDN'T FOLLOW YOUR ANSWER, I COULDN'T GIVE YOU MARKS.

Question 28 (2 marks) **Marks**

The picture below shows two wave pulses approaching each other on a stretched string at time t = 0 s. Both pulses have a speed of 1.0 m·s^{-1}.



Draw the shape of the string due to the two pulses at t = 4 s on the empty graph below. **2**



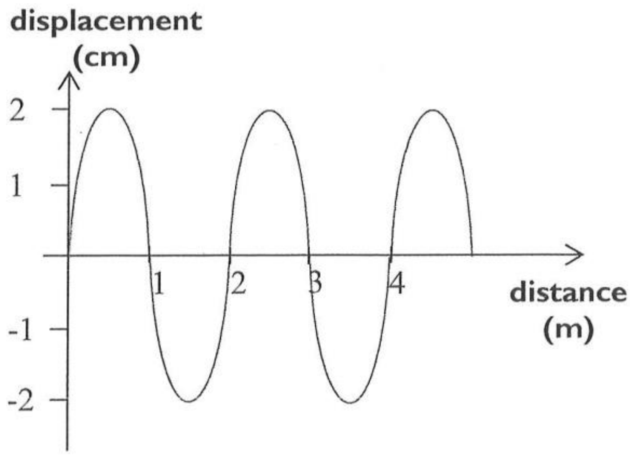
(1) For showing the correct position of the two pulses

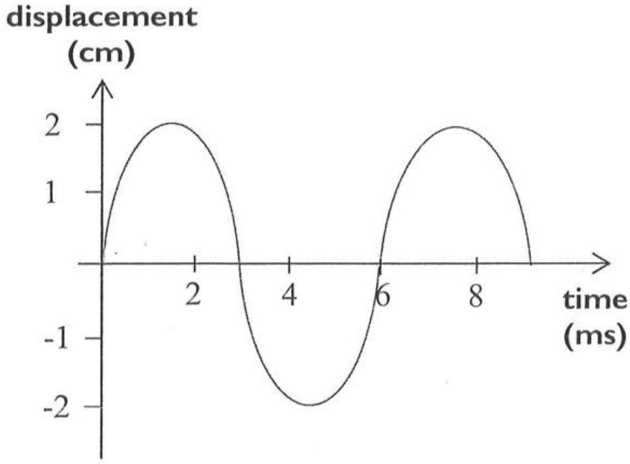
(1) For showing the correct superposition.

(↳ NB: If the pulses, incorrectly, do not overlap → 0 !!)

Question 29 (5 marks) **Marks**

The diagrams below represent the same wave.





For the wave shown, determine:

(a) its amplitude. **1**

2 cm

(b) its wavelength. **1**

2 m

(c) its period. **1**

6 ms (NB 6s or 6 or 0.06s = 0)

NB Carry through in (d) and (e) if (c) is wrong.

(d) its frequency. **1**

167 Hz

(e) its speed. **1**

333 ms^{-1}

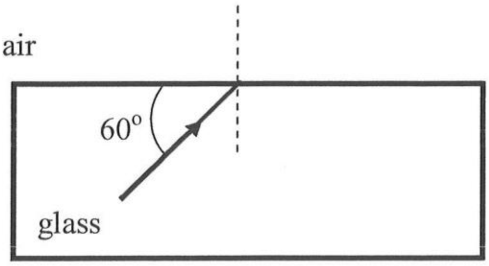
MRW

Class

Name

Question 30 (5 marks) **Marks**

The diagram below shows light passing from a glass block, with a refractive index of 1.52, into air.



(a) Calculate the angle of refraction of the light. **2**

$n_i \sin i = n_r \sin r$ correct substitution into correct formula

$1.52 \sin 30 = 1 \sin r$ giving correct answer.

$r = 49.5°$ ✓✓ 2 mks.

Note: if $1.52 \sin 60 = 1 \sin r$ ✓× 1 mk.

if $1.52 \sin i = 1 \sin 60$ ×× 0 mks.

(b) Calculate the critical angle of the glass. **1**

$n_{glass} \sin i = n_{air} \sin r$ correct substitution into correct formula.

$1.52 \sin i_c = 1 \sin 90$

$i_c = 41.1°$ ✓ 1 mk.

(c) The glass block is now immersed in an unknown transparent fluid. Determine the refractive index of the unknown fluid in order for the critical angle of this new interface to be 60°. **2**

Possibility 1: glass to fluid	Possibility 2: fluid to glass
$n_i \sin i = n_r \sin r$	$n_i \sin i = n_r \sin r$
$1.52 \sin 60 = n_r \sin 90$	$1.52 \sin 90 = n_r \sin 60$
$n_r = 1.32$ ✓✓ 2 mks.	$n_r = 1.76$ ✓✓ 2 mks.

