VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

ANS -

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Victorian Certificate of Education 2021

STUDENT NUMBER | | | | | | | | | Letter |

PHYSICS
Written examination

Wednesday 10 November 2021

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	20	20	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 book of 42 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

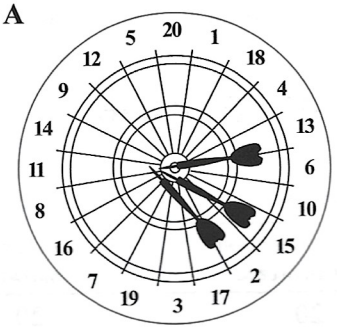
Instructions for Section A

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}.

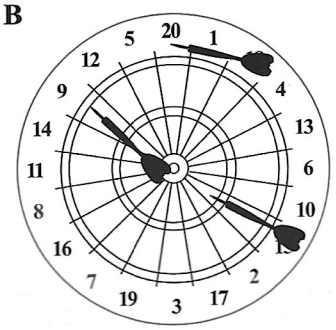
Question 1

The aim of darts is to hit the bullseye at the centre of a dartboard. Four darts players (A, B, C and D) each threw three darts. The results of their throws are shown below.

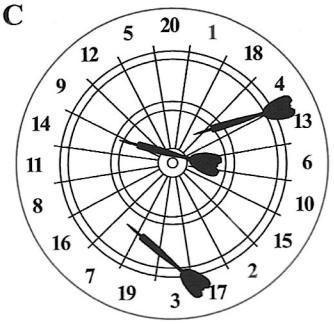
Player A



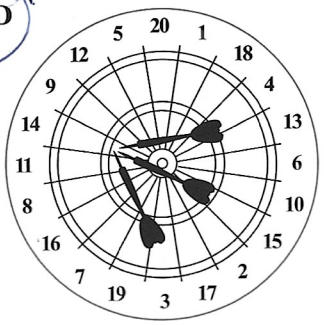
Player B



Player C



Player D



Which one of the players produced a set of attempts that could be described as being precise but inaccurate?

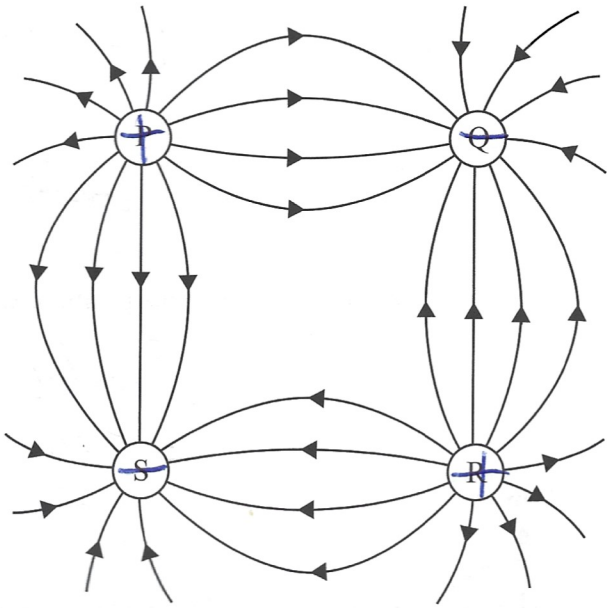
A. Player A
B. Player B
C. Player C
D. Player D

All Throws Close. Away from bullseye.

Question 2

The diagram below shows the electric field lines between four charged spheres: P, Q, R and S.
The magnitude of the charge on each sphere is the same.

For Point charges:
Field lines go:
out of +ve
Into -ve.

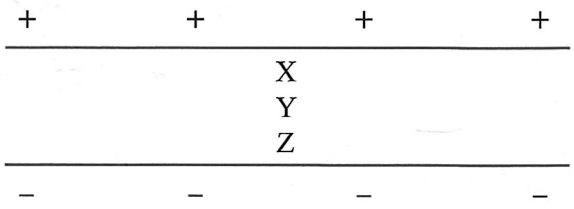


Which of the following correctly identifies the type of charge (+ positive or − negative) that resides on each of the spheres P, Q, R and S?

	P	Q	R	S
A.	−	+	−	+
B.	+	−	+	−
C.	−	−	+	+
D.	+	+	−	−

Question 3

The diagram below shows two parallel metal plates with opposite charges on each plate.
X, Y and Z represent different distances from the positive plate.



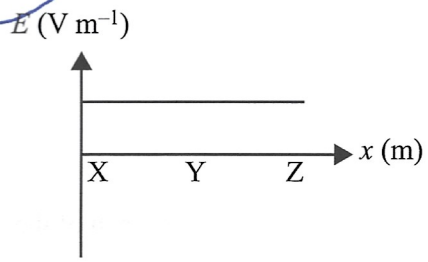
$E = \frac{V}{d}$.

constant

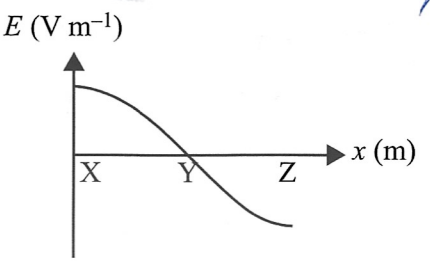
Which one of the following graphs best shows the electric field strength, E, versus the position, x, between the two parallel plates?

Parallel Plates → Field Constant between.

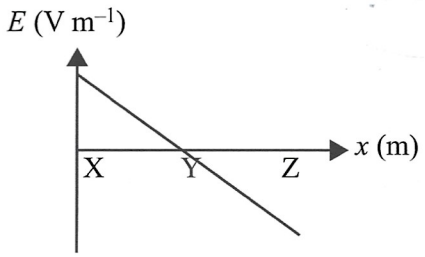
A.



