VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

**Victorian Certificate of Education
2023**

Letter

STUDENT NUMBER

PHYSICS
Written examination

150/130 = 1.1538 min/Mark.

1 min 9 sec.

Monday 29 May 2023

Reading time: 10.30 am to 10.45 am (15 minutes)
Writing time: 10.45 am to 1.15 pm (2 hours 30 minutes)

150 min

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks	
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A	20	20	20	*23 min*
B	21	21	110	*127 min*
			Total 130	

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 38 pages
- Formula sheet
- Answer sheet for multiple-choice questions

Instructions
- Write your student number in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the formula sheet.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions

<div style="border:1px solid">

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.
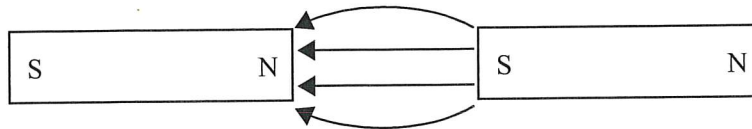
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

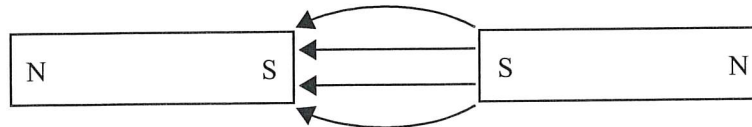Take the value of g to be 9.8 m s^{-2}.

</div>

Question 1

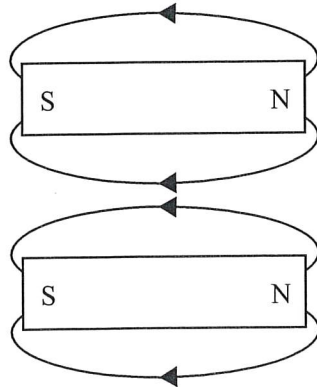Which one of the following diagrams best represents the magnetic field between two magnets?
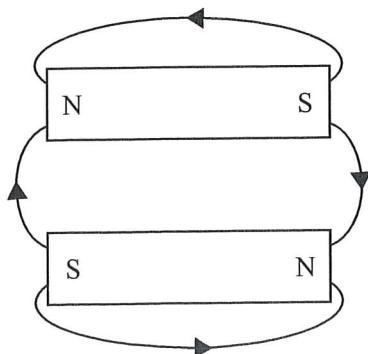
A.

B.

C.

D.

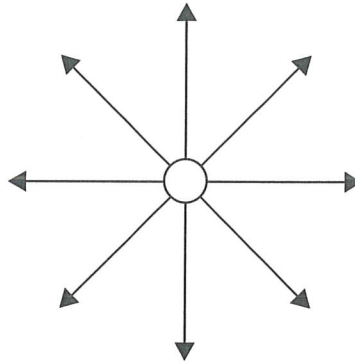*Field lines go N to S.*

Question asks for Best representation

Question 2

Consider the diagram below, which shows a stationary object with field lines that extend outwards from the object.

Lines come out -
→ Electric .
Further out, the
wider the spacing
of the lines
→ non - uniform

The field shown is most likely to be identified as an example of

A.   an electric field that is uniform.

B.   an electric field that is non-uniform.

C.   a gravitational field that is uniform.

D.   a gravitational field that is non-uniform.

Question 3

Two identical satellites, S_1 and S_2, each of mass m, are placed into two circular orbits around Earth. Satellite S_1 has an orbital radius of $5R$. Satellite S_2 has an orbital radius of R.

Which one of the following best gives the value of $\dfrac{\text{gravitational force exerted on } S_1 \text{ by Earth}}{\text{gravitational force exerted on } S_2 \text{ by Earth}}$?

$F = \dfrac{GMm}{r^2}$

A. $\dfrac{1}{25}$

B. $\dfrac{1}{10}$

C.   10

D.   25

$\dfrac{GMm_1}{(5R)^2} \div \dfrac{GMm_2}{R^2}$

$= \dfrac{GMm_1}{25R^2} \times \dfrac{R^2}{GMm_2} = \dfrac{1}{25}$

Question 4

Which one of the following statements about the polarisation of waves is correct?

A.   Transverse waves can be polarised.

B.   Longitudinal waves can be polarised.

C.   Both longitudinal and transverse waves can be polarised.

D.   Neither longitudinal nor transverse waves can be polarised.

Occurs only for Transverse
Light can be polarised
Sound can't

SECTION A – continued
TURN OVER

Question 5

The diagram below shows an ideal transformer in which the primary coil is connected to a battery and a switch. An ammeter is connected to the secondary coil.

soft iron core

ammeter

primary coil   secondary coil
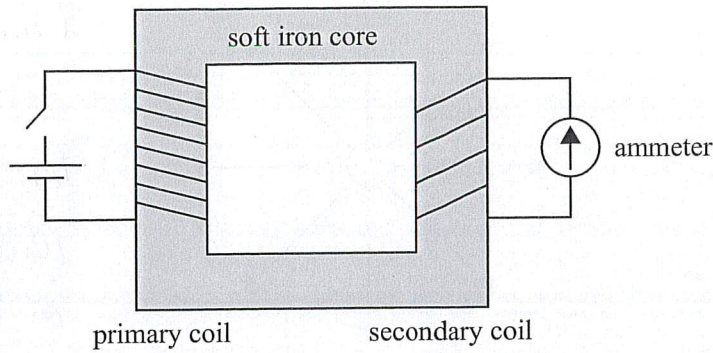
When the switch is closed, the pointer on the ammeter momentarily deflects. How could the deflection on the ammeter be made larger?

A. decrease the number of primary coils

B. decrease the number of secondary coils

C. increase the number of secondary coils

D. place a resistor in series with the ammeter

Handwritten annotation:

Turns Ratio

$\dfrac{I_s}{I_p} = \dfrac{N_p}{N_s}$

$N_p \uparrow$ OR $N_s \downarrow$

Question 6

An RMS current of 15.6 A is equivalent to a peak-to-peak current of

A. 11.0 A

B. 22.1 A

C. 44.1 A

D. 55.2 A

Handwritten annotation:

$I_{RMS} = \dfrac{1}{\sqrt{2}} I_{peak}$

$15.6 \times \sqrt{2} = I_p$

$I_p = 22.06.$

$I_{p-p} = 2 \times I_p$

$\quad = 2 \times 22.06$

$\quad = 44.12$

SECTION A – continued

Question 7

Electrical generators may use slip rings or split-ring commutators when generating electricity. When operating at equal frequencies, the output voltages of these two types of generators can be displayed together on an oscilloscope screen.

The output of the split-ring commutator is displayed as a dotted line.

The output of the slip rings is displayed as a solid line.

Which one of the following diagrams best represents the two outputs?

A.

B.

C.

D.
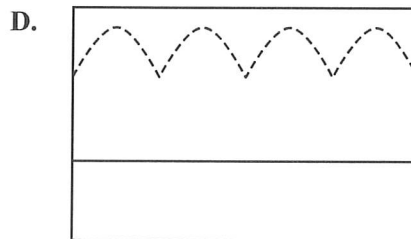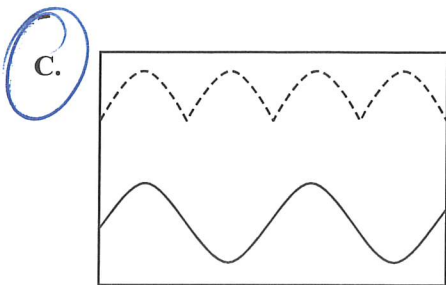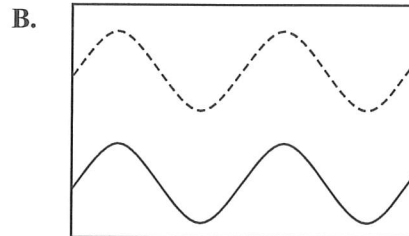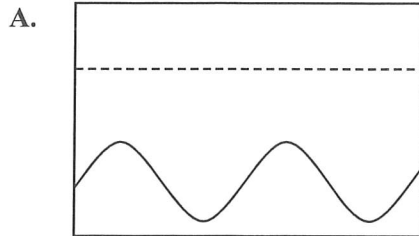
Question 8

Saturn has 83 moons. One of them, Enceladus, has a mass 1.08×10^{20} kg and a circular orbit of radius 2.38×10^8 m.

The mass of Saturn is 5.68×10^{26} kg.

Which one of the following is closest to the gravitational force of attraction between Enceladus and Saturn?

A. 0 N

B. 1300 N

C. 4.9×10^8 N

D. 7.2×10^{19} N

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

$$= \frac{6.67 \times 10^{-11} \times 5.68 \times 10^{26} \times 1.08 \times 10^{20}}{(2.38 \times 10^8)^2}$$

$$= 7.22 \times 10^{19}$$

Use the following information to answer Questions 9 and 10.

The diagram below shows two stationary trolleys on a smooth surface, with an ideal spring compressed between them. Trolley A has mass of 1.0 kg and Trolley B has mass of 2.5 kg. The spring is released and the trolleys move off in opposite directions. The spring falls straight down.