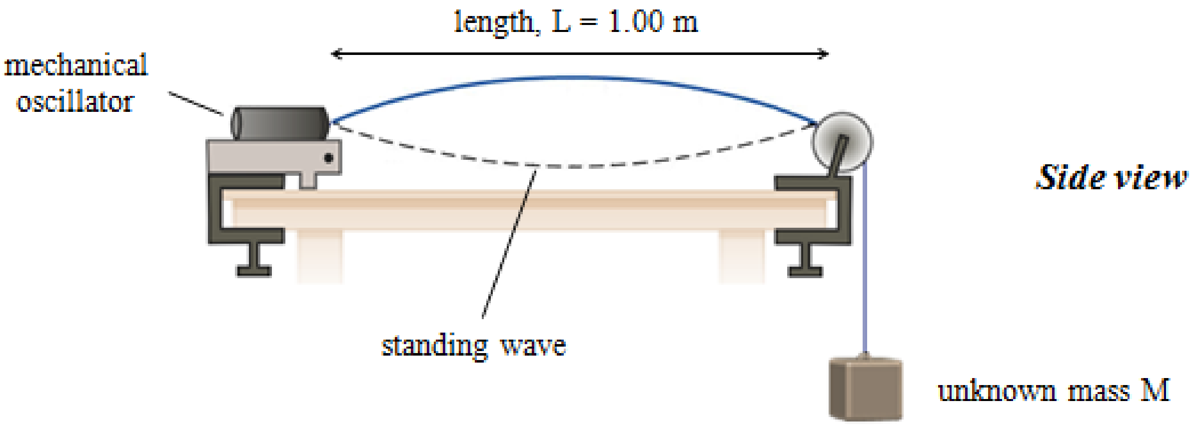
−1 mk for each mistake

Note: if used $n \sin 60 = 1 \sin 90$

×× 0 mks.

Question 31 (4 marks)

A pupil performs an experiment on the production of standing waves on guitar strings. He sets up the following equipment.



The mass, *M*, hanging from the string keeps the tension in the string equal to Mg.

The pupil adjusts the frequency of the mechanical oscillator until he creates a standing wave, with a wavelength equal to double the length of the string, *L*, which he holds constant at 1.00 m.

The pupil's teacher tells him that the frequency, *f*, required to produce this standing wave is given by the following equation:

$$f^2 = \frac{Mg}{4\mu L} \qquad \boxed{\text{Equation 1}}$$

where μ is known as the *linear density* of the string, and is equal to the mass of a one metre length of the string.

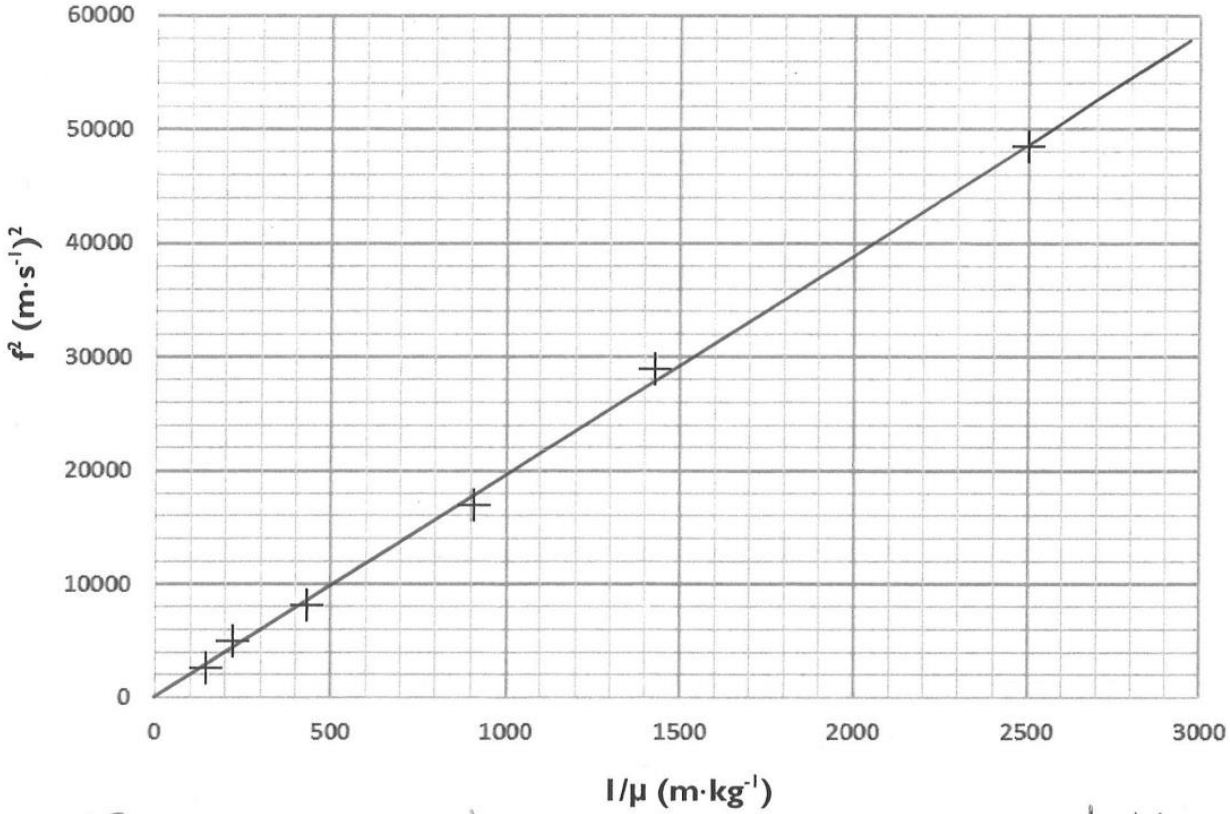
The pupil repeats the experiment for six strings from his guitar, and records his results in the table below:

