Neap

Trial Examination 2022

VCE Physics Units 3&4

Written Examination

Question and Answer Booklet

Reading time: 15 minutes
Writing time: 2 hours 30 minutes

Student's Name: ______________________________

Teacher's Name: ______________________________

Structure of booklet

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	18	18	110
			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 booklet of 36 pages

Formula sheet

Answer sheet for multiple-choice questions

Instructions

Write your **name** and your **teacher's name** in the space provided above on this page, and on the answer sheet for multiple-choice questions.

Unless otherwise indicated, the diagrams in this booklet 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 booklet.

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.

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2022 VCE Physics Units 3&4 Written Examination.

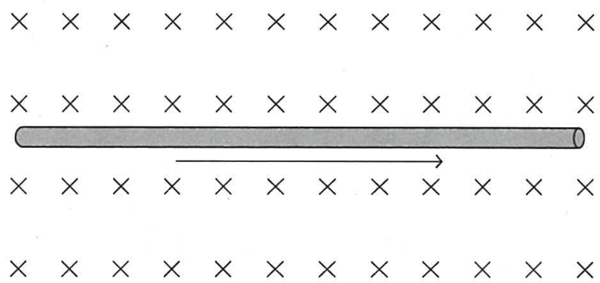
SECTION A – MULTIPLE-CHOICE QUESTIONS

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 booklet are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1

A wire with a length of 0.50 m is placed in a magnetic field with a strength of 0.20 T, as shown in the diagram below. The current in the wire is 2.00 A.



The magnitude of the force on the wire is

A. 0.0 N
B. 0.20 N
C. 0.40 N
D. 2.0 N

$l = 0.5$ m
$B = 0.20$ T
$I = 2.00$ A

$F = ?$
$F = nILB$
$= 1 \times 2 \times 0.5 \times 0.2$
$= 0.2$ N.

Question 2

A satellite of mass 2000 kg is in orbit around Earth at a position where Earth's gravitational field strength is 0.30 N kg^{-1}.

The weight of the satellite is

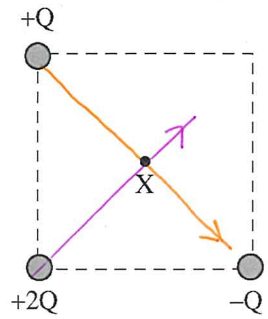
A. 600 N F_g
B. 600 kg
C. 2000 N
D. 2000 kg

$m = 2000$ kg
$g = 0.30$ N kg^{-1}

$F_g = mg$
$= 2000 \times 0.30$
$= 600$ N.

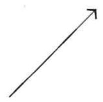
Question 3

Three charges, +Q, –Q and +2Q, are arranged at the vertices of a square. Position X is in the centre of the square, as shown in the diagram below.



Which one of the following arrows best represents the direction of the net electric field at position X?

A. 

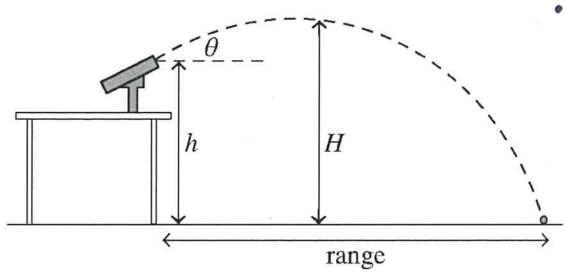
B. 

C. 

D. 

Question 4

A projectile is fired at an angle from a table and strikes the ground, as shown in the diagram below. Air resistance acting on the projectile is negligible.



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

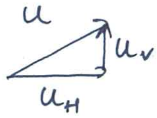
  $\therefore d$ is affected by v & t

- t is affected by vertical height

In the diagram:

- h represents the launch height above ground
- θ represents the launch angle
- H represents the maximum height reached above ground.

Additionally, u represents the launch speed.



- $u_H = u\cos\theta$

  $\therefore u_H$ affected by u & θ

Which one of the following lists all variables that the range of the projectile is dependent on?

A. H, h, θ

B. u, h, θ

C. u, H, θ

D. u, h, H

- t affected by vertical component

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

  "h"

Therefore, range is dependent upon u, θ & h B

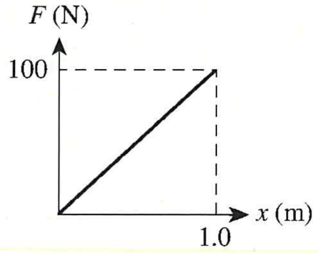
Question 5 – potential energy

A spring is loaded such that it has 10 J of energy stored in it.

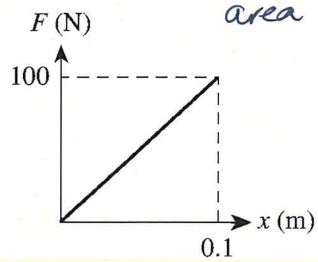
Which of the following graphs of force (N) versus spring extension (m) corresponds with the energy stored?

area under graph = W
= $\frac{1}{2}$ b×h .

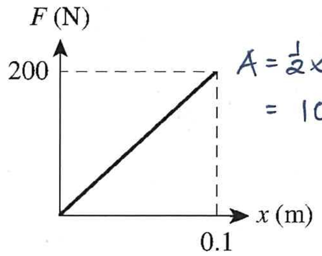
A.



B.

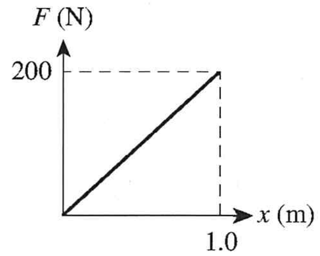


C.



$A = \frac{1}{2} \times 0.1 \times 200$
$= 10J$

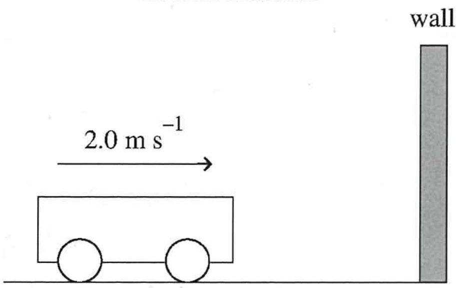
D.



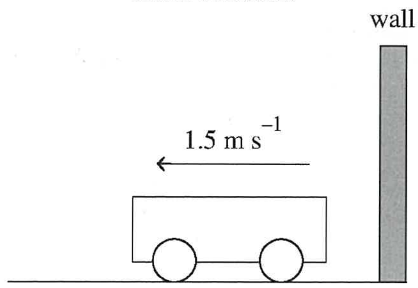
Question 6

A dynamics cart of mass 0.20 kg is pushed towards a fixed wall. The cart strikes the wall at 2.0 m s^{-1} and rebounds backwards at 1.5 m s^{-1}, as shown in the diagram below.

Before collision



After collision



Determine the magnitude and direction of the cart's change in momentum.

A. 0.10 kg m s^{-1} to the left

B. 0.10 kg m s^{-1} to the right

C. 0.70 kg m s^{-1} to the left

D. 0.70 kg m s^{-1} to the right

$L \overset{-\quad +}{\longleftrightarrow} R$

$u = +2.0\ ms^{-1}$

$v = -1.5\ ms^{-1}$

$\Delta p = m\Delta v$
$= 0.2(v_f - v_i)$
$= 0.2(-1.5 - 2)$
$= -0.7\ kgms^{-1}$
$= 0.7\ kgms^{-1}$ left

Question 7

A proton of mass 1.67×10^{-27} kg is moving at a speed of 1.8×10^{8} m s^{-1} ($\gamma = 1.25$).

What is the value of the proton's kinetic energy?

A. 3.76×10^{-11} J

B. 1.35×10^{-11} J

C. 1.25×10^{-19} J

D. 7.52×10^{-20} J

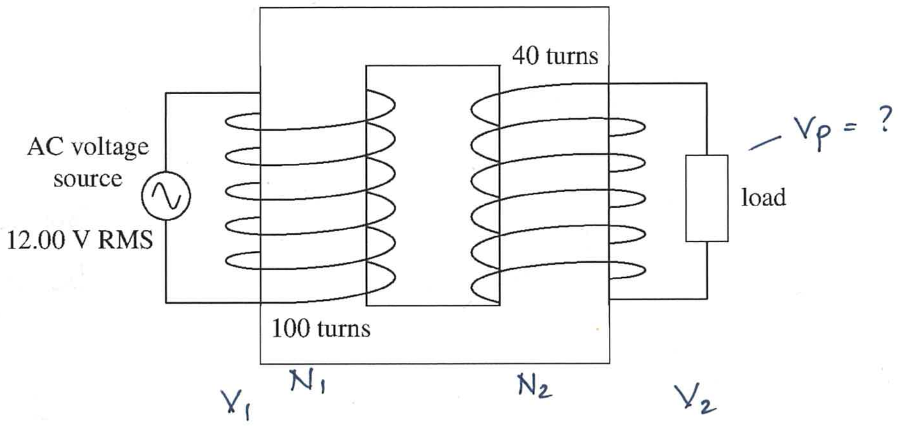
at relativistic speeds $E_K = (\gamma - 1)mc^2$

$= (1.25 - 1) \times 1.67 \times 10^{-27} \times (3.0 \times 10^8)^2$

$= 3.76 \times 10^{-11}$ J

Use the following information to answer Questions 8 and 9.