+ve.
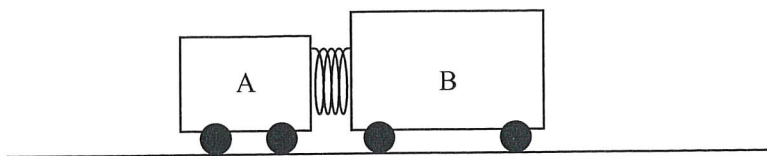
Question 9

In the first experiment, Trolley A moves to the left at 0.80 m s^{-1}.

Which one of the following is closest to the speed of Trolley B?

A. 0.32 m s^{-1}
B. 0.80 m s^{-1}
C. 2.0 m s^{-1}
D. 3.1 m s^{-1}

Handwritten working:
$P_i = P_f$
$0 = 1 \times v_A + 2.5 \times v_B$
$0 = 1 \times -0.8 + 2.5 \times v_B$
$0.8 = 2.5 \, v_B$
$v_B = 0.32.$

Question 10

The experiment is repeated with a different spring. The spring is compressed 2.8 cm and released. Now Trolley A moves to the left at 1.0 m s^{-1} and Trolley B moves to the right at 0.4 m s^{-1}.

Which one of the following is closest to the spring constant of this spring?

A. 710 N m^{-1}
B. 1100 N m^{-1}
C. 1800 N m^{-1}
D. 6300 N m^{-1}

Question 11

Which one of the following best describes a hypothesis? — *to be tested*

A. an explanation that is correct
B. a statement that is widely accepted by physicists
C. an explanation that has been supported by experimental evidence
D. a possible explanation that needs to be tested by experimental evidence

Handwritten working:
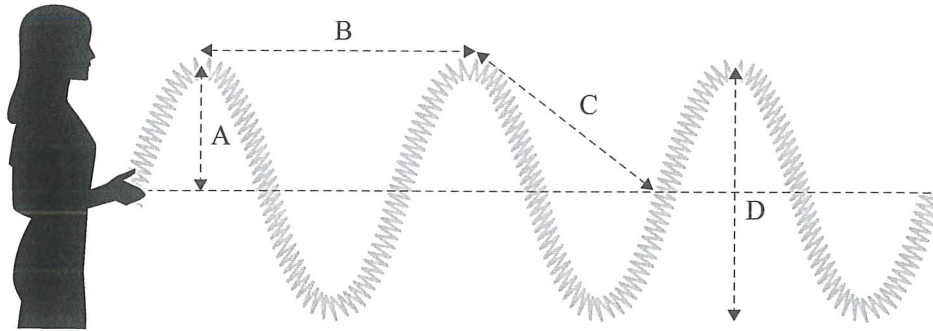
Before release. $U_s = \frac{1}{2} k (0.028)^2$ $E_k \text{ Total} = 0$
$= 3.92 \times 10^{-4} k.$

After release $U_s = 0$ $E_k \text{ Total} = E_{KA} + E_{KB}$
$= \frac{1}{2} \times 1 \times 1^2 + \frac{1}{2} \times 2.5 \times 0.4^2$
$= 0.7$

Total Energy Before = Total Energy After
$3.92 \times 10^{-4} k = 0.7$
$k = 1785.71$

Question 12

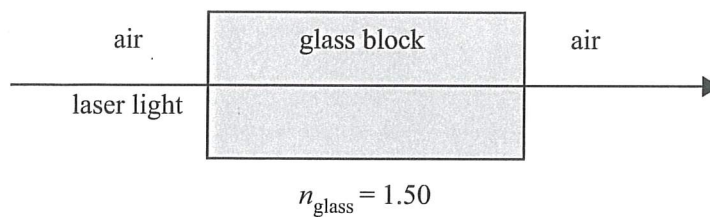Sophia is moving the end of a Slinky spring up and down, creating a transverse wave.

Which of the lines labelled with arrows best represents the amplitude of the wave?

A. line A

B. line B

C. line C

D. line D

Question 13

A ray of monochromatic laser light travels from air, straight through a glass block of refractive index 1.50, as shown below.

$$n_{glass} = 1.50$$

Which one of the following best describes what happens to the speed, the wavelength and the frequency of the light ray when it is travelling through the glass block, compared to when it is travelling through air?

	Speed	Wavelength	Frequency
A.	decreases ✓	same	same ✓
B.	decreases ✓	decreases ✓	same ✓
C.	decreases ✓	same	decreases
D.	increases	same	same ✓

Frequency determined by the Source.
No change

$$U = \lambda f$$

$$f = \frac{v}{\lambda}$$

$n_g > n_a \Rightarrow$ *Slows down.*
To keep f the Same $\lambda \downarrow$ also.

SECTION A – continued
TURN OVER

Question 14

A standing wave is produced on a flexible string, as shown in the diagram below. The diagram shows the wave at two different times – the solid line represents what the wave looks like at a particular time and the dotted line represents what the wave looks like exactly half a cycle later.

$\leftarrow$ -------------------- 5.0 m -------------------- $\rightarrow$
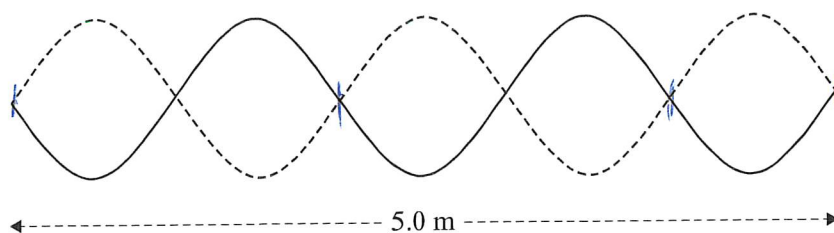
Which one of the following is closest to the wavelength of the standing wave?

$2\frac{1}{2}\lambda = 5m$

$\lambda = 2$

A.   0.5 m

B.   1.0 m

C.   1.5 m

D.   2.0 m

Question 15

Violet light shines on a metal surface and electrons are emitted. The maximum kinetic energy of electrons emitted is measured to be 0.120 eV.

This energy, when expressed in joules, is closest to

A. 1.33×10^{-20} J

B. 1.92×10^{-20} J

C. 1.33×10^{-18} J

D. 1.92×10^{-18} J

$0.120 \text{ eV} \rightarrow J$

$0.120 \times 1.6 \times 10^{-19}$

$= 1.92 \times 10^{-20}$

Question 16

A proton of mass 1.67×10^{-27} kg is accelerated until its de Broglie wavelength is 5.00×10^{-9} m. The speed of the proton is then closest to

A. 1.33×10^{-18} m s^{-1}

B. 1.26×10^{-2} m s^{-1}

C. 79.4 m s^{-1}

D. 5.04×10^{4} m s^{-1}

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

$5.00 \times 10^{-9} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times v}$

$v = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 5.00 \times 10^{-9}} = 79.4$

Question 17

Which one of the following light sources produces a full continuous spectrum of visible light?

A.   He–Ne laser

B.   infra-red heat lamp

C.   incandescent globe

D.   mercury vapour lamp

SECTION A – continued

DO NOT WRITE IN THIS AREA

[handwritten: Threshold.]

[handwritten: $\lambda \times 2 \Rightarrow f \times \frac{1}{2} \Rightarrow$ Below Threshold.]
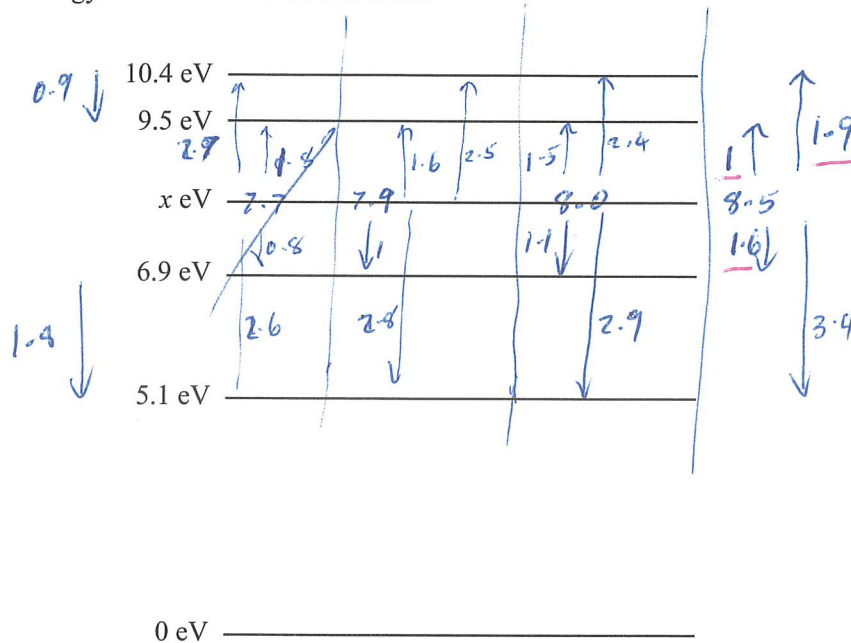
Question 18

Light of wavelength 300 nm is just able to cause the photoelectric emission of electrons from a lead surface. If light of twice this wavelength were incident on a lead surface

A. no photoelectric emission would occur. *[circled]*

B. half as many electrons would be ejected per second.

C. the same number of electrons would be ejected per second, with twice the energy.

D. the same number of electrons would be ejected per second, with more energy but not necessarily twice as much energy.

Question 19

Some of the energy levels for an unknown atom are shown in the diagram below, with one of the lines labelled x eV. These energy levels are not drawn to scale.