String (note)	Linear Density μ ($\times 10^{-3}$ kg·m^{-1})	1/μ (m·kg^{-1})	Frequency f (Hz)	f^2 (Hz^2)
E	0.4	2500	220	48400
A	0.7	1429	170	28900
D	1.1	909	130	16900
G	2.3	435	90	8100
B	4.5	222	70	4900
E	6.8	147	50	2500

Question 31 continued on next page.

Question 31 continued. **Marks**

The pupil then plotted the graph f^2 versus $1/\mu$ to verify Equation 1:



if answer based on equation 1 rearranged $M = \frac{f^2 4\mu L}{g}$ with no reference to gradient ✓× 1mk only

(a) Write an expression for the mass, M, hanging from the string in terms of the gradient of the graph and other variables. **2**

gradient = $f^2 / \frac{1}{\mu} = \mu f^2$ ✓ 1 mk.

$M = 4\mu L f^2 / g$

$M = \frac{4L \times \text{gradient}}{g}$ ✓ 1 mk for equation with gradient named

−1 mk for each mistake (e.g. 4 missing, g missing.

Note: since L = 1, it can be missing from equation

(b) Draw the line of best fit of the graph above and use its gradient to calculate the value of the hanging mass, M. **2**

*value depends on line drawn.

e.g. gradient = $\frac{48400 - 0}{2500} = 19.36$ ✓ 1 mk for correct gradient calculation

−1 mk for each mistake

$19.36 = \frac{M \times 9.8}{4 \times 1}$

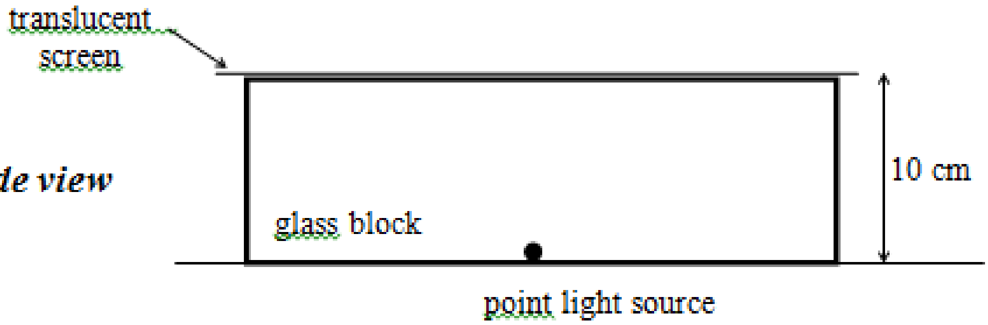
$M = 7.9$ kg ✓ 1 mk.

Note: value for M based on expression given in (a) using a gradient i.e. not substitution into formula (equation 1).

Question 32 (5 marks)

The diagram below shows a glass block with a translucent screen on top of it.

Side view



At the base of the glass block is a magenta (i.e. purple) point light source that emits light of two specific wavelengths:

- red light, of wavelength 7.20×10^{-7} m in air,
- blue light, of wavelength 4.50×10^{-7} m in air.