The following diagram shows an AC power source supplying energy to a load via an ideal transformer.



Question 8

Determine the peak voltage developed in the load.

A. 4.80 V

B. 6.79 V

C. 8.49 V

D. 42.43 V

determine V_{rms} (load) & then convert to V_p.

$\frac{V_2}{V_1} = \frac{N_2}{N_1}$ $\quad V_2 = \frac{N_2}{N_1} \times V_1 = \frac{40}{100} \times 12 = 4.8 V_{rms}$

$\therefore V_p = V_{rms}\sqrt{2} = 4.8\sqrt{2} = 6.8$ V

Question 9

The load experiences a peak current of 1.23 A.

Determine the average power supplied to the load.

A. 2.09 W

B. 2.95 W

C. 4.17 W

D. 5.90 W

average power is in rms values.

$P_{Rms} = V_{Rms} I_{Rms}$.

$P_{Rms} = ?$

$V_{Rms} = 4.8$ V (load)

$I_p = 1.23$

$I_{rms} = \frac{1.23}{\sqrt{2}}$

$= 0.8697$

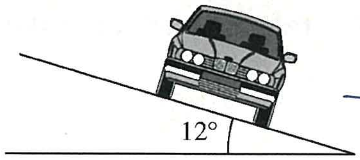
$\therefore P_{rms} = 4.8 \times 0.8697$

$= 4.17$ W.

Question 10

A car of weight W is making a banked turn on a road, as shown in the diagram below. The angle of the banked turn is 12°.

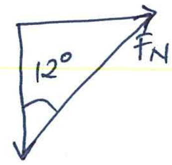
Banked track ∴ F_c towards centre of circular track.



$F_c \rightarrow$

F_c (F_{net})

Which one of the following represents the centripetal force? F_c (F_{net})



$F_c = F_g \tan\theta$

$= W \tan 12°$

A. $W \times \sin(88°)$

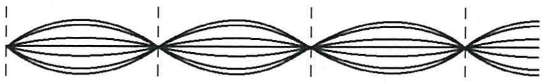
B. $W \times \sin(12°)$

C. $W \times \tan(88°)$

D. $W \times \tan(12°)$

Question 11

A string is displaying the wave behaviour that is shown in the following diagram. The frequency of the wave is 700 Hz.



One fixed end.

7th harmonic ∴ $n = 7$.

$f = \frac{nv}{4L}$

Which other possible frequencies can the string support if the wave is travelling at the same speed?

$f_7 = 700 = \frac{nv}{4L}$ where $n = 7$

A. 175 Hz, 350 Hz, 525 Hz

B. 100 Hz, 300 Hz, 500 Hz

C. 400 Hz, 500 Hz, 600 Hz

D. 87.5 Hz, 175 Hz, 350 Hz

$f_n = nf_1$

∴ $700 = 7f_1$ ∴ $f_1 = 100$ Hz.

One fixed end, ∴ $n = 1, 3, 5, 7$ etc.

Question 12

Heisenberg's uncertainty principle states that it is not possible to be precise about a particular quantity of a particle without being imprecise about another quantity.

Two such quantities are

A. the particle's position in the x-plane and the particle's momentum in the y-plane. Refering to different planes

B. the particle's position in the x-plane and the particle's momentum in the x-plane.

C. the particle's position in the x-plane and the particle's energy in the y-plane.

D. the particle's position in the x-plane and the particle's energy in the x-plane.

} talking about energy instead of momentum.

Question 13

The production of light by the transition of electrons between energy levels in a material occurs in

A. light-emitting diodes. → current flow.

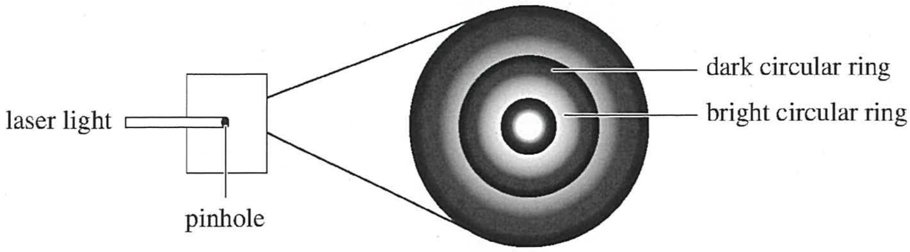
B. incandescent lamps. → heat filament

C. lasers.

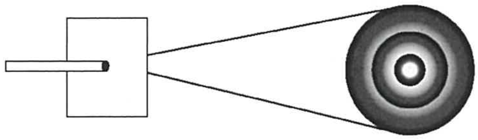
D. synchrotrons. → accelerating electrons.

Question 14

A laser light is shone through a very small pinhole. The resulting pattern of bright and dark circular rings is shown in the diagram below.



A change is made to the experiment. The resulting pattern is shown in the diagram below.



Smaller pattern, less diffraction

What change was made to the experiment?

A. A laser light with a smaller frequency was used.

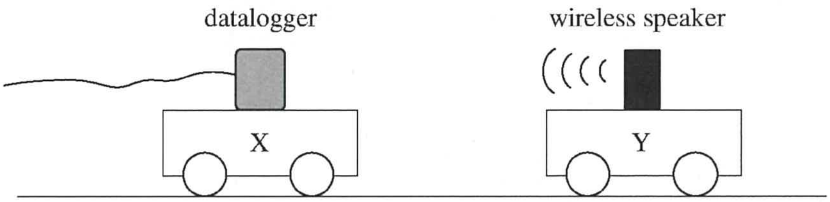
B. The diameter of the pinhole was decreased.

C. The intensity of the laser light was reduced.

D. A laser light with a smaller wavelength was used.

Question 15

The diagram below shows two dynamics carts, X and Y, on a track. Cart Y has a speaker fixed on it that is playing a single note at a constant intensity. Cart X has a datalogger fixed on it that is connected to a computer and it records the frequency of the note played from the wireless speaker.



A number of experiments that were conducted are described in the table below.

Experiment	Conditions
1	Cart X moves to the left at 3.0 m s^{-1} and cart Y moves to the right at 3.0 m s^{-1}.
2	Cart X and cart Y both move to the right at 2.0 m s^{-1}.
3	Cart X moves to the left at 2.0 m s^{-1} and cart Y moves to the right at 2.0 m s^{-1}.
4	Cart X moves to the left at 4.0 m s^{-1} and cart Y moves to the left at 1.0 m s^{-1}.

$\Delta v = 6\ ms^{-1}$ moving apart same velocity

moving together.

$\Delta v = 4\ ms^{-1}$ moving apart same velocity but slower than (a).

$\Delta v = 3.0\ ms^{-1}$ same direction

In which experiment did the datalogger record the lowest frequency?

A. 1

B. 2

C. 3

D. 4

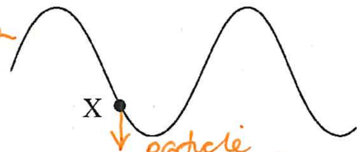
when v increases, frequency decreases.

∴ answer is A because relative speed difference is highest for experiment 1.

Question 16

The following diagram shows position X on a travelling wave at a particular instant.

wave direction ←



particle motion

If the wave moves to the left, then position X moves

A. left.

B. right.

C. upwards.

D. downwards.

Question 17

Which one of the following categories of light will undergo the **least** diffraction if it passes through a small slit?