[energy level diagram with levels: 10.4 eV, 9.5 eV, x eV, 6.9 eV, 5.1 eV, 0 eV. Handwritten annotations: 0.9, 2.9, 1.4, 0.8, 1.6, 2.5, 1.5, 2.4, 1.9, 8.5, 8.0, 1.1, 1.6, 7.7, 7.9, 2.6, 2.8, 2.9, 3.4]

A part of the emission spectrum of the atom shows lines at 1.0 eV, 1.6 eV and 1.9 eV.

The value of x is closest to

A. 7.7

B. 7.9

C. 8.0

D. 8.5 *[circled]*

[handwritten: Look for Differences in energy between x and other Levels. Trial + Error — Time consuming.]

Question 20

A pion and its antiparticle, each at rest, annihilate and produce only two photons with a total energy of 4.5×10^{-11} J. The masses of the pion and its antiparticle are the same.

The rest mass of the pion is closest to

A. 1.3×10^{-28} kg

B. 2.5×10^{-28} kg *[circled]*

C. 5.0×10^{-28} kg

D. 7.5×10^{-20} kg

*[handwritten: $E = Mc^2$
$4.5 \times 10^{-11} = M \times (3 \times 10^8)^2$
$M = 5 \times 10^{-28}$
Total Mass converted
Masses the Same $\Rightarrow$ pion half of this
$M_{pion} = 2.5 \times 10^{-28}$]*

END OF SECTION A

TURN OVER

SECTION B

> **Instructions for Section B**
>
> Answer **all** questions in the spaces provided.
>
> Where an answer box is provided, write your final answer in the box.
>
> If an answer box has a unit printed in it, give your answer in that unit.
>
> In questions where more than one mark is available, appropriate working **must** be shown.
>
> Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
>
> Take the value of g to be 9.8 m s^{-2}.

Question 1 (3 marks)

Two small charges, A and B, are placed 6.0 cm apart in a straight line, as shown in Figure 1.
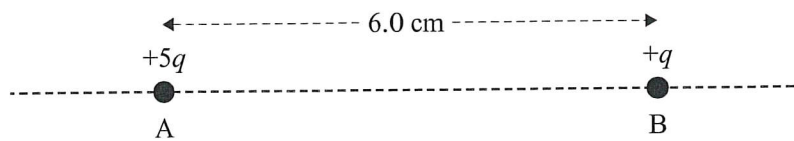

Figure 1

Charge A has a magnitude of $+5q$ coulombs and charge B has a magnitude of $+q$ coulombs.

If the force exerted by charge A on charge B is 5.1×10^{-24} N to the right, determine the value of q.

$$F = \frac{kq_1q_2}{r^2}$$

$$5.1 \times 10^{-24} = \frac{8.99 \times 10^9 \times 5q \times q}{(0.06)^2}$$

$$1.836 \times 10^{-26} = 4.995 \times 10^{10} \, q^2$$

$$4.08 \times 10^{-37} = q^2$$

$$q = 6.391 \times 10^{-19}$$

$$= 6.4 \times 10^{-19}$$

$$\boxed{6.4 \times 10^{-19}} \quad C$$

Question 2 (3 marks)

A positively charged particle carrying a charge of $+1.5 \times 10^{-8}$ C enters a region between two large, charged plates with opposite charges, as shown in Figure 2.

The potential difference between the plates is 2.0 kV, and the kinetic energy of the charged particle as it enters the hole is 2.8×10^{-5} J. Ignore gravitational effects and air resistance.
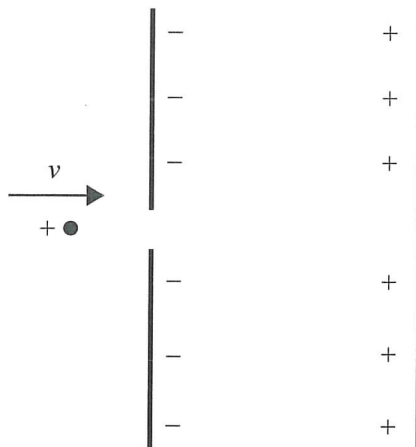
Figure 2

Ariel and Jamie discuss what they think will happen to the particle after it enters the region between the two equally but oppositely charged plates.

Ariel says that the particle has insufficient kinetic energy to reach the positively charged plate and will travel part of the way before returning towards the negatively charged plate.

Jamie says that the particle will collide with the positively charged plate and then head back towards the negatively charged plate.

Evaluate Ariel and Jamie's statements, giving clear reasons for your answer.

Crossing

Energy Change in Field $= qV = 1.5 \times 10^{-8} \times 2.0 \times 10^{3} = 3.0 \times 10^{-5}$ J

K.E. of charged Particle $= 2.8 \times 10^{-5}$ J

Energy required to reach positive plate $(3.0 \times 10^{-5}$ J$)$ greater than the K.E. of the particle $(2.8 \times 10^{-5}$ J$)$.

Thus Areil's statement is correct

Note: 3 Marks   – Calculation
                – Comparison of K.E. to Energy needed
                – Who's statement is correct.

Question 3 (3 marks)

Two thin, light aluminium tubes, A and B, are supported in a vertical wooden rack, as shown in Figure 3.
Both of the aluminium tubes rest horizontally on wooden pegs.

Field around A

aluminium tube A

Field around B

aluminium tube B

wooden pegs

DC power supply

wooden rack
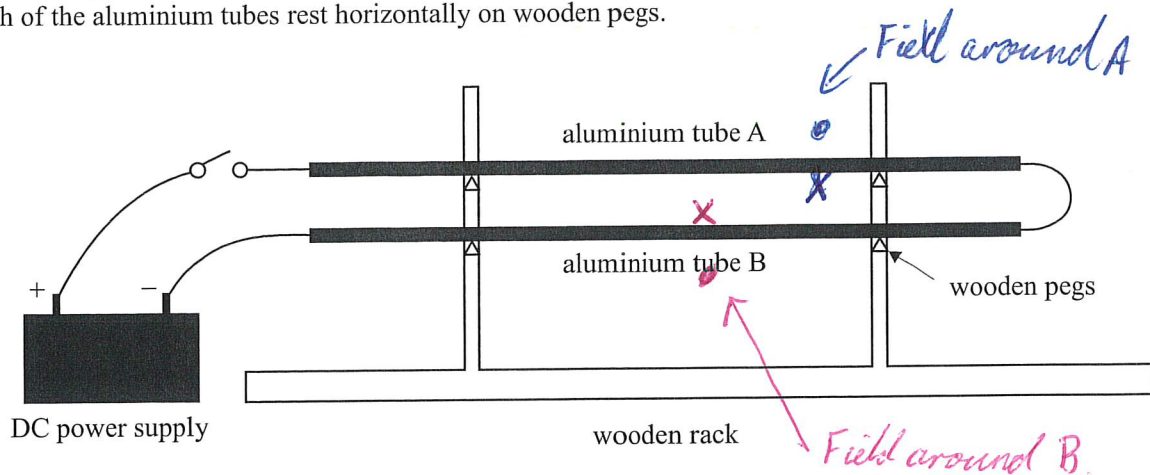
Figure 3

The two thin, light aluminium tubes form a series circuit with a DC power supply. It was observed that one
of the tubes jumped upwards when the DC power supply was switched on.

Identify which tube jumped upwards and explain why this occurred.

Aluminium tube $\boxed{A}$

Between the tubes
   Direction of field due to A is into page.
   Direction of field due to B is into Page.
The tubes will repel.
   Tube B is held and can't move down.
Tube A moves up.

Note: Try to keep it simple and use the minimum
number of words necessary.

Question 4 (4 marks)

Two electrons, e_1 and e_2, are emitted, one after the other, from point P in a uniform magnetic field, as shown in Figure 4.

Both electrons travel perpendicular to the magnetic field, but in opposite directions. Throughout their journey, both electrons remain within the magnetic field.

Electron e_1 travels at twice the speed of e_2. Relativistic effects can be ignored as both electrons are travelling at low speeds. Electrostatic effects at point P can be ignored as the two electrons are emitted at different times.
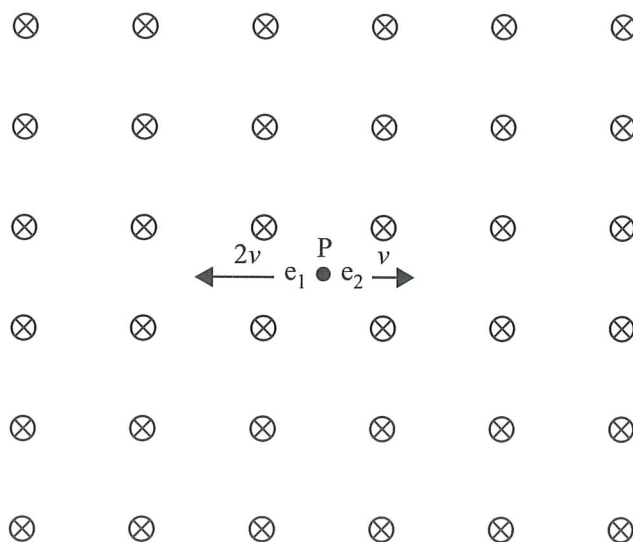
$$r = \frac{mv}{qB}$$

Figure 4

Which one of the following three outcomes occurs?