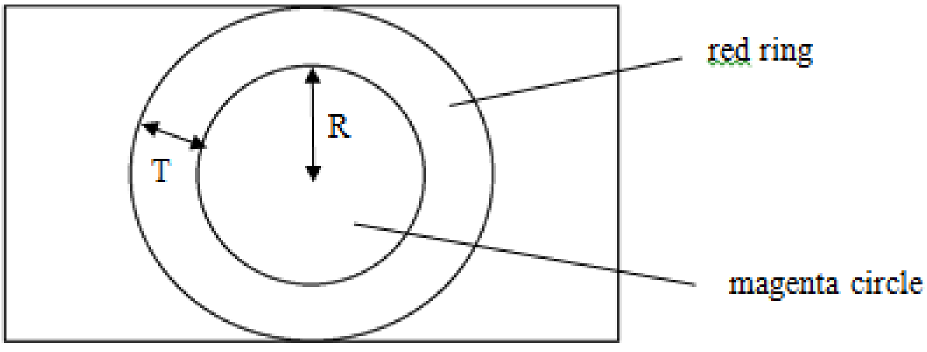
The refractive index of the glass block varies depending on the wavelength of the light.
For a given wavelength in air, λ, the refractive index, n_λ, varies according to the following formula:

$$n_\lambda = \frac{k}{\sqrt[3]{\lambda}} \quad \text{where } k = 1.26 \times 10^{-2} \text{ m}^{1/3} \text{ for all wavelengths in air}$$

When a thin translucent screen is placed on top of the glass block and viewed from above, the following is observed:

NB – You can ignore the refractive properties of the translucent screen, because it is so thin.

View from above



Question 32 continued on next page.

Question 32 continued.

(a) To gain any marks, candidates' answer had to be based on the different critical angles for red and blue light. AND include the

(a) Explain this observation. **2**

following that in the circle of radius R, the incident angle is small enough that both red and blue light refracts, allowing us to see magenta. However, after R, the critical angle for blue light occurs meaning total internal reflection occurs and now only the red light leaves the medium and is seen. At T, the critical angle for red light is reached and total internal reflection for both wavelengths occurs, meaning neither light is observed.

Note: Many answers contained good DESCRIPTIONS but lacked any suitable explanations using physics. 0 mks

(b) Calculate the radius of the magenta circle, *R*, and the width of the red ring, *T*. **3**

R.I.

$n_{red} = \frac{1.26 \times 10^{-2}}{\sqrt[3]{7.20 \times 10^{-7}}} = 1.406$

$n_{blue} = \frac{1.26 \times 10^{-2}}{\sqrt[3]{4.50 \times 10^{-7}}} = 1.644$

✓ 1 mk for calculation of both n_{blue}, n_{red}.

critical angle

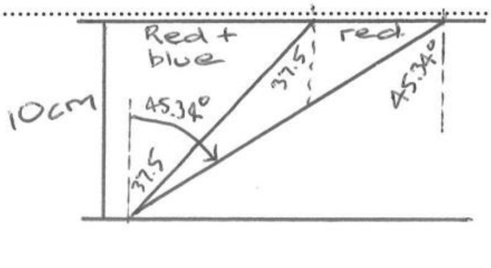
red: $1.406 \sin i_c = 1 \sin 90$

$i_c = 45.34^\circ$

blue: $1.644 \sin i_c = 1 \sin 90$

$i_c = 37.5^\circ$

✓ 1 for calculation of both critical angles.



✓ 1 mk for correct calculation of R and T.

blue: $\tan 37.5 = \frac{R}{10}$

$R = 7.7\text{cm}$

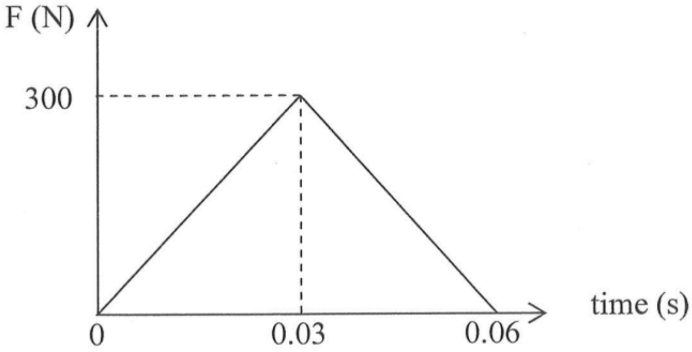
red: $\tan 45.34^\circ = \frac{R+T}{10}$

$R + T = 10.119\text{ cm}$

$\therefore T = 2.42\text{cm}$.

Question 33 (5 marks) **Marks**

Consider the following graph of the force, F, of a racquet acting on a tennis ball as a function of time. Initially a tennis ball of mass 0.150 kg had a velocity of 25 $m \cdot s^{-1}$ towards the racquet. As a result of being hit by the racquet, the ball returned directly along the same path.



(a) Calculate the magnitude of the impulse of the force of the racquet which acted on the tennis ball during the 0.06 s. **2**

Calculate Area ✓ ① mk.

calculate correct area ✓ ① mk.

Area = Impulse $= 2 \times (\frac{1}{2} \times 0.03 \times 300)$

$= 9 \text{ Ns}$

note u is in opposite direction to F.