• diffraction $\frac{\lambda}{w}$

smallest λ will undergo least diffraction

A. UV

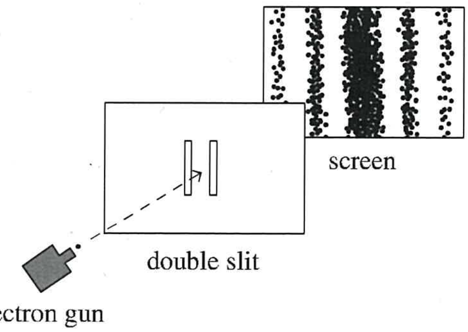
B. microwave

C. infra-red

D. TV

Question 18

An experiment is conducted in which an electron gun fires electrons of the same energy one at a time toward a double slit arrangement. The electrons produce a pattern of strikes on the screen behind the double-slit arrangement, as shown below.



ugh

The pattern on the screen represents evidence that the electrons act as

A. particles throughout the entire experiment.

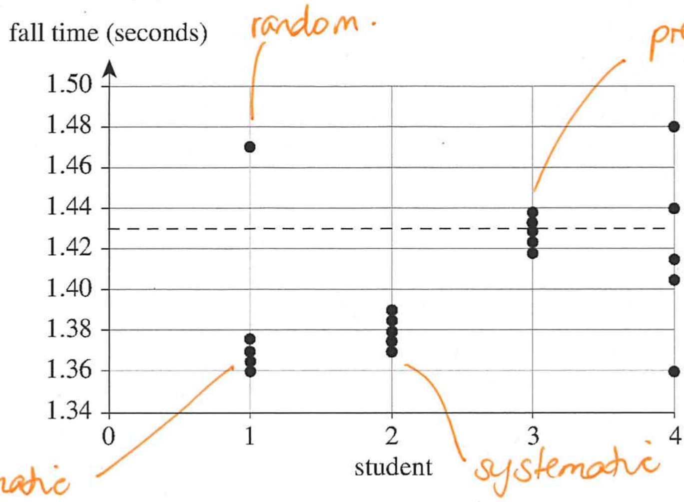
B. waves throughout the entire experiment.

C. particles when they strike the screen and as waves prior to striking the screen.

D. particles when they pass through one of the two slits and as waves when they interfere with each other to produce the pattern on the screen.

Use the following information to answer Questions 19 and 20.

Four students take turns dropping a golf ball from the same height to the ground and measuring the time of the fall. Each student conducts five trials. Their results are plotted on the graph below.



The students calculate that the golf ball should take 1.43 seconds to fall the distance to ground. They have drawn a dotted line at this value to compare their results.

not accurate (not close to actual)

Question 19

Which student has the most precise but non-valid data?

precision
- data close together.

A. student 1

B. student 2

C. student 3

D. student 4

Question 20

Which student's data shows systematic and random errors?

A. student 1

B. student 2

C. student 3

D. student 4

END OF SECTION A

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 booklet are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (7 marks)

Figure 1 shows an electron being accelerated from rest in a region of an electric field created by an accelerating voltage, V_{acc}.

Upon reaching the grid at the accelerating voltage, the electron passes through into a region of a constant magnetic field. The electron's motion changes to form an arc.

work done across electric field to accelerate electron.

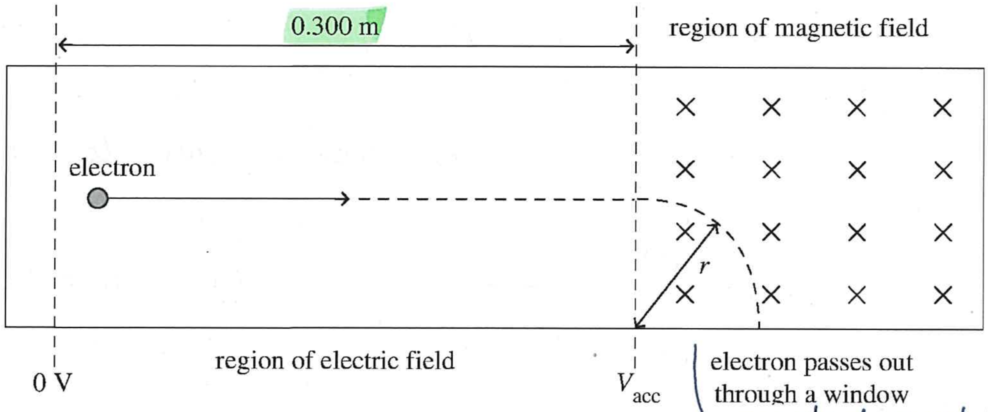


Figure 1

The electron arrives at the accelerating voltage grid at a speed of 5.93×10^6 m s^{-1}. The arc of the motion of the electron has a radius, r, of 1.50 cm.

a. Determine the magnitude of the electric field strength provided by the accelerating voltage. Show your working. 3 marks

work done by electric field.

$E = ?$

$q = 1.6 \times 10^{-19}$ C

$d = 0.300$ m

$W = Eqd = \frac{1}{2}mv^2$ — work done equal to kinetic energy of electron as it exits electric field.

$E = \dfrac{\frac{1}{2}mv^2}{qd}$

$= \dfrac{\frac{1}{2} \times 9.11 \times 10^{-31} \times (5.93 \times 10^6)^2}{1.6 \times 10^{-19} \times 0.3}$

$= 333.7$ NC^{-1}

333.7 N C^{-1}

 VCEPhys34_QB_2022

b. Determine the magnitude of the force acting on the electron while it is in the region of the magnetic field. Show your working. 2 marks

$m = 9.11 \times 10^{-31}$ kg $F = ?$ $F = \frac{mv^2}{r} = \frac{9.11 \times 10^{-31} \times (5.93 \times 10^6)^2}{0.0150}$

$r = 0.0150$ m

$v = 5.93 \times 10^6$ $= 2.14 \times 10^{-15}$ N.

* don't have a mag. field strength to work with, & result is circular motion.

$\boxed{2.14 \times 10^{-15}}$ N

c. Determine the magnitude of the magnetic field. Show your working. 2 marks

$F = qvB$ $B = \frac{2.14 \times 10^{-15}}{1.6 \times 10^{-19} \times 5.93 \times 10^6}$

$B = \frac{F}{qv}$

$= 0.002255$ T

$= 2.26 \times 10^{-3}$ T.

$\boxed{2.26 \times 10^{-3}}$ T

r = (height above Earth + Earth's radius).

Question 2 (6 marks)

The International Space Station (ISS) is in a low-Earth orbit of approximately 400 km above Earth's surface.

a. Determine the magnitude of the acceleration of the ISS in this orbit. Show your working. 3 marks

$a = ?$

$G = 6.67 \times 10^{-11}$

$M_E = 5.98 \times 10^{24}$ kg.

$r = (6.37 \times 10^6) + (400 \times 10^3)$

$= 6770000$ m.

$a = \frac{GM}{r^2}$

$= \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6770000)^2}$

$= 8.70$ ms^{-2}

8.70 m s^{-2}

b. The orbit of the ISS decays slowly over time as the space station slowly spirals inwards towards Earth's atmosphere. The ISS needs boosting a few times a year to return it to its original orbit.

Without boosting, will the average orbital period of the ISS stay the same, increase or decrease as it spirals inwards towards Earth? Explain your answer. 3 marks

pre-rearranged formule on summary sheet.

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

G, M & π are constant

- as the ISS spirals in, r decreases
- as r decreases, T decreases.

OR Keplers Law

$\frac{r^3}{T^2} = k.$ $T^2 = \frac{r^3}{k}$ ∴ as r decreases T also decreases.

Question 3 (7 marks)

Figure 2 shows a schematic diagram of a simple DC motor. A current is flowing through the coil and the motor is turning in the direction shown.

must be an upward force on side LM.

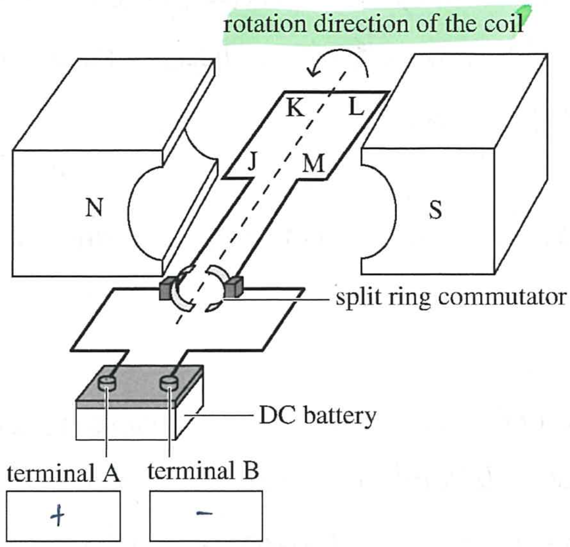


Figure 2

a. Write '+' for positive and '–' for negative in the boxes above to indicate which terminal is positive and which is negative. 1 mark

b. Using physics principles, justify your answer to **part a.** 3 marks

· using RH rule & noting direction of rotation
- side LM is experiencing an upwards force.
- magnetic field from north → south (L to R).
- thumb points from L to M when fingers are L to R and palm upwards on side L to M.
- hence current (conventional) runs from L to M, which runs + to –
- hence terminal A is +
- " terminal B is –

c. The split-ring commutator consists of two copper rings that are separated by a split.
Explain how this design enables the split-ring commutator to serve its purpose. 3 marks

- with every half rotation each brush disconnects from one half-ring & connects to the other half-ring.