- Outcome 1 – Electron e_1 returns to point P in the shortest time.
- Outcome 2 – Electron e_2 returns to point P in the shortest time.
- Outcome 3 – Both electrons take the same time to return to point P.

Outcome ⟦ 3. ⟧

Explain your answer. Radius of circle

e_1 $r_1 = \frac{M(2v)}{qB}$ e_2 $r_2 = \frac{Mv}{qB}$

distance travelled

$d_{e_1} = 2\pi r_1$ $d_{e_2} = 2\pi r_2$

$r_1 = 2\frac{Mv}{qB}$ $= 2\pi(2r_2)$ $= 2\pi r_2$

$r_1 = 2 r_2$ $= 4\pi r_2$

$= 2 d_{e_2}$

e_1 travels twice the distance of e_2.
but at twice the speed.
∴ Same time

Question 5 (3 marks)

Figure 5 shows the sun, the moon and Earth.

The mass of the sun is approximately 3.3×10^5 times the mass of Earth.

The distance from the sun to the moon is approximately 390 times the distance from Earth to the moon.

Figure 5

Calculate $\dfrac{\text{magnitude of the sun's gravitational force on the moon}}{\text{magnitude of Earth's gravitational force on the moon}}$.

$$F_{s-m} = \frac{G M_s M_m}{(r_{s-m})^2} \qquad F_{E-M} = \frac{G M_E M_m}{(r_{E-m})^2}$$

$$= \frac{G (3.3 \times 10^5 M_E) M_m}{(390\, r_{E-m})^2}$$

$$\frac{F_{s-m}}{F_{E-m}} = \frac{G(3.3 \times 10^5 M_E) M_m}{(390\, r_{E-m})^2} \times \frac{(r_{E-m})^2}{G M_E M_m}$$

$$= \frac{3.3 \times 10^5}{390^2}$$

$$= 2.1696$$

$$= 2.2$$

2.2

Question 6 (5 marks)

Measuring very small changes in Earth's surface mass, the 600 kg satellite GRACE-FO1 is in a circular orbit around Earth at an altitude of 500 km. The radius of Earth is 6.37×10^6 m.

a.   Calculate the magnitude and direction of the satellite's centripetal acceleration. Give your answer correct to three significant figures.   3 marks

Held in place by gravity $\Rightarrow$ acc^n due to gravity is centripetal acc^n

$$a = \frac{G M_e}{r^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.37 \times 10^6 + 500 \times 10^3)^2} = 8.4511$$

8.45	m s^{-2}

Towards centre of Earth.

b.   Figure 6 shows a graph of the gravitational force that would act on GRACE-FO1 for a range of altitudes.

Could use these estimates

$(500, 5100)$

$(1400, 3900)$

$1.5 cm = 2000 N$

$\Rightarrow 1.7 cm = 2267 N$

$0.10 m = 133 N$

$4000 \leftarrow 133 = 3867$
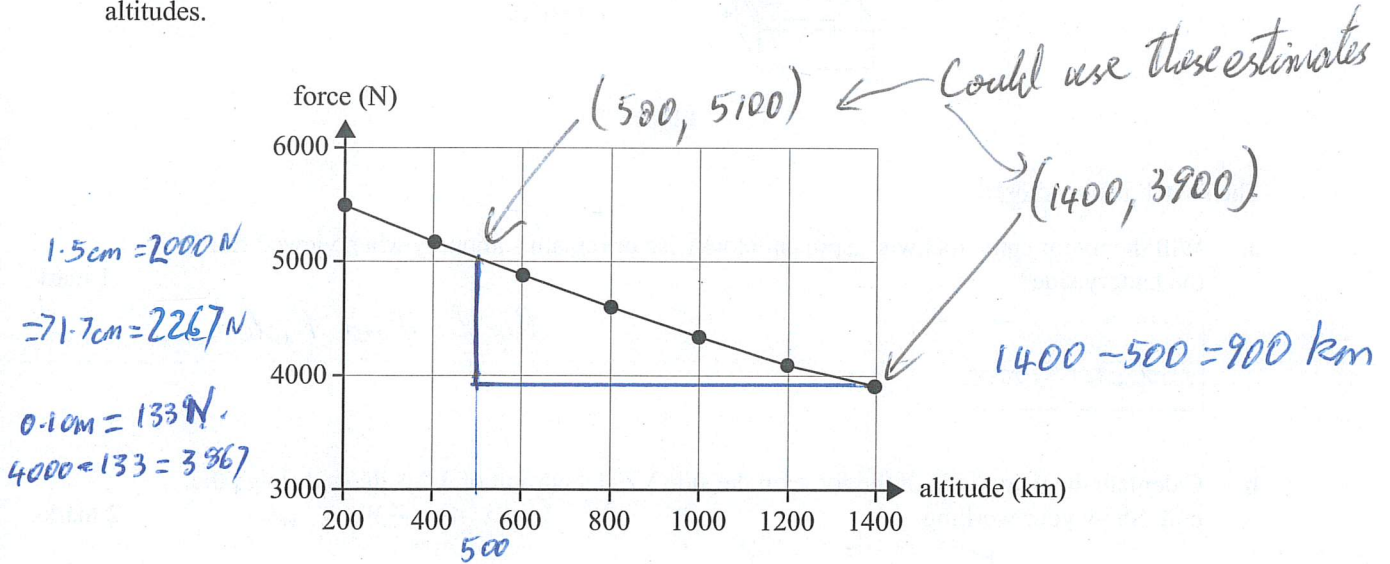
$1400 - 500 = 900$ km

Figure 6

Estimate the energy required to lift the satellite from its present orbit at an altitude of 500 km to a new orbit at an altitude of 1400 km.   2 marks

$$\text{Area} = \text{Work} = \text{Energy Required} = \frac{1}{2} \times 2267 \times 900 \times 10^3 + 3867 \times 900 \times 10^3$$

$$= 1.02 \times 10^9 + 3.48 \times 10^9$$

$$= 4.5 \times 10^9$$

4.5×10^9	J

Note: Could use area of a trapezium formula, and the estimates for the points.

SECTION B – continued
TURN OVER

Question 7 (3 marks)

Figure 7 shows a schematic diagram of a simple DC motor, powered by a battery.

The motor has a rectangular coil, WXYZ, consisting of 45 turns. The side WX has a length of 6.0 cm and the side XY has a length of 4.0 cm. The coil is connected to a split-ring commutator. Two permanent magnets provide a uniform magnetic field of 80 mT. Both the coil and the commutator are free to turn.

Area of coil
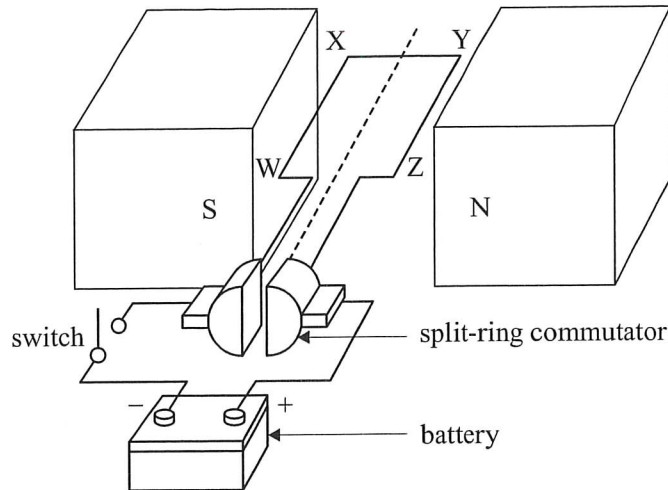$= 0.06 \times 0.04$
$= 2.4 \times 10^{-3} \, m^2$.
(Not Needed).

Figure 7

The switch is now closed.

a. Will the motor spin clockwise, spin anticlockwise or remain stationary when viewed from   1 mark
    the battery side?