(b) Determine the magnitude of the final velocity of the tennis ball. **3**

Answer (a) $= 0.150(v - (-25))$ ✓✓✓ 3mks

e.g. $9 = 0.150(v + 25)$ $\therefore v = 35 \text{ ms}^{-1}$

Notes: if Ans(a) $= 0.150(v - 25)$

$\therefore v = 85 \text{ ms}^{-1}$ ✓✓✗ 2mks.

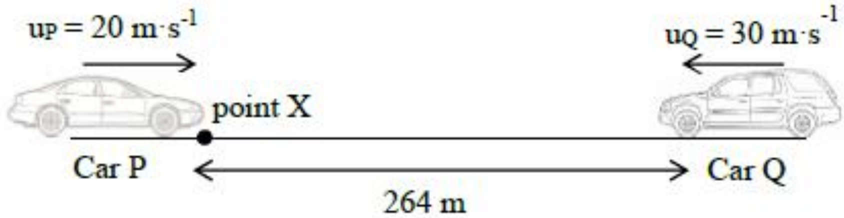
✗ −1 mk for any mistake.

CRIB – PCK

17 marks

Question 34 (6 marks) **Marks**

Two cars are travelling along a straight road as shown in the diagram below.
At the instant shown, Car P passes point X and the two cars are 264 m apart.
Car P travels at a constant speed of 20 m·s^{-1}.
Car Q is initially travelling at 30 m·s^{-1} and, at the instant shown, starts to decelerate at the constant rate of 2 m·s^{-2}.



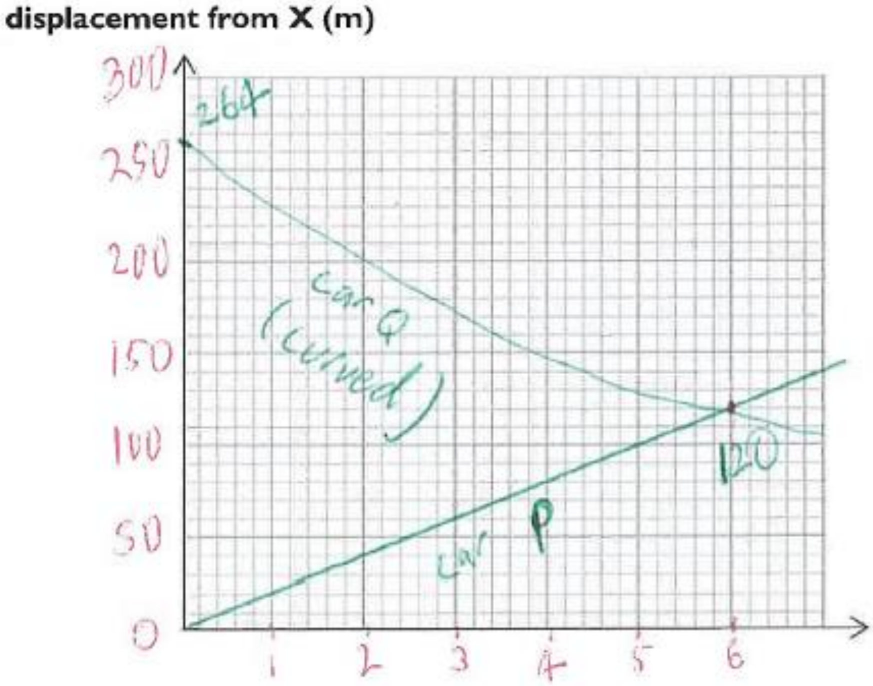
mark	form
na	1%
0	9%
1	20%
2	11%
3	59%

(a) Determine the time that elapses before the cars meet.

Using Distance	Using Displacement
Cars meet when $d_P + d_Q = 264$ $d_P = 20t$ $d_Q = 30t - \frac{1}{2}2t^2$ $d_Q = 30t - t^2$ when $d_P + d_Q = 264$ then $20t + 30t - t^2 = 264$	Cars meet when $r_P = r_Q$ $r_P = 20t$ $r_Q = 264 - (30t - t^2)$ or $r_Q = 264 - 30t + t^2$ when $r_P = r_Q$ then $20t = 264 - 30t + t^2$
Solving quadratic $t^2 - 50t + 264$ t=6 s or 44 s (6 s is correct solution because 44 s is after they pass and car Q's velocity become positive)	

	Marking scheme
1	Forming correct formulas for d_P, d_{PQ} or r_P, r_Q
2	Forming quadratic correctly with correct relationship
3	Correct answer with working (choosing correct solution to quadratic)

(b) On the same set of axes below, sketch displacement versus time graphs to show the positions of each car relative to the point X shown on the diagram. Take t = 0 s as the time when car P passes X and continue the graphs until the cars meet.