- this causes the current in the loop to reverse direction

- this results in the force experienced by each loop to reverse direction each half turn.
- this ensures continuous rotation of the loop.

Question 4 (8 marks)

Figure 3a shows a square coil of area 0.020 m^2 and 100 turns placed between the poles of two magnets. The size of the magnetic field at the area of the coil is 0.50 T.

Figure 3b shows the two magnets pulled sufficiently far apart such that the resulting magnetic field at the position of the coil is 0 T.

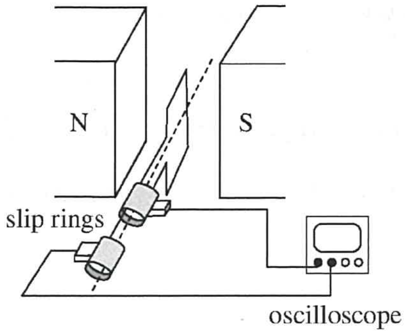
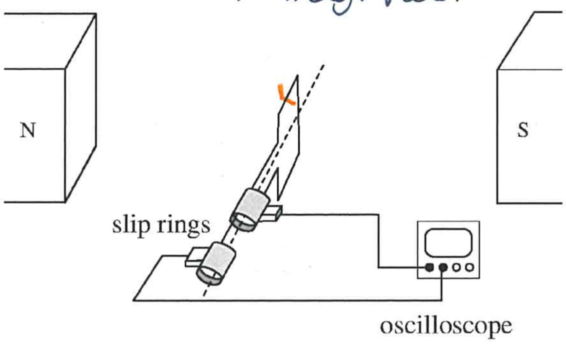


Figure 3a

→ mag. field



use right hand grip rule for (b)

Figure 3b

In both figures, the ends of the coil are connected to two slip rings that are connected to an oscilloscope datalogger. The time taken to pull the magnets from the position in Figure 3a to the position in Figure 3b is 0.10 seconds.

a. Calculate the magnitude of the average EMF induced in the coil as the magnets move from their positions in Figure 3a to their positions in Figure 3b. Show your working. 3 marks

$EMF_{av} = ?$

$n = 100$

$B_i = 0.50T$, $B_f = 0\ T$ } $\Delta B = 0.5T$

$t = 0.1s$

$A = 0.020\ m^2$

$EMF_{av} = \frac{n\Delta\Phi}{\Delta t}$

$= \frac{nB_iA}{\Delta t}$

$= \frac{100 \times 0.50 \times 0.020}{0.10}$

$= 10\ V$

10 V

b. Draw an arrow on the coil in Figure 3b to show the direction of the induced current in the coil as the magnets are pulled away. Provide an explanation to justify your answer. 3 marks

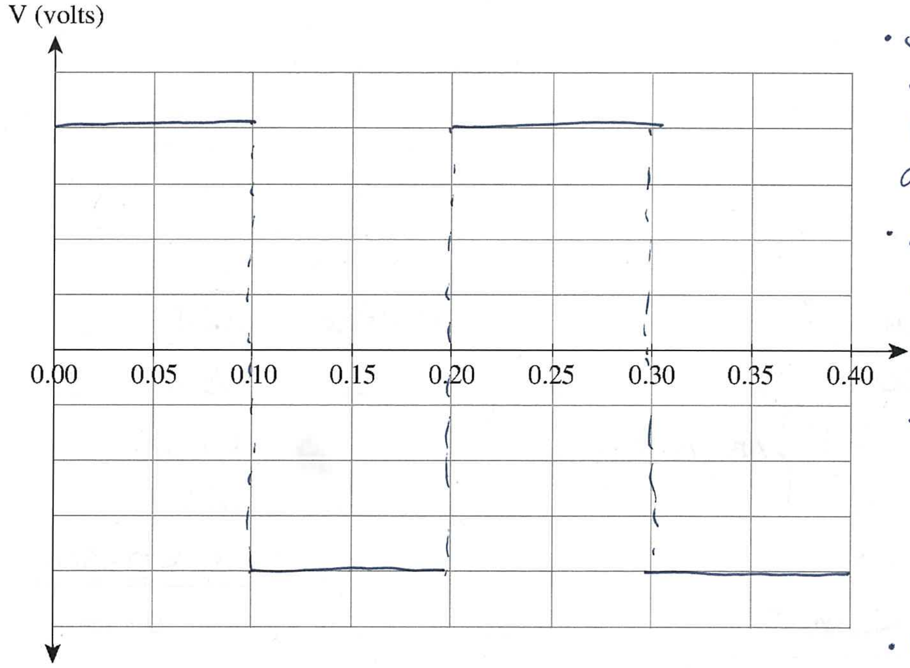
• Lenz's Law: an induced emf will produce a current whose magnetic field will oppose the original change in flux.

• to restore flux, magnetic field (induced) from L to R.
• use R.H.G. rule to determine direction of current in loop.
• using top of loop as reference, fingers point L to R through centre of loop, thumb points out of page.

c. The magnets are returned to the initial position shown in Figure 3a. They are moved from the position of Figure 3a to that of Figure 3b, then returned to Figure 3a without any pause. This movement is repeated once more.

Each change of position takes 0.10 seconds. At all times, the magnets maintain a constant speed relative to each other. The position of the coil at $t = 0$ is shown in Figure 3a.

On the axes provided below, sketch the output signal that would be displayed on the oscilloscope datalogger over the 0.40 seconds of movement. (A scale on the y-axis is not required.) 2 marks



• similar to scenario where loop enters/exits a magnetic field
• flux changes at a constant rate

∴ emf is constant during each 0.1 s phase.

• emf changes (positive/negative) as direction of motion of magnets changes will change induced emf, induced current + induced mag. field.

Question 5 (6 marks)

A model electrical transmission system shown in Figure 4 is created in a physics laboratory. The globe requires a minimum of 3.6 V to operate brightly.

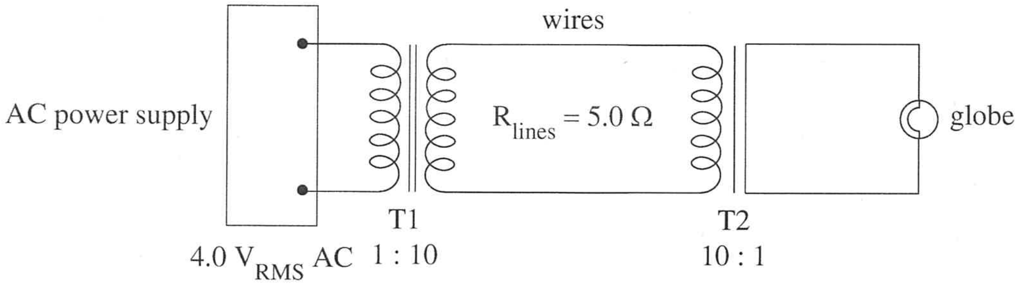


Figure 4

The students use two transformers, T1 and T2, with ratios of 1:10 and 10:1 respectively, and a 4.0 V_{RMS} AC power supply. The transformers are assumed to be ideal. The students use a light globe that will operate brightly as long as a minimum voltage of 3.6 V is supplied to it. The wires of the model transmission lines have a total resistance of 5.0 Ω. The students measure the current in these wires to be 1.0 A.

a. Determine the magnitude of the power that is available to the globe. Show your working. 3 marks

· although in ideal transformers power is conserved, there is power loss across the lines. Determine power generated, & then power loss in lines, to determine power in globe.