    Right - Hand Rule

    Anticlockwise

b. Calculate the magnitude of the force on the side YZ if a current of 3.2 A flows through the   2 marks
    coil. Show your working.   ← Same length as WX

$$F = nILB$$
$$= 45 \times 3.2 \times 0.06 \times 80 \times 10^{-3}$$
$$= 0.6912$$

    0.69   N

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Question 8 (7 marks)

Sarah and Raminda construct a simple alternator, as shown in Figure 8.
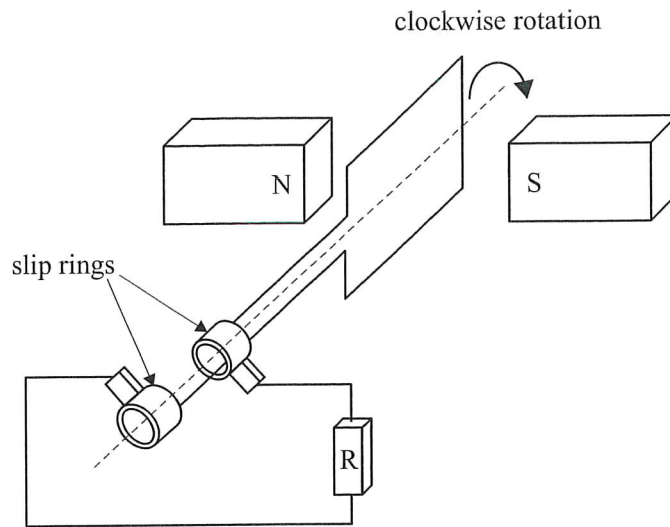
Figure 8

When the coil is rotating steadily, it takes 50.0 ms to complete one revolution and the peak EMF generated is 4.30 V.

a. Calculate the frequency of the alternator.   1 mark

$$f = \frac{1}{T} = \frac{1}{50 \times 10^{-3}} = 20$$

| 20 | Hz |

b. Calculate the EMF, V_{RMS}, generated. Show your working and give your answer correct to three significant figures.   2 marks

$$V_{RMS} = \frac{1}{\sqrt{2}} V_{peak}$$
$$= \frac{1}{\sqrt{2}} \times 4.30$$
$$= 3.0405$$

| 3.04 | V |

c.   To increase the magnitude of the EMF produced by the alternator, Raminda suggests making a number of changes to the alternator.

Sarah insists that each change be investigated one at a time.

In the spaces provided, indicate whether each suggestion will increase, decrease or have no effect on the EMF produced by the alternator.   4 marks

Suggested change	Effect on EMF (increases, decreases or has no effect)
reduce the resistance of resistor R	No effect.
increase the strength of the permanent magnets	Increase
reduce the period of rotation of the coil to 25 ms	Increase
increase the number of turns of the rotating coil	Increase.

$$\mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t} \quad \leftarrow \quad \Phi_B = B_\perp A$$

SECTION B – continued
TURN OVER

Question 9 (7 marks)

A local community wishes to power its town hall using hydro-electricity. A waterfall drives an AC generator, with power delivered to the hall via transmission lines, as shown in Figure 9. The generator has an RMS power output of 4.2 kW when operating normally.
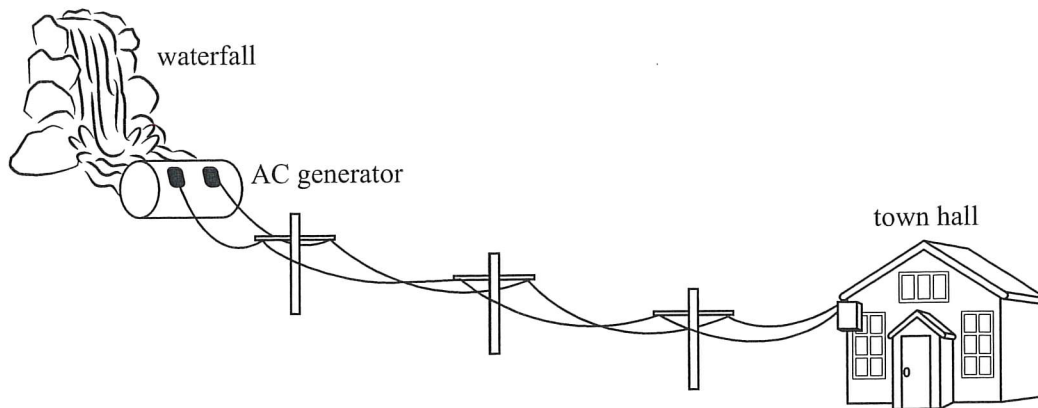
Figure 9

The town hall's electrical loads have a total resistance of 20 Ω and require 2.6 kW of RMS power when operating normally.

a. Calculate the RMS voltage at the town hall under these conditions. Show your working.　　2 marks

$$P = \frac{V^2}{R}$$

$$2.6 \times 10^3 = \frac{V^2}{20}$$

$$V = 228.035$$

$$V^2 = 5.2 \times 10^4$$

$$\boxed{228} \quad \text{V}$$

b. Calculate the resistance of the transmission lines.　　3 marks

Power loss in lines　　　　　At Town Hall

$$P_{loss} = 4.2k - 2.6k \qquad P = 2600 \qquad V = 228$$

$$P_{loss} = 1600 \text{ W}. \qquad\qquad P = VI$$

$$\qquad\qquad\qquad\qquad 2600 = 228 \, I$$

$$P_{loss} = I^2 R \qquad\qquad I = 11.4 \text{ A}$$

$$1600 = 11.4^2 \times R$$

$$R = 12.311$$

$$\boxed{12.3} \quad \Omega$$

c.   Suggest two changes the community could make to the system that would reduce power losses
      without changing the output of the AC generator or the load at the town hall.   2 marks

1. Put in a transformer to increase the transmission
    voltage which would decrease the current and Power loss.

2. Replace the transmission lines with ones
    of lower resistance

Question 10 (6 marks)

A single rectangular loop of wire containing a cut out section labelled EF moves to the right at a constant speed of 2.4 m s^{-1}, as shown in Figure 10a. At time $t = 0$, the right-hand edge of the loop enters a constant magnetic field into the page.
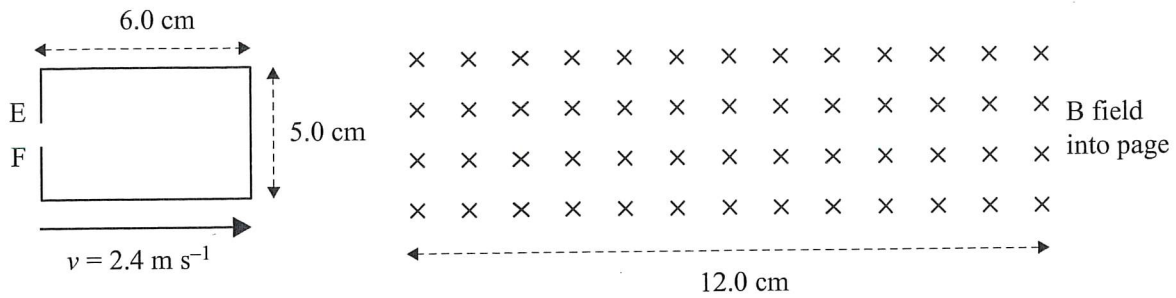
Figure 10a

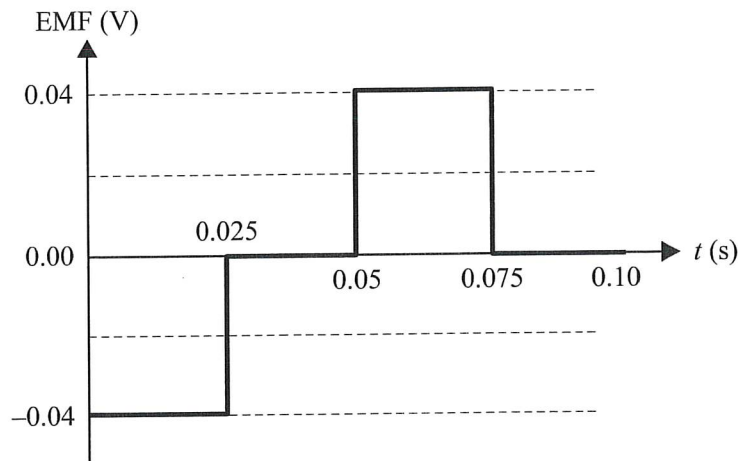The induced EMF produced as a function of time is shown in the graph in Figure 10b.
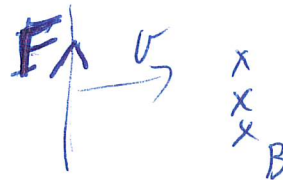
Figure 10b

While the loop enters, and is partially within, the field, an EMF is generated between points E and F.

a.   Which point, E or F, is positive?   1 mark

F

F↑ ⇒ I↑

⇒ I F to E.

⇒ F +ve

b. Explain why the induced EMF is constant during the time period 0.00 s to 0.025 s.   2 marks

The speed of the coil is constant

$\Rightarrow \frac{\Delta \Phi}{\Delta t}$ is constant

$\therefore$ constant EMF induced

c. Calculate the strength of the magnetic field through which the rectangular loop travels.   3 marks

$\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t}$

$-0.04 = -1 \times \frac{\Delta \Phi}{0.025}$

$\Delta \Phi = 1 \times 10^{-3}$

$B \times A = 1 \times 10^{-3}$

$B \times 3 \times 10^{-3} = 1 \times 10^{-3}$

$B = 0.3333$

$$\boxed{0.33} \quad \text{T}$$

Area $= 0.05 \times 0.06$
$= 3 \times 10^{-3}$

$\mathcal{E} = 0.04$ from Graph.