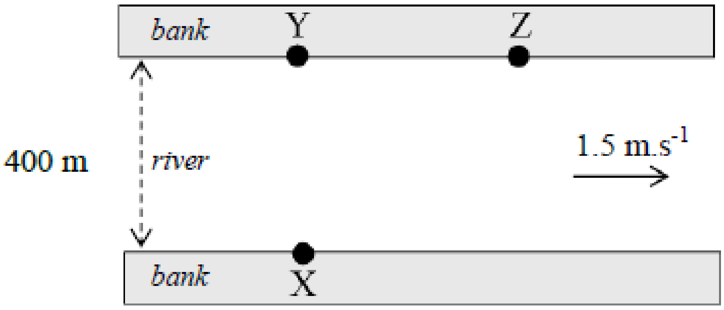


mark	form
na	6%
0	6%
1	14%
2	36%
3	39%

	Marking scheme
1	Car P and Car Q meet at 6 s (or time specified in (a)
1	Car P starts a 0m, Car Q at 264m (requires correct scale)
1	Car P is a straight line and car Q is curved correctly indicating it is slowing down (requires lines to be labelled)

Question 35 (7 marks) **Marks**

Two swimmers (A and B) at point X on one side of a river are in a race where the finishing line is at point Y directly opposite. The river is 400 metres wide and has a current of 1.5 m·s^{-1}, as shown in the following diagram.

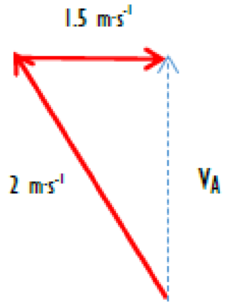


They both dive in at the same time and swim across the river. In still water, both swimmers move at 2 m·s^{-1}.

Swimmer A directs himself so that his resultant motion is in the direction XY, while Swimmer B always swims with his body perpendicular to the current and lands at point Z. He then runs to point Y with a speed of 8 m·s^{-1}.

(a) Draw two vector diagrams to determine the respective resultant speed of Swimmer A and Swimmer B **when in the water**.

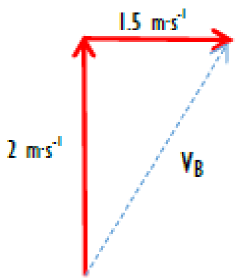
Swimmer A in water



Resultant speed of Swimmer A:

$v_A = \sqrt{2^2 - 1.5^2} = \mathbf{1.32\ m{\cdot}s^{-1}}$

Swimmer B in water



Resultant speed of Swimmer B:

$v_B = \sqrt{2^2 + 1.5^2} = \mathbf{2.5\ m{\cdot}s^{-1}}$

	Marking scheme
2	Correct velocity vector addition diagrams for both swimmer A and B. • Vectors need correct arrows. • Vectors are joined correctly head to tail. • Vectors need to be correctly labelled.
2	Correct speed calculated by Pythagoras from vector diagram for A and B (no carry forward errors)

mark	form
na	1%
0	8%
1	8%
2	13%
3	17%
4	55%

Question 35 continued

(b) Determine which swimmer reaches Point Y first by calculating the time taken by each swimmer to finish the race.

Time across for swimmer A, $t_A = \frac{400}{1.32} = \mathbf{302.4\ s}$

Time for swimmer B to cross river, $t_{B1} = \frac{perpendicular\ distance}{perpendiculr\ speed} = \frac{400}{2}\ or\ \frac{500}{2.5} = \mathbf{200\ s}$

Distance YZ = $(velocity\ of\ water) \times (t_{B1}) = 1.5 \times 200 = 300m$

Distance XY = 500m (by trig or Pythagoras)

Time for swimmer B to run YZ, $t_{B2} = \frac{300}{8} = \mathbf{37.5}\ s$

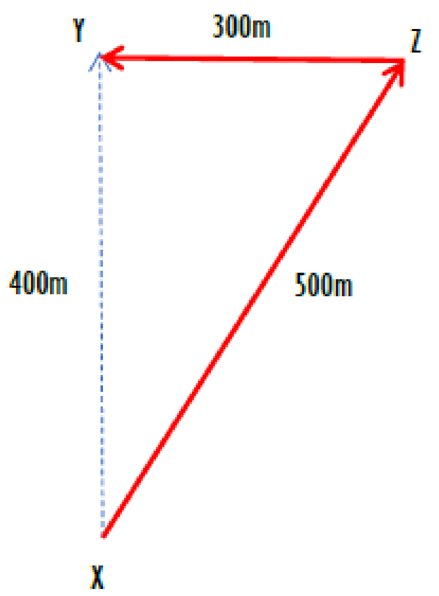
Total time for swimmer B for XZY, $t_B = t_{B1} + t_{B2} = \frac{400}{2} + \frac{300}{8} = \mathbf{237.5s}$

	Marking scheme
1	Correct time for swimmer A to finish (302.4s)
1	Correct time for swimmer B to cross river XZ (200s)
1	Correct distance (300m)or time (37.5s) of ZY calculated AND Total time for swimmer B to finish race

Comments

- Too many calculated the time across river using 400m at 2.5m/s instead of the actual distance travelled diagonally.
- Marks were not allocated for 'who won' as this is a direct consequence of the times for each swimmer.