$\frac{I_1}{I_2} = \frac{N_2}{N_1}$

$I_1 = \frac{N_2}{N_1} \times I_2 = \frac{10}{1} \times 1 = 10A$

$P_{produced} = VI = 4 \times 10 = 40W$

$P_{loss} = I^2R = 1^2 \times 5 = 5W$

$\therefore P_{globe} = 40 - 5 = 35\ W.$

35 W

b. State whether the globe will operate brightly. Provide a calculation to support your answer. 3 marks

$V_{lines} = \frac{V_2}{V_1} = \frac{N_2}{N_1}$

$V_2 = \frac{N_2}{N_1} \times V_1$

$= \frac{10}{1} \times 4$

$= 40V.$

$V_{drop} = IR$

$= 1 \times 5 = 5V.$

$V_{into\ T2} = 40 - 5$

$= 35V.$

Then $V_2 = \frac{N_2}{N_1} \times V_1$

$= \frac{1}{10} \times 35$

$= 3.5\ V$

Globe needs 3.6V & therefore will not shine brightly.

Question 6 (3 marks)

In Figure 5a, a block is held on top of a spring and is at rest. The natural length of the spring is 1.0 m and the mass of the spring is negligible. The spring is compressible.

In Figure 5b, the block is released and compresses the spring such that the next time the block is momentarily at rest, the spring is compressed by d metres.

• conservation of energy approach

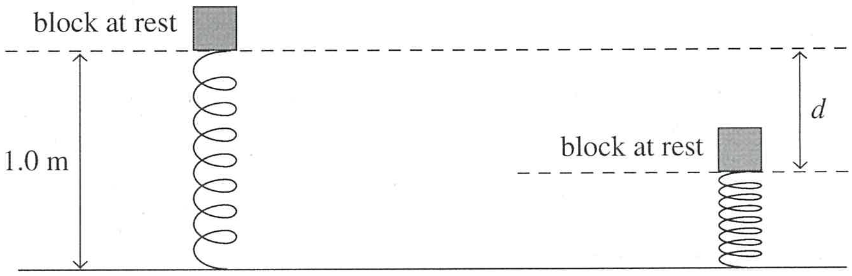


Figure 5a **Figure 5b**

The spring has a spring constant of 50 N m^{-1}. The block has a mass of 0.40 kg.

Determine the value of d, correct to two significant figures. Show your working.

$k = 50\ \text{Nm}^{-1}$ $\quad \Delta E_g = \Delta E_s$

$m = 0.40\,\text{kg}$ $\quad mg\Delta h = \frac{1}{2}k\Delta x^2$

$d = ?\ (\Delta x)$ $\quad 0.40 \times 9.8 \times \Delta h = \frac{1}{2} \times 50\, x^2$

$0.40 \times 9.8 \times d = \frac{1}{2} \times 50\, d^2$

$3.92 d = 25 d^2$ (divide both sides by d)

$3.92 = 25 d$ $\quad d = \frac{3.92}{25}$

$= 0.16$ m

$\boxed{0.16 \text{ m}}$

2 sig figs.

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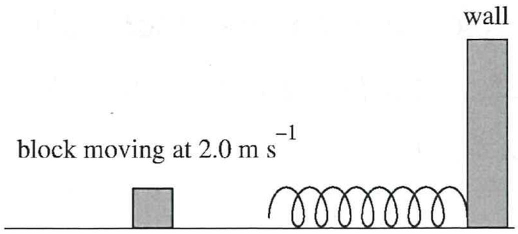
Question 7 (5 marks)

Figure 6 shows a spring fixed to a wall sitting on a frictionless surface. A block of mass 0.40 kg moves and strikes the spring at 2.0 m s^{-1}. The stiffness constant of the spring is 50 Nm^{-1}.



$k = 50\ \text{Nm}^{-1}$

the block will decelerate

Figure 6

a. What is the magnitude of the work done by the spring on the block when the block compresses the spring by 0.15 m? Show your working. 2 marks

$W = ?$ as the spring is compressed, E_s increases.

$\Delta E_s = W \quad \therefore \Delta E_s = \frac{1}{2}k\Delta x^2$

$= \frac{1}{2} \times 50 \times 0.15^2$

$= 0.56\ \text{J}$

0.56 J

* force applied as block slows is not constant.
* also don't know if block has stopped.

b. Is the block able to compress the spring by 0.20 m? Provide a calculation to support your answer. 2 marks

ΔE_K of block $= \Delta E_s$ (max)

Consider ΔE_K

$\Delta E_K = E_{K\,final} - E_{K\,initial}$

$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= 0 - \frac{1}{2} \times 0.4 \times 2^2$

$= 0.8\ \text{J}$

$\therefore \Delta E_s(\text{max}) = 0.8\ \text{J}$

When $\Delta E_K = \Delta E_s$ solving for x.

$0.8 = \frac{1}{2}k\Delta x^2$

$0.8 = \frac{1}{2} \times 50 \times x^2$

$\frac{2 \times 0.8}{50} = x^2$

$x^2 = \frac{1.6}{50}$

$x = 0.18\ \text{m}.$

$\therefore$ max compression $= 0.18\ \text{m}$, not $0.2\ \text{m}$.

c. The block comes to rest momentarily for a particular compression of the spring.

In terms of the principle of conservation of momentum, state what happens to the momentum of the block as it comes to rest. 1 mark

As the block comes to rest its momentum is transferred to other bodies in the system, such as the spring.

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Question 8 (5 marks)

A pendulum bob of mass 0.200 kg is released from rest and swings in an arc, as shown in Figure 7. The string that connects to the bob and the board above it has an insignificant mass, and no frictional forces exist anywhere during the swing. The bob falls a distance of 0.30 m from its release point to its lowest point. The distance from the centre of mass of the bob along the string to the board is 1.00 m.

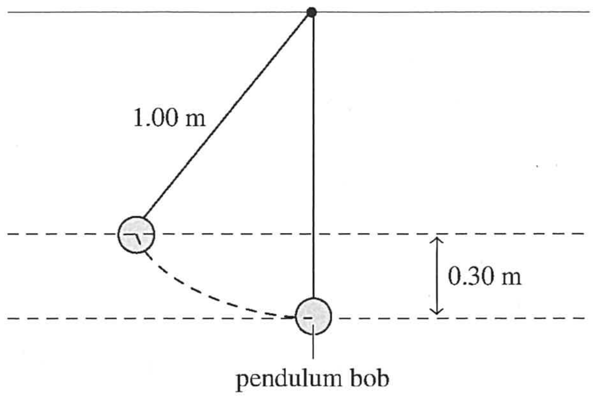

Figure 7

a. Show that the speed of the bob at its lowest point is 2.42 m s^{-1}. 2 marks

$\Delta E_g = \Delta E_k$ → Conservation of energy ΣE_m (before) $= \Sigma E_m$ (after).

$mg\Delta h + \cancel{\frac{1}{2}mv^2} = \cancel{mg\Delta h} + \frac{1}{2}mv^2$ ↑ solve for this

$m = 0.200$ kg $0.2 \times 9.8 \times 0.3 = \frac{1}{2} \times 0.2 \times v^2$

$h = 0.30$ m $v^2 = \frac{0.588}{0.1}$

$g = 9.8$ ms^{-2}

$= 5.88$

$v = \sqrt{5.88}$

$= 2.42$ ms^{-1}

b. Determine the tension of the string at its lowest position. Show your working. 3 marks

$F_T = ?$ $F_{net} = \cancel{F_N}\ F_T - F_g$

$F_T = F_{net} + F_g$

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

$= \frac{0.2 \times 2.42^2}{1} + 0.2 \times 9.8$

$= 1.17 + 1.96$

$= 3.13$ N

3.13	N

Question 9 (4 marks)

A golf ball is launched horizontally from the top of a platform that is 10.0 m above ground. The ball strikes a board 30.0 m away at a position that is 3.0 m above ground. This is shown in Figure 8.

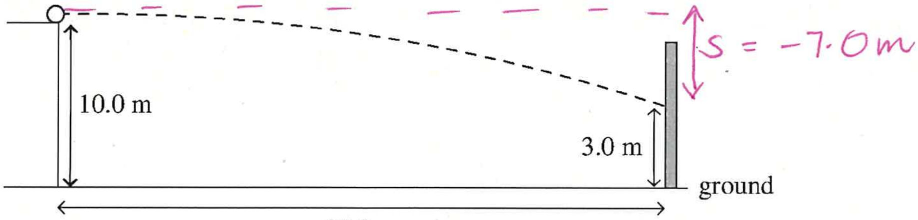

Figure 8

+
-

a. Determine the amount of time the ball takes to strike the board after being launched. Show your working and express your answer to two significant figures. 2 marks

initial vertical velocity = 0 ms⁻¹

$u = 0 \text{ ms}^{-1}$ $\qquad s = ut^0 + \frac{1}{2}at^2$

$g/a = 9.8 \text{ ms}^{-2}$ $\qquad -7.0 = \frac{1}{2}(-9.8)t^2$

$S = -7.0 \text{ m}$ $\qquad t^2 = \frac{-7}{-4.9}$ $\qquad t = \sqrt{1.429}$

$t = ?$ $\qquad = 1.2 \text{ s}$

1.2 s

b. Determine the speed at which the ball is launched. Show your working. 2 marks

speed (initial) is horizontal velocity

$v = ?$ $\qquad v = \frac{d}{t} = \frac{30.0}{1.2}$

$= 25 \text{ ms}^{-1}$

25 m s^{-1}

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Question 10 (6 marks)

Two carts, A and B, are connected by a spring and are moving as a unit. Cart A is of mass 1.5 kg. Cart B is of mass 2.5 kg. Cart B has a spring compressed against cart A as they travel at 2.0 m s^{-1} to the right as a single unit. This is shown in Figure 9a.