$v = \frac{d}{t}$

$t = \frac{d}{v} = \frac{0.06}{2.4} = 0.025$

time to move into field

Question 11 (9 marks)

Lee ties a small ball of mass 100 g to a string and rotates it in a vertical circle, as shown in Figure 11a. Assume that the ball is rotated at a constant speed of 3.0 m s^{-1}. The radius, r, of the circle is 0.60 m. Figure 11b shows a side view.
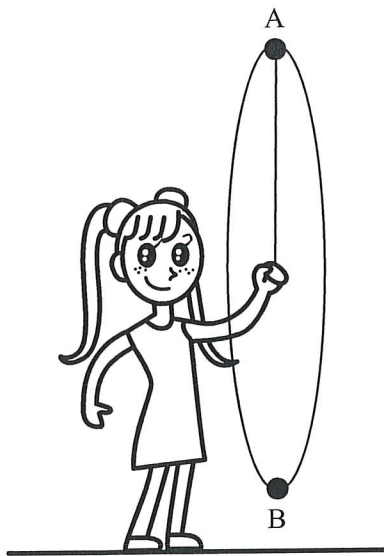

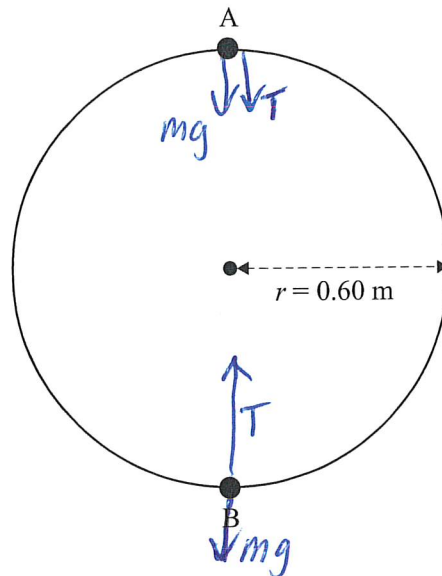**Figure 11a**   **Figure 11b**

a.   On Figure 11b, draw arrows to represent each of the forces acting on the small ball at position A, at the top of the circle, and at position B, at the bottom of the circle. Label each arrow clearly and use the lengths of the arrows to show the relative approximate magnitudes of the forces. No calculations are required.   4 marks

b.   Calculate the tension force in the string when the ball is at position B. Use $g = 10$ m s^{-2}.   2 marks

$$F_e = T - mg$$

$$\frac{mv^2}{r} = T - mg$$

$$\frac{0.1 \times 3^2}{0.6} = T - 0.1 \times 9.8$$

$$1.5 = T - 0.98$$

$$T = 2.48$$

2.48   N

c. Lee now increases the speed of the ball to a new constant speed, which is greater than 3.0 m s^{-1}, and notices that the string breaks when the ball is at position B.

Explain why the string is more likely to break at position B than at position A.   3 marks

v increases, thus increasing the centripetal force needed.

mg is constant, so the Tension in the string must increase.

The string is then more likely to break at B as the tension is at its greatest there.

Alternative

At A.

$$\frac{mv^2}{r} = mg + T_A$$

$$T_A = \frac{mv^2}{r} - mg$$

At B

$$\frac{mv^2}{r} = T_B - mg.$$

$$T_B = \frac{mv^2}{r} + mg.$$

$$T_B > T_A \quad \text{thus more likely to break at B}.$$

Question 12 (8 marks)

Two students investigate the physics of long jumps. They analyse a video of their friend Jemina as she runs along a track and then jumps. She lands in a sand pit that is level with the track.

Jemina's horizontal speed at the moment she jumps is 8.0 m s^{-1}. She is in the air for 0.6 s before landing in the sand pit. The students use $g = 10$ m s^{-2} for their calculations. The motion is modelled as that of a point mass, as shown in Figure 12.
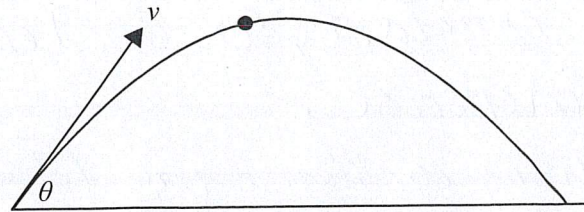

Figure 12

a. Calculate the horizontal distance that Jemina would be expected to travel if her motion were modelled as a projectile with point mass as shown in Figure 12. Show your working.   2 marks

$$V = \frac{d}{t}$$
$$d = vt = 8.0 \times 0.6 = 4.8$$

$$\boxed{4.8} \quad \text{m}$$

b. Calculate Jemina's vertical speed as she takes off from the track. Show your working.   2 marks

at top. $u = ?$ $v = 0$ $a = -10$ $t = 0.3$
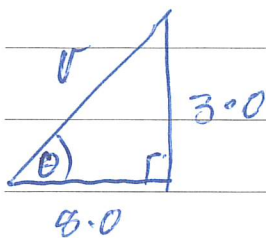$$v = u + at$$
$$0 = u - 10 \times 0.3$$
$$0 = u - 3.0 \qquad u = 3.0$$

$$\boxed{3.0} \quad \text{m s}^{-1}$$

split the motion in half.
since we know at the top momentarily at rest in the vertical direction
Time to highest point half of total flight time.

c.   Calculate Jemina's velocity as she launches. Include both the magnitude and the angle from the horizontal of her velocity at take-off.   3 marks

$$V = \sqrt{8.0^2 + 3.0^2}$$

$$= 8.544$$

$$\theta = Tan^{-1}\left(\frac{3.0}{8.0}\right)$$

$$= 20.556°$$

8.5 m s^{-1}	21 °

d.   The students use a tape measure to check the horizontal distance that Jemina actually jumps, and find that it is less than the distance they calculated in **part a.**

Suggest **one** possible reason for this.   1 mark

Air resistance

Note: Air resistance is the reason the question is getting at.

Be careful not to say any more than necessary.

It may be tempting to say Wind. But depending on the direction of the wind in relation to the direction of the jump, the effect of wind can vary.

SECTION B – continued
TURN OVER

Question 13 (13 marks)

As part of their practical investigations, two Physics students, Chris and Arya, investigate changes in gravitational potential energy and elastic potential energy for a 2.0 kg mass initially hanging on a spring.

The spring has an unstretched length of 1.0 m, as shown at position P in Figure 13a.

The 2.0 kg mass is placed by Arya on the unstretched spring and it hangs stationary at position Q in Figure 13b.

Their Physics teacher tells them that they can use $g = 10$ m s^{-2} for their calculations.

a. Show that the spring constant of the spring, k, is 20 N m^{-1}.   1 mark

$$F_s = kx. \qquad F_s = W. \qquad k \times 1^{.0} = 2.0 \times 10$$
$$W = mg \qquad kx = mg \qquad k = 20 \ Nm^{-1}$$

Chris then pulls the mass down a further 1.0 m below position Q, to position R, and releases it so that it oscillates between positions R and P, as shown in Figure 13c.
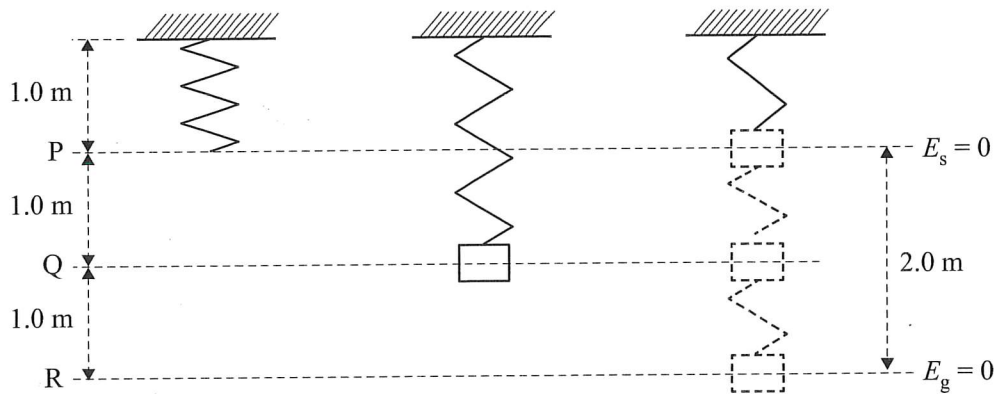

Figure 13a   Figure 13b   Figure 13c

The students decide that the gravitational potential energy, E_g, is zero at position R, and that they can use the formula for gravitational potential energy, $E_g = mg\Delta h$, where Δh is the height above position R.

The students also decide that the elastic potential energy is zero at the top position P, and that they can use the elastic potential energy formula $E_s = \frac{1}{2}k(\Delta x)^2$, where Δx is the extension of the spring beyond its unstretched length.

Arya enters the following information into a table.