Swimmer B Displacement



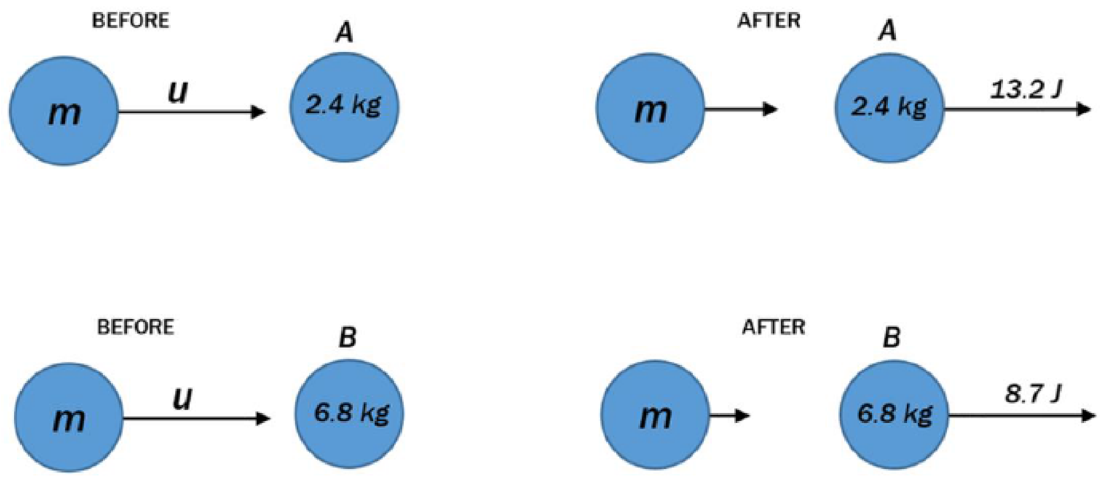
mark	form
na	9%
0	10%
1	20%
2	13%
3	48%

Question 36 (4 marks) **Marks**

An unknown mass, m, has a fixed but unknown velocity, u.

To determine these two unknown values, the unknown mass is allowed to collide *elastically* and separately with two stationary masses A and B ($m_A = 2.4$ kg and $m_B = 6.8$ kg).

As shown in the diagrams below, when the unknown mass collides with A, A recoils with a kinetic energy of 13.2 J. When the unknown mass collides with B, B recoils with a kinetic energy of 8.7 J.



Determine the unknown mass, m, and its unknown velocity, u. **4**

Show all working.

SOLUTION

The subscript x is used to denote that the variable in the formula is the same for collision with A and B. This saves duplicating the same equations for each collision

Table of given data

Mass of A,B	*Kinetic Energy of A,B*	*Final Velocity of A,B*	*Final Momentum of A,B*
given	given	$v_x = \sqrt{\frac{2k_x}{m_x}}$	$p_x = m_x v_x$
$m_x = \begin{Bmatrix} m_A = 2.4\ kg \\ m_B = 6.8\ kg \end{Bmatrix}$	$k_x = \begin{Bmatrix} k_A = 13.2\ J \\ k_B = 8.7\ J \end{Bmatrix}$	$v_x = \begin{Bmatrix} v_A = 3.32\ m \cdot s^{-1} \\ v_B = 1.60\ m \cdot s^{-1} \end{Bmatrix}$	$p_x = \begin{Bmatrix} p_A = 7.96\ Ns \\ p_B = 10.88\ Ns \end{Bmatrix}$

Let c_x be the final velocity of the unknown mass after collision (which will be different for collision A and B)

mark	form
na	8%
0	13%
1	18%
2	34%
3	14%
4	15%

⚠

1. Momentum and Kinetic Energy Method

$\sum p_i = \sum p_f \qquad\qquad mu = mc_x + m_x v_x \qquad (1)$

$2\sum KE_i = 2\sum KE_f \qquad\qquad mu^2 = mc_x^2 + m_x v_x^2 \qquad (2)$

Eliminate the unknown c_x by solving equation 1 for c_x

$$c_x = \frac{mu - m_x v_x}{m} \text{ or } c_x = u - \left(\frac{m_x}{m}\right) v_x \qquad (3)$$

and then substituting c_x into equation 2.

$$mu^2 = m\left(\frac{mu - m_x v_x}{m}\right)^2 + m_x v_x^2 \qquad (4)$$

Equation 4 can be simplified to

$$mu = \frac{v_x}{2}(m_x + m) \qquad (5)$$ Numerically $mu = 1.66m + 3.98$ $mu = 0.80m + 5.44$

Equation 5 can be solved simultaneously for u or m.