As the carts travel, the spring expands and dislodges the two carts such that cart A continues to travel to the right at 1.0 m s^{-1}, as shown in Figure 9b.

an "explosive collision"

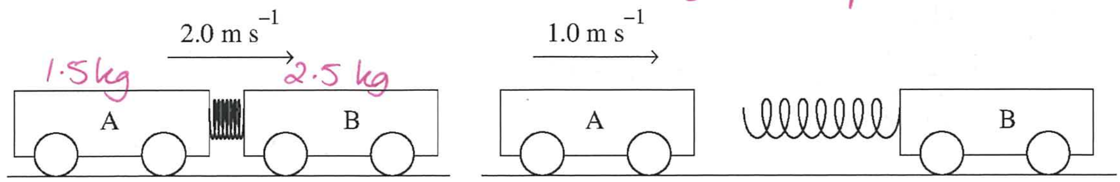


Figure 9a **Figure 9b**

$v_3 = ?$

a. Determine the speed of cart B after the carts have separated. Show your working. 3 marks

$- \quad +$

$m_1 = (1.5 + 2.5) = 4.0$ kg

$u_1 = +2.0$ ms^{-1}

$m_2 = 1.5$ kg

$v_2 = +1.0$ ms^{-1}

$m_3 = 2.5$ kg

$v_3 = ?$

$m_1u_1 = m_2v_2 + m_3v_3$

$(4.0 \times +2.0) = (1.5 \times +1.0) + 2.5v_3$

$8.0 = 1.5 + 2.5v_3$

$8.0 - 1.5 = 2.5v_3$

$v_3 = \dfrac{8.0 - 1.5}{2.5} = 2.6$ ms^{-1}

2.6 m s^{-1}

b. Explain why the separation of the two carts is neither elastic nor inelastic. Calculations are not required. 3 marks

- elastic/non-elastic collisions consider conservation of E_K.
- when spring expands, stored E_s converted to E_K.
- therefore, E_K before cannot be equal to E_K after → the transformation of E_s to E_K complicates the system.

Question 11 (5 marks)

A spacecraft travels from Earth in a direct line to a star system at a speed of 0.850c. The astronauts onboard measure the time of travel to be 1.78 years. A command centre monitors the mission from Earth.

a. Determine the value of γ, correct to three significant figures. Show your working. 2 marks

$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ ratio of $v : c$ = 0.850c ∴

$= \frac{1}{\sqrt{1-0.850^2}} = 1.898 = 1.90$

3 sig. figs.

$\gamma =$ 1.90

b. How far is the star system from Earth according to the command centre? Show your working. 3 marks

$t = \gamma t_0$ time passing slowly on spaceship clock.

$= 1.90 \times 1.78$

$= 3.382$ yrs.

$v = \frac{d}{t}$ ∴ $d = vt$

$= 0.850 \times 3.382.$

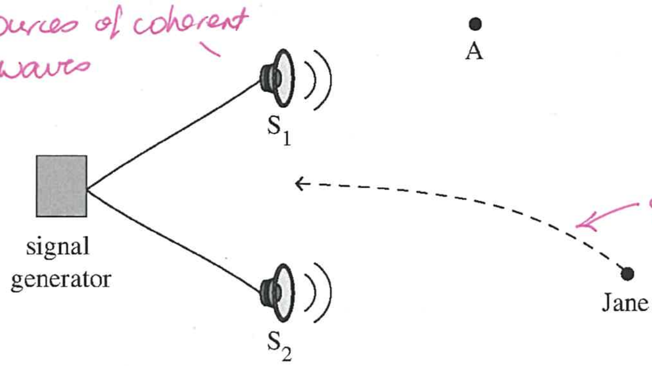
$= 2.87$ light years

2.87 light years

Question 12 (5 marks)

In a large hall, a class of Physics students sets up two large speakers, S_1 and S_2, that are connected to a signal generator. The walls of the hall have sound-absorbing surfaces that reflect little or no sound. The students play a single note simultaneously through both speakers. One of the students, Jane, stands at various positions in front of the speakers. Jane's path (shown by the dashed line) and position A are indicated in Figure 10.

2 sources of coherent waves



quiet all the way along. Must be a nodal line

Figure 10

The speed of sound in air is 340 m s^{-1}.

Jane walks toward the speakers and observes the sound to be very soft and hardly audible for the entire walk.

a. Explain the observation made by Jane as she walks. 2 marks

• since the sound is quiet along the path Jane walks, she must be walking along a nodal line

• a nodal line passes through areas of destructive interference where waves cancel each other out.

b. The distance from S_1 to position A is 4.5 m and the distance from S_2 to position A is 8.5 m. Jane stands at position A and her friends change the note being played through the speakers so that she hears the sound change in frequency as well as being high in intensity.

Determine **two** possible frequencies at which Jane hears a loud sound at position A.

Show your working. 3 marks

• at A, $pd = n\lambda = 8.5 - 4.5 = 4.0$ m

$\therefore 4.0 = n\lambda$

$4.0 = \frac{nv}{f}$

$f = \frac{nv}{4.0} = \frac{n\,340}{4.0} = 85n$

when $n = 1$,

$f_1 = 85 \times 1 = 85$ Hz

when $n = 2$

$f_2 = 85 \times 2$

$= 170$ Hz ;

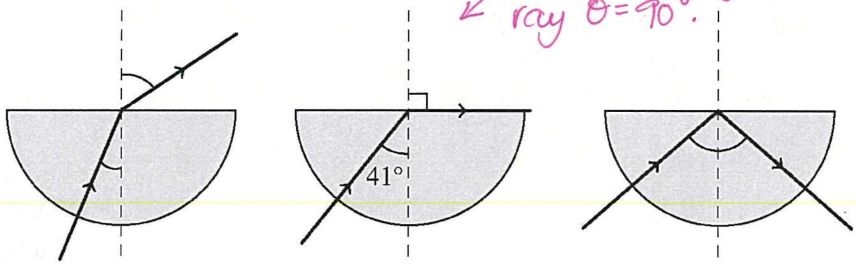
etc.

85 Hz	170 Hz

Question 13 (4 marks)

A ray of white light is shone through the curved section of a plastic block so that it strikes the centre of the flat side. The ray originates in the air outside the block. This action is repeated twice with the angle of entry into the block being changed each time. The traces of the rays for all three trials are shown in Figure 11. The angle of 41° is shown in the middle trial.

at critical angle, refracted ray $\theta = 90°$.



For total internal reflection $n_1 > n_2$

Figure 11

The refractive index of air is 1.00.

$n_1 = ?$

a. Determine the refractive index of the plastic block. Show your working. 2 marks

$n_1 = ?$ $\quad n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad$ or $n_1 = \dfrac{n_2}{\sin\theta_c}$

$\theta_1 = 41°$ $\quad n_1 \sin 41 = 1 \times \sin 90$

$n_2 = 1.0$ $\quad n_1 = \dfrac{1}{\sin 41} = 1.52.$ $\quad$ etc.

$\theta_2 = 90°$

$\boxed{1.52.}$

b. A ray of white light is shone onto a triangular plastic prism, as shown in Figure 12. The ray passes through the prism and spreads into the colours of the rainbow.