Position	h (m)	E_g (J)	Δx (m)	E_s (J)
P	2.0	40.0	0	0
	1.5	30.0	0.5	2.5
Q	1.0	20.0	1.0	10.0
	0.5	10.0	1.5	22.5
R	0	0	2.0	40.0

b. Using the formulas for E_g and E_s, verify that Arya's $E_s = 10$ J at position Q is correct and fill in the missing data points in the table. Show your working for each calculation.   3 marks

At Q $E_s = \frac{1}{2} k \Delta x^2$ At Q $E_g = Mgh$.   At $h = 0.5$ $E_s = \frac{1}{2} k \Delta x^2$

$E_s = \frac{1}{2} \times 20 \times (1.0)^2$ $E_g = 2 \cdot 0 \times 10 \times 1.0$ $E_s = \frac{1}{2} \times 20 \times (1.5)^2$

$= 10 \text{ J}$ $= 20 \text{ J}$ $= 22.5 \text{ J}$

c. On the axes below, plot the E_g and E_s versus position data for the oscillating mass. On your graph:
- choose an appropriate scale and numbers for the y-axis
- use small circles for the E_g data and small triangles for the E_s data   *Note: the Symbols to be used.*
- draw a line/curve of best fit through the plotted points for the E_g data
- draw a line/curve of best fit through the plotted points for the E_s data.   4 marks
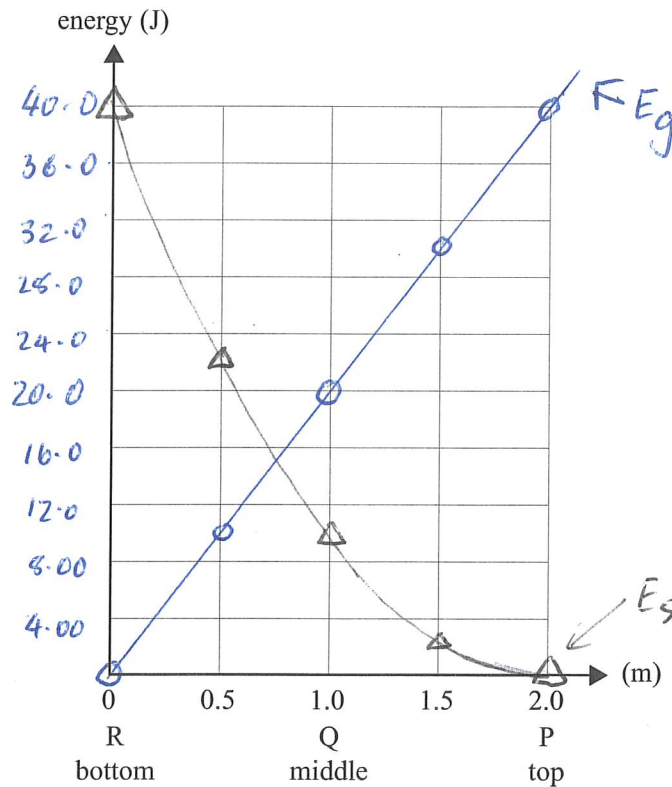
Note: Use a ruler for the straight line
Take your time with the curve.

d. Determine the speed of the mass as it goes through position Q. Show your working.   3 marks

$$E_{Total} = E_g + E_s + E_K$$
$$40.0 = 20.0 + 10.0 + E_K$$
$$10.0 = E_K.$$
$$10.0 = \frac{1}{2}mv^2$$
$$10.0 = \frac{1}{2} \times 2.0 \times v^2$$
$$10.0 = v^2$$
$$v = 3.162277 = 3.2$$

A fair bit of working needs to be shown.

← Use 2 sig. figs. as most of the data has 2 sig. figs.

$$\boxed{3.2} \quad \text{m s}^{-1}$$

e. Arya and Chris discuss the graphs that they have drawn. Chris says that their calculation must be wrong because the graphs should add up to a constant amount – the total energy of the system. However, Arya says that the graphs are correct.

Explain why Chris is incorrect.   2 marks

Chris is incorrect because he has not taken Kinetic energy into account. Kinetic energy has not been graphed.

Question 14 (4 marks)

A spaceship of length 71 m, measured when stationary on Earth, is travelling horizontally past an observer on Earth at a speed of 0.80c.

a. The spaceship emits a beam of light towards the observer.

State the speed of the light as measured by the observer on Earth. Justify your answer.   2 marks

3.0×10^8 ms^{-1}

Einstein's theory states the speed of light is constant for all observers.

b. Calculate the length of the spaceship as measured by the observer on Earth.   2 marks

$$\gamma = \frac{1}{\sqrt{1-\frac{(0.8c)^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1-0.64}}$$

$$= \frac{1}{\sqrt{0.36}}$$

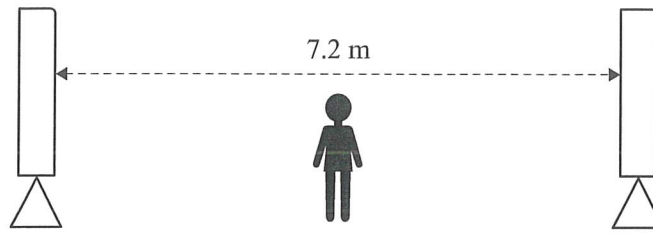$$= 1.67$$

$$L = \frac{L_0}{\gamma}$$

$$= \frac{71}{1.67}$$

$$= 42.5 \text{ m}$$

Note: Spaceship is in motion relative to the observer on Earth ⇒ Length contracted.

Question 15 (6 marks)

Nialle is standing between two loudspeakers on the school oval, as shown in Figure 14. Sound of a single frequency of 200 Hz is being emitted equally from both speakers. The distance between the speakers is 7.2 m.

Figure 14

When Nialle stands exactly halfway between the speakers, the sound is quite loud. Nialle begins to walk towards one speaker and notices that the sound gets quieter and then louder.

a. Calculate the wavelength of the 200 Hz sound, taking the speed of sound to be 360 m s^{-1}.   1 mark

$$v = \lambda f \qquad\qquad \lambda = 1.8 m$$
$$360 = \lambda \times 200$$

$$\boxed{1.8} \text{ m}$$

b. Nialle decides that this observation must be due to interference.

Explain how interference accounts for the loud and quiet points.   3 marks

The path difference of the sound from each speaker.
In the middle the path difference is 0λ, so
constructive interference occurs → Loud.
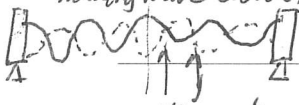Moving towards one speaker the path difference becomes
$\frac{1}{2}\lambda$ and destructive interference occurs → quiet

c. Calculate the spacing between two adjacent quiet points.   2 marks

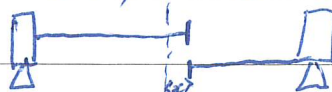Path difference of $\frac{1}{2}\lambda$, then $\frac{3}{2}\lambda$
0.9m ,   2.7m.

This is tricky one.
Standing Wave envelope.

Min → $\frac{\lambda}{2}$ apart = 0.9

$$\boxed{0.9m} \text{ m}$$

←3.6m→
$(3.6+x) - (3.6 - x) = 0.9m$
$2x = 0.8m$
$x = 0.45.$

$(3.6+x) - (3.6-x) = 2.7$
$2x = 2.7$
$x = 1.35$

$1.35 - 0.45 = 0.9$

SECTION B – continued
TURN OVER

Question 16 (3 marks)

Priya and Dan are playing music in a soundproof recording room. Priya leaves the room while Dan is still playing. She notices that when she is standing at point X with the door open, as shown in Figure 15, she can still hear the music. The music is not only softer, but some of the frequencies also seem to be relatively much softer. The door to the recording room is 1 m wide.
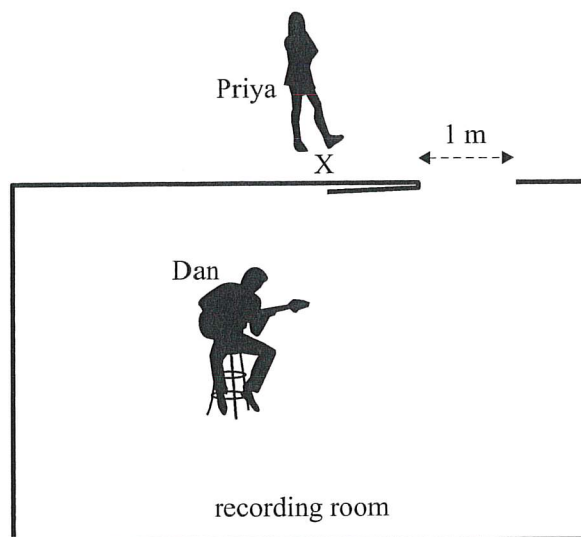
Figure 15

Outline in what way the music sounds different to Priya and explain why.

Diffraction of the Sound waves causes this.
Diffraction depends on the ratio $\frac{\lambda}{w}$
Wavelengths ~1.0m will be diffracted and Priya will hear them well - The lower frequency (Bass sounds.)
Wavelengths < 1.0m will not diffract in the door way and Priya will not hear them well - The high frequency (treble sounds.)

Note: Some of the lower volume could be attributed to the sound energy spreading out over a larger area.
The relative 'loudness' of frequencies is due to diffraction.