SOLVING FOR MASS	SOLVING FOR VELOCITY
Equation 5 solved for m	Equation 5 solved for u
$m = \frac{m_x v_x}{2u - v_x}$ (5a)	$u = \frac{v_x}{2}\left(\frac{m_x}{m} + 1\right)$ (5b)
Equations 5, 5a and 5b are the same equations for both collision A and collision B (two equations are formed when $x \to A$ and $x \to B$). These two equations can be solved simultaneously.	
Equation 5 solved simultaneously for m by dividing A/B	Equation 5b solved simultaneously for u by equating A=B
$\frac{mu}{mu} = \frac{\frac{v_A}{2}(m_A + m)}{\frac{v_B}{2}(m_B + m)}$ (6a)	$\frac{m_A v_A}{2u - v_A} = \frac{m_B v_B}{2u - v_B}$ (6b)
or $m = \frac{m_B v_B - m_A v_A}{v_B - v_A}$ (7a) $m = \frac{p_B - p_A}{v_A - v_B}$ (8a)	$u = \frac{1}{2}\frac{\left(\frac{1}{m_A} - \frac{1}{m_B}\right)}{\left(\frac{1}{m_A v_A} - \frac{1}{m_B v_B}\right)}$ (7b) or $u = \frac{v_A v_B}{2}\left(\frac{m_A - m_B}{m_A v_A - m_B v_B}\right)$ (8b)
Numerical values can be substituted	
$m = \frac{6.8 \times 1.60 - 2.4 \times 3.32}{1.60 - 3.32}$	$u = \frac{3.32 \times 1.60}{2}\left(\frac{2.4 - 6.8}{2.4 \times 3.32 - 6.8 \times 1.60}\right)$
$\boldsymbol{m = 1.7\ kg}$	$\boldsymbol{u = 4.0\ m \cdot s^{-1}}$
m can also be found from equation 5b if u is already calculated	u can also be found from equation 5a if m is already calculated.

2. Centre of Mass Method

For the object being hit.

$$v_x = 2V_{CM} - 0 \tag{9}$$

Where V_{CM} is the velocity of the centre of mass.

$$2V_{CM} = \frac{\sum p_i}{\sum m} = \frac{2mu}{m+m_x} \tag{10}$$

So

$$v_x = \frac{2mu}{m+m_x} \tag{11}$$

This is the same as equation (5). This gives 2 equations when $x \to A$ and $x \to B$ which can be solved simultaneously for m and u as before.

3. Relative Velocity Method

Relative velocities before and after collision gives the following equation

$$u - 0 = v_x - c_x \tag{12}$$

so

$$c_x = v_x - u \tag{13}$$

This can be substituted into the conversation of momentum equation (1) to eliminate c_x.

$\sum p_i = \sum p_f$

$$mu = mc_x + m_x v_x \tag{1}$$

$$mu = m(v_x - u) + m_x v_x \tag{14}$$

This is the same as equation (5). This gives 2 equations when $x \to A$ and $x \to B$ which can be solved simultaneously for m and u as before.

For Reference

The final velocity of the unknown mass can also be calculated.

$$c_x = \begin{Bmatrix} c_A = -0.68\, m \cdot s^{-1} \\ c_B = -2.4\, m \cdot s^{-1} \end{Bmatrix}$$

Marking Scheme	Mark
Solves simultaneously to find correct answer for mass AND initial velocity (working shown)	4
Finds correct answer for mass OR initial velocity (with working shown) OR Derives 2 equations of m, u only (like equation 5) to solve by eliminating other unknowns, but fails to solve.	3
2 pairs of correct equations (for both A and B) OR Determines velocity (or momentum) for A and B after collision AND One pair of correct equations (for both A and B) (eg $\sum p$, $\sum KE$, relative velocity or centre of mass)	2
Determines velocity (or momentum) for A and B after collision OR One pair of correct equations (ie, for both A and B) (eg $\sum p$, $\sum KE$, relative velocity or centre of mass)	1

Commentary

- Many answers failed to realise that the final velocity (c_A, c_B) of the unknown mass would be non-zero and different when colliding with A and B. Different variable names had to be created and assign to each collision. If answers did use different (c_A, c_B) then many tried to solve for these variables, rather than eliminating them by simultaneous solving.
- Most of the successful answers used the centre of mass method or relative velocity method.