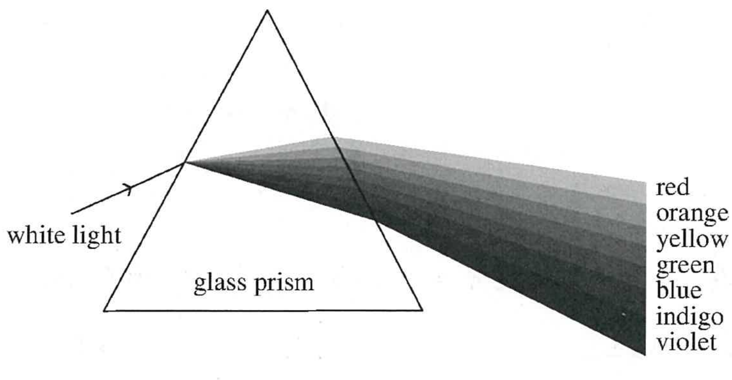


Figure 12

Explain how the spread of the colours results from the original ray of white light. As part of your answer, make reference to the order of the colours and the degree of the spread. 2 marks

- as the light ray passes from air into the prism, dispersion occurs.
- red light (lowest f, largest λ) is refracted the least
- blue light (highest f, smallest λ) is refracted the most
- each λ has its own refractive index in the prism → effects refraction &

∴ results in dispersion.

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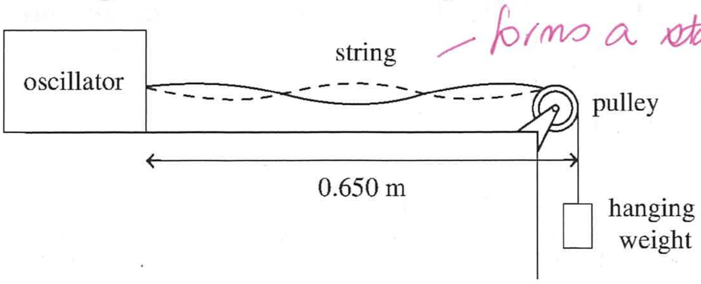
Question 14 (8 marks)

A guitar string is set up on a table, as shown in Figure 13. The oscillator is tuned so that the string behaves as shown. The length of the string between the oscillator and the pulley is 0.650 m.



– forms a standing wave with 3 antinodes

Figure 13

a. Explain why the string displays the behaviour shown in Figure 13. 3 marks

L = 0.650m

• oscillator vibrates at a frequency & propagates a transverse wave along the string

• wave is reflected at pulley & forms a standing wave.

• in a standing wave, the positions of nodes & antinodes (for a given frequency) are fixed.

• the frequency of oscillation matches a natural resonating frequency of the spring.

b. Determine the speed of the wave in the string if the oscillator is vibrating at 291 Hz. Show your working. 2 marks

at $f = 291$ Hz, $n = 3$ (according to diagram)

$L = 0.650$ m

$v = ?$

Standing wave with 2 fixed ends: $f = \frac{nv}{2L}$.

$\therefore v = \frac{2Lf}{n}$

$= \frac{2 \times 0.650 \times 291}{3}$

$= 126 \text{ ms}^{-1}$

126 m s^{-1}

- will a standing wave form?

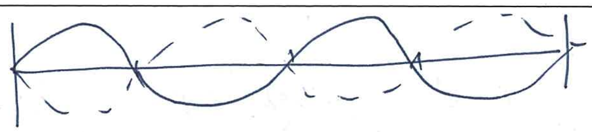
c. Explain the effect that changing the frequency to 388 Hz would have on the behaviour of the string. You may use a diagram to support your answer.

3 marks

The fundamental frequency of the string is $\frac{f_3}{n} = \frac{291}{3} = 97$ Hz.

$\frac{388}{97} = 4.$

$\therefore f = 388$ Hz is the 4th harmonic



Question 15 (9 marks)

Three experiments are conducted in which light of the same colour is used to irradiate a metal cathode in a vacuum tube. The intensity of light is altered for each experiment. The highest intensity is I_3 and the lowest intensity is I_1.

The photoelectric current versus potential difference for the experiments are graphed in Figure 14.

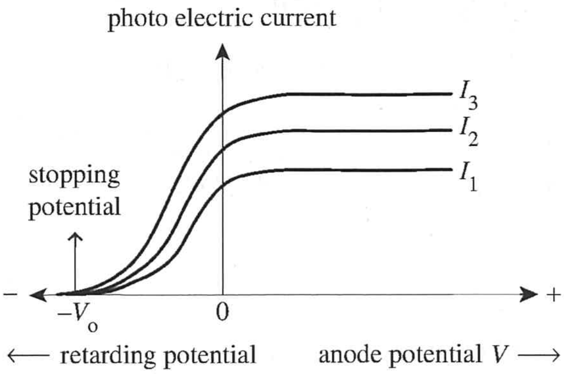


Figure 14

Photoelectric effect → particle model.

a. Explain which model for light (wave or particle model) is fully supported by the results. In your answer, make specific reference to the graph above and include a brief description of the model chosen. 5 marks

• particle model → light travels as discrete packets of energy (quanta / photons) that are either absorbed fully by electrons or not at all. Energy of photons is dependent upon f ($E = hf$)

• the three photocurrents on the right of the graph indicate as intensity of light increases, photocurrent increases (proportional)

• since an electron absorbs only one photon, the photoelectrons emitted per second is proportional to the intensity of the light, as shown by the plateaus on the RHS of graph.

• stopping voltage is related to $E_{k\,max}$

• max $E_k = hf - hf_0$. That is, as frequency of incident light increases, $E_{k\,max}$ increases.

• $E_{k\,max}$ and stopping voltage depend only on frequency of incident light. Intensity of incident light does not affect $E_{k\,max}$. Hence, all three lines have same stopping voltage (V_0).

The value of V_0 in a particular experiment is 1.5 V and the work function of the metal cathode is 2.2 eV.

b. Determine the frequency of light used in this experiment. Show your working. 2 marks

If using J, $q = 1.6 \times 10^{-19}$ C.

$f = ?$ $V_0 = E_{k\,max}$ (eV)

$V_0 = 1.5\,V$ $qV_0 = hf - \phi$

$\phi = 2.2\,eV$. $1 \times 1.5 = 4.14 \times 10^{-15} f - 2.2$

working with eV $\therefore q = 1$ $f = \dfrac{1.5 + 2.2}{4.14 \times 10^{-15}} = 8.94 \times 10^{14}$ Hz.

$\boxed{8.94 \times 10^{14}}$ Hz

c. Would light of frequency 2.5×10^{14} Hz cause photoelectron emission? Support your answer with calculations. 2 marks

Energy associated with this frequency:

$E = hf$

$= 4.14 \times 10^{-15} \times 2.5 \times 10^{14}$

$= 1.035$ eV.

Since $\phi = 2.2$ eV, a photoelectron will not be emitted.

Question 16 (3 marks)

A photon of energy 50 eV is compared to an electron of de Broglie wavelength 0.663 nm.

Does the photon or the electron have greater momentum? Support your answer with calculations.

Electron:

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

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

$= \frac{6.63 \times 10^{-34}}{0.663 \times 10^{-9}}$

electron $\boxed{p = 1.0 \times 10^{-24}\ \text{kgms}^{-1}}$ ✱

Photon - need λ

$E = hf$ and $f = \frac{c}{\lambda}$

$\therefore E = \frac{hc}{\lambda}$

$\lambda = \frac{hc}{E}$

Then, to find p

$\lambda = \frac{h}{p}$ (de Broglie)

$\therefore p = \frac{h}{\lambda}$ and therefore $p = \frac{h}{\frac{hc}{E}}$

rearrange: $p = \cancel{h} \times \frac{E}{\cancel{h}c}$

convert to J

$p = \frac{E}{c} = \frac{50 \times 1.6 \times 10^{-19}}{3.0 \times 10^{8}}$

photon. $\boxed{p = 2.7 \times 10^{-26}\ \text{kgms}^{-1}}$ ✱

Thus $p_{electron} = 1.0 \times 10^{-24}\ \text{kg ms}^{-1}$

$p_{photon} = 2.7 \times 10^{-26}\ \text{kgms}^{-1}$

Electron has greater momentum.

Question 17 (6 marks)

Figure 15 shows the energy levels for mercury. One energy level is missing.