Question 17 (5 marks)

An optical fibre consists of a transparent cylindrical glass core surrounded by transparent glass cladding. A ray of monochromatic light is incident on an optical fibre at an angle θ_1. It refracts to an angle θ_2 inside the fibre. It then travels in the core until it reflects at the critical angle at the interface between the core and the cladding, as shown in Figure 16.
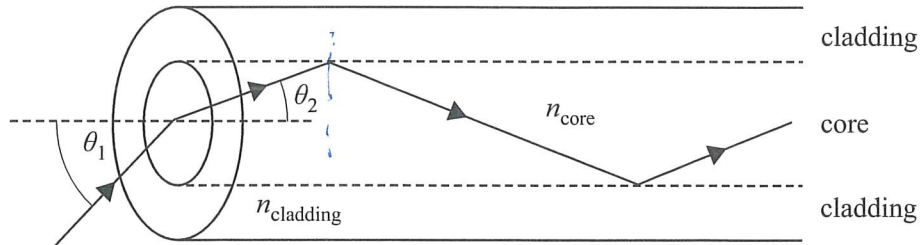
Figure 16

The refractive index of the core, n_{core}, is 1.55 and the angle θ_2 is 31°.

a. Calculate the value of θ_1. Take the refractive index of air to be 1.00   2 marks

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$1.00 \sin\theta_1 = 1.55 \sin 31°$$
$$\sin\theta_1 = 0.798309$$
$$\theta_1 = \sin^{-1}(0.798309) = 52.9689°$$
$$= 53°$$

$\boxed{53}$ °

b. Calculate the refractive index of the cladding.   3 marks

$90 - 31$
$= 59°$

$$n_{core} \sin\theta_{core} = n_{cladding} \sin\theta_{cladding}$$
$$1.55 \sin 59° = n_{cladding} \sin 90°$$
$$n_{cladding} = 1.328609$$
$$= 1.33$$

$\boxed{1.33}$

Note: Information says it reflects at the critical angle.
$\Rightarrow \theta_2 = 90°$

Careful with the geometry on this one.

Question 18 (6 marks)

Students carry out a Young's double-slit experiment using the experimental set-up shown in Figure 17. Laser light passes through two closely spaced narrow slits and forms a pattern of light and dark bands on a screen. The bands are numbered – the even numbers are bright bands and the odd numbers are dark bands. The band spacing is X. Band 6 is equidistant from each of the two slits.
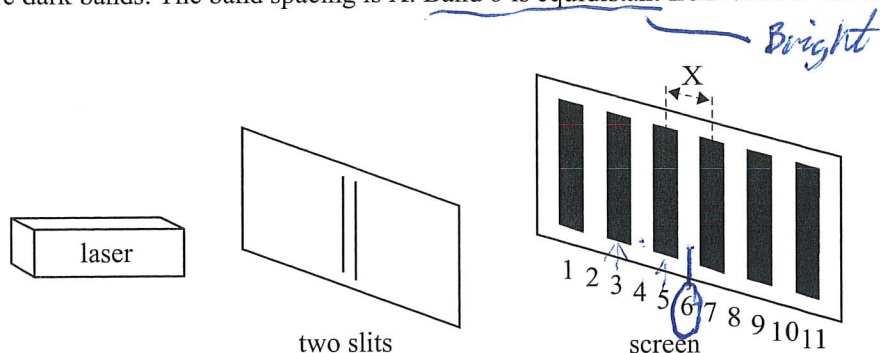
Figure 17

a.   Using a wave model of light, explain why Band 3 is dark.   2 marks

The path difference between Band 3 and each slit is $\frac{3}{2}\lambda$.
Destructive interference occurs and the band is dark.

b.   The two slits are 1.00 m from the screen. The wavelength of the laser is 600 nm. The spacing between the two slits is 0.100 mm.

Calculate the band spacing, X, in millimetres.   2 marks

$$\Delta x = \frac{\lambda L}{d}$$

$$= \frac{600 \times 10^{-9} \times 1.00}{0.100 \times 10^{-3}} = 6 \times 10^{-3} \, m$$

$$= 6 \, mm$$

| 6 | mm |

c.   The whole apparatus is now immersed in an insulating liquid of refractive index 1.2. The spacing of the bands changes.

Explain why the spacing of the bands changes and include a calculation of the new band spacing.   2 marks

The light slows down when in the liquid, and the wavelength changes.

$$n = \frac{c}{v}$$

$$1.2 = \frac{3.0 \times 10^8}{v}$$

$$v = 2.5 \times 10^8 \, m/s. \quad now.$$

Frequency stays the same
$$3.0 \times 10^8 = 600 \times 10^{-9} \times f$$
$$f = 5 \times 10^{14}.$$

new wavelength
$$2.5 \times 10^8 = \lambda \times 5 \times 10^{14}$$
$$\lambda = 5 \times 10^{-7} \, m$$

New Spacing
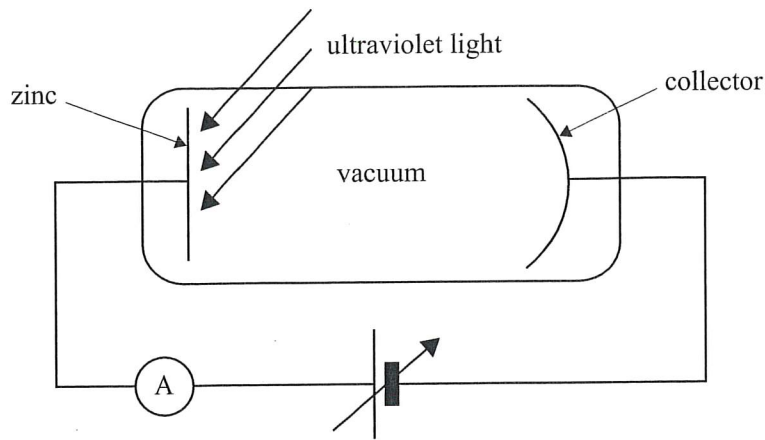$$\Delta x = \frac{5 \times 10^{-7} \times 1}{0.100 \times 10^{-3}}$$
$$= 5 \times 10^{-3}$$
$$= 5 \, mm$$

Note: $6 \div 1.2$ gives the answer also.

Question 19 (4 marks)

In an experiment on the photoelectric effect, Sam shines ultraviolet light onto a zinc plate and ejects photoelectrons, as shown in Figure 18.

Figure 18

a. The work function of zinc is 4.30 eV.

Calculate the minimum frequency of the ultraviolet light that could eject a photoelectron. 2 marks

$\phi = h f_0$

$4.30 = 4.14 \times 10^{-15} f_0$

$f_0 = 1.0386 \times 10^{15}$

$= 1.04 \times 10^{15}$

$\boxed{1.04 \times 10^{15}}$ Hz

b. Sam wants to produce a greater photocurrent – that is, to emit more photoelectrons. He considers using a much brighter red light instead of the original ultraviolet light source used in **part a.**

Is Sam's idea likely to produce a greater photocurrent? Explain your answer. 2 marks

No.
The frequency of red light is lower than the threshold frequency. No photoelectrons will be emitted.

SECTION B – continued

Question 20 (5 marks)

A beam of electrons, each with a momentum 4.60×10^{-24} kg m s^{-1}, is passed through a salt crystal to produce a diffraction pattern, as shown in Figure 19.
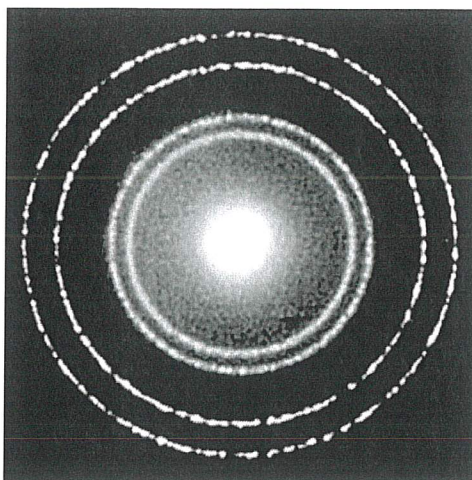

Figure 19

a. Calculate the de Broglie wavelength of the electrons. Show your working.   2 marks

$$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{4.6 \times 10^{-24}}$$

$$= 1.4413 \times 10^{-10}$$

$$\boxed{1.44 \times 10^{-10}} \text{ m}$$

b. Explain why electron diffraction patterns from salt crystals provide evidence for the wavelike nature of matter.   3 marks

Diffraction is a wave behaviour.
Amount of diffraction depends on the ratio $\frac{\lambda}{w}$
The de Broglie wave length is comparable to
the spacing in the Salt crystal.
Diffraction occurs.
Indicating wavelike nature of the electrons/matter.

SECTION B – continued
TURN OVER

Question 21 (3 marks)

The energy levels of the hydrogen atom are discrete (quantised) and there are no levels between them.

Explain, in terms of the properties of the electron in the hydrogen atom, why only certain energy levels are allowed.

The electron wave properties.
Only certain levels are possible, where the circumference of the electrons orbit equals a whole number of wavelengths and a standing wave occurs.
For orbits not a whole number of wavelengths destructive interference occurs, so it cannot exist.

END OF QUESTION AND ANSWER BOOK