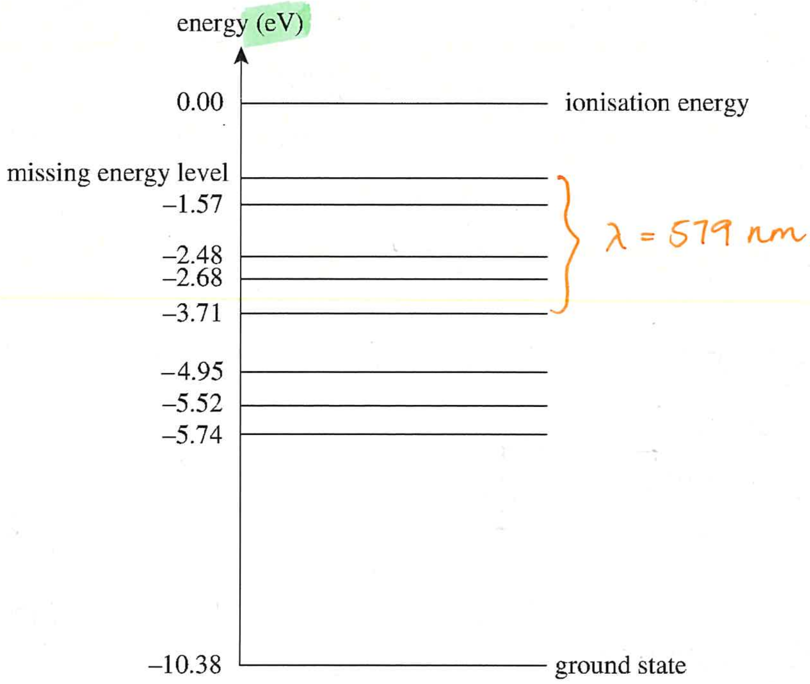


Figure 15

An electron from the missing energy level falls to the energy level of −3.71 eV and emits a photon of wavelength 579 nm.

a. Determine the value of the missing energy level. Show your working. 3 marks

$c = f\lambda$

$\therefore f = \frac{c}{\lambda}$

$\lambda = 579\,nm$

$= 579 \times 10^{-9}\,m$

$E = hf$

$= 4.14 \times 10^{-15} \times \frac{3.0 \times 10^{8}}{579 \times 10^{-9}}$

$= 2.15\,eV$

$\therefore$ energy level

$= -3.71 - 2.15$

$= -1.56\,eV$

−1.56 eV

b. Describe how an electron occupying one of these energy levels is modelled by wave–particle duality.

3 marks

• the electron has mass & speed and is present in an energy level & therefore has particle properties.
• energy is also manifested as a standing wave.
• the circumference of the energy level is the whole number of de Broglie wavelengths possessed by the electron, so it has wave-like properties.

Question 18 (13 marks)

Two students, Andrew and Sarah, are investigating the spring constant, k, of a spring. A standard mass is held in a stationary position at the bottom of an unextended spring. When released, the mass oscillates. The students use a stopwatch to time 20 vertical oscillations (20 times the period, T). The arrangement of the spring and mass are shown in Figure 16.

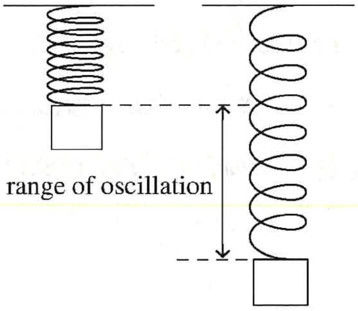


Figure 16

The students conduct the experiment with a series of standard masses, M, whose uncertainty is very low. They calculate the period from their measurements of 20 oscillations and determine the uncertainty in the period to be ±0.05 seconds.

a. Identify the independent variable, the dependent variable and one controlled variable involved in this experiment. 3 marks

Independent variable mass

Dependent variable period of oscillation / time for 20 oscillations.

Controlled variable stopwatch, spring, release position (only one)

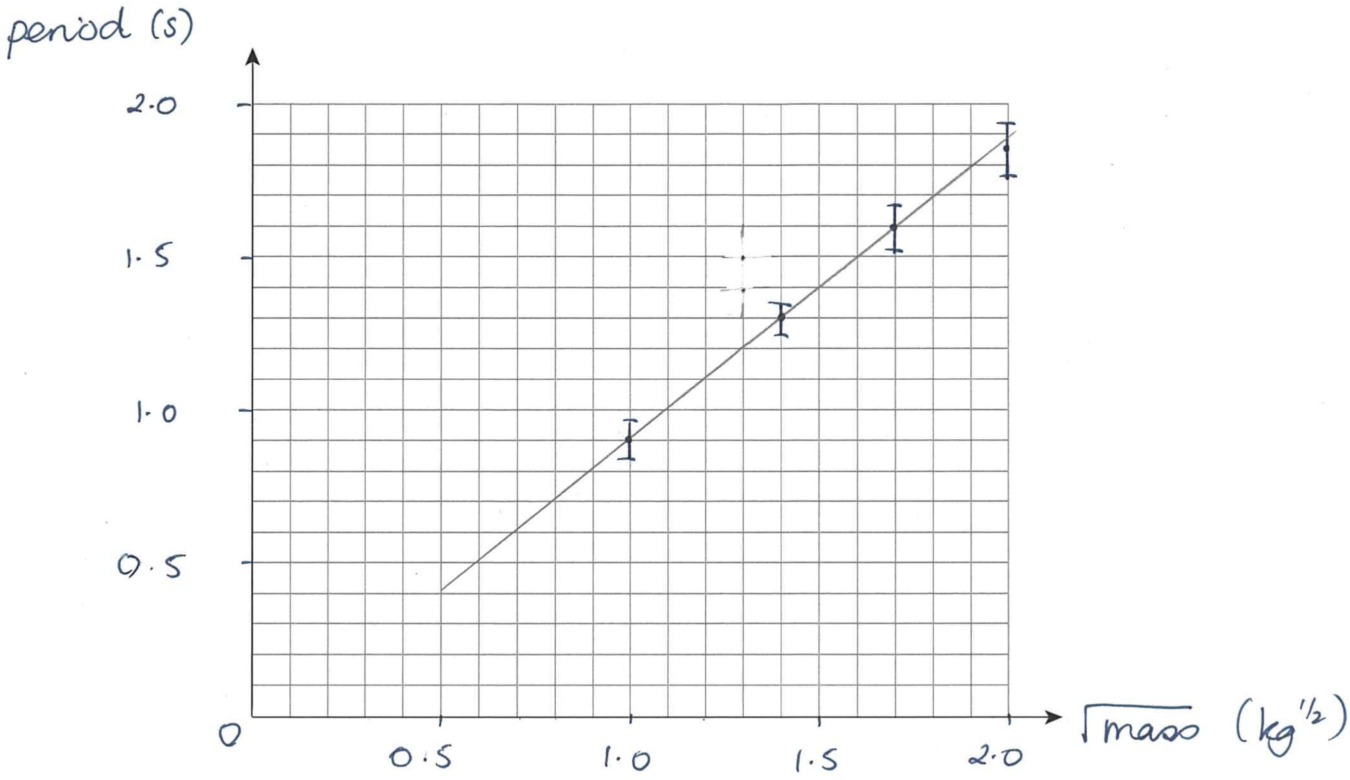
b. **i.** The students have recorded their data in the table below.
Complete the table by calculating the values of $\sqrt{\text{standard mass}}$ $(\sqrt{M})$. 1 mark

M **(kg)**	$\sqrt{M}\left(\mathrm{kg}^{\frac{1}{2}}\right)$	**Period (seconds)**
1.00	1	0.90
2.00	1.4	1.30
3.00	1.7	1.60
4.00	2.	1.85

ii. On the axes provided below:

- plot a graph of T versus $\sqrt{M}$ using the data from the table in **part b.i.**
- include the correct uncertainty bars for the T values
- label each of the axes correctly
- draw a line of best fit.

6 marks



gradient $= \frac{T}{\sqrt{M}}$ $\therefore T = \text{gradient} \times \sqrt{M}$.

iii. Using the line of best fit from **part b.ii.** and the formula $T = 2\pi\sqrt{\frac{M}{k}}$, which relates T and M, determine the value of the spring constant, k. Show your working.

3 marks

You need to use the gradient of the line of best fit, and consider the formula provided.

Since gradient $= \frac{T}{\sqrt{M}}$

rearrange: $T = \text{gradient} \times \sqrt{M}$.

original formula $T = 2\pi\sqrt{\frac{M}{k}}$.

gradient $= \frac{2\pi}{\sqrt{k}}$.

$\therefore \sqrt{k} = \frac{2\pi}{\text{gradient}}$

$k = \frac{4\pi^2}{\text{gradient}^2}$

N m^{-1}

END OF QUESTION AND ANSWER BOOKLET

Gradient (from line of best fit) → (1.8, 1.7) & (1.2, 1.1)

$= \frac{1.7 - 1.1}{1.8 - 1.2} = \frac{0.6}{0.6} = 1.0$

$\therefore k = \frac{4\pi^2}{1^2}$

$= 39.5 \text{ Nm}^{-1}$

answer will vary depending on gradient calculated.