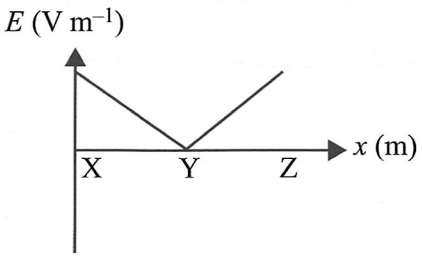
B.



C.



D.



Question 4

The planet Phobetor has a mass four times that of Earth. Acceleration due to gravity on the surface of Phobetor is 18 m s^{-2}.

If Earth has a radius R, which one of the following is closest to the radius of Phobetor?

A. R
B. $1.5R$
C. $2R$
D. $4R$

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

Earth: $9.8 = \frac{GM_e}{R_e^2}$

$M_e = \frac{9.8 R_e^2}{G}$

Phobetor: $18 = \frac{G 4M_e}{r^2}$

$18 r^2 = G 4 M_e$

$18 r^2 = \frac{8 \times 4 \times 9.8 R_e^2}{8}$

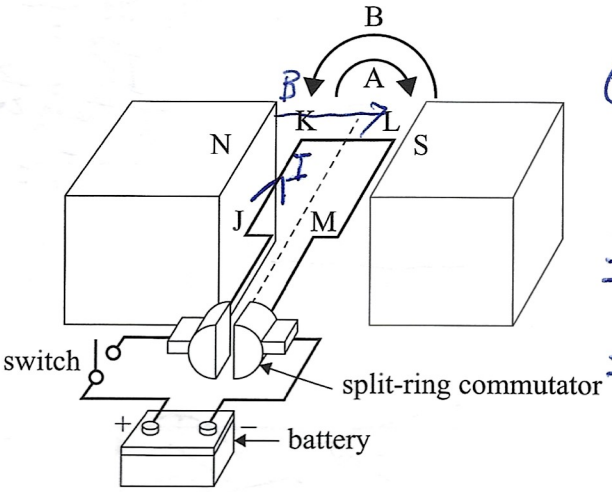
$r^2 = \frac{4 \times 9.8}{18} R_e^2$

$r^2 = 2.17 R_e^2 \rightarrow r = 1.47 R_e$

Note: VCAA Report gives an alternative method - Same Answer.

Question 5

The diagram below shows a small DC electric motor, powered by a battery that is connected via a split-ring commutator. The rectangular coil has sides KJ and LM. The magnetic field between the poles of the magnet is uniform and constant.



Right-Hand Rule
Current J → K.
Field to right.
⇒ Force Down.
⇒ Rotate anticlockwise

The switch is now closed, and the coil is stationary and in the position shown in the diagram.

Which one of the following statements best describes the motion of the coil when the switch is closed?

A. The coil will remain stationary.

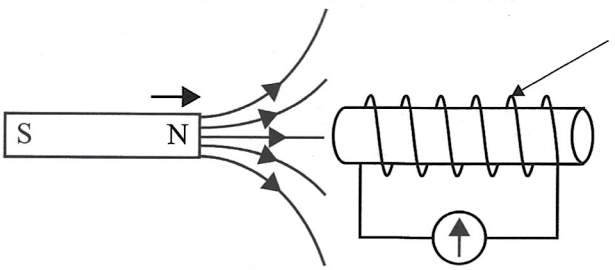
B. The coil will rotate in direction A, as shown in the diagram.

C. The coil will rotate in direction B, as shown in the diagram.

D. The coil will oscillate regularly between directions A and B, as shown in the diagram.

Question 6

A magnet approaches a coil with six turns, as shown in the diagram below. During time interval Δt, the magnetic flux changes by 0.05 Wb and the average induced EMF is 1.2 V.



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

$1.2 = 6\frac{0.05}{\Delta t}$

$\Delta t = \frac{6 \times 0.05}{1.2}$

$= 0.25$

Which one of the following is closest to the time interval Δt?

A. 0.04 s

B. 0.01 s

C. 0.25 s

D. 0.50 s

Question 7

A mobile phone charger uses a step-down transformer to transform 240 V AC mains voltage to 5.0 V. The mobile phone draws a current of 3.0 A while charging. Assume that the transformer is ideal and that all readings are RMS.

Which one of the following is closest to the current drawn from the mains during charging?

A. 48 A

B. 16 A

C. 1.2 A

D. 0.06 A

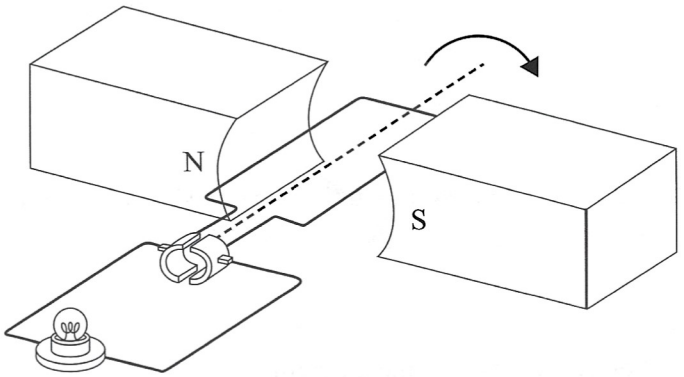
$\frac{V_1}{V_2} = \frac{I_2}{I_1}$ $\frac{240}{5} = \frac{3.0}{I_1}$

$\frac{I_1}{3.0} = \frac{5}{240}$

$I_1 = \frac{5 \times 3.0}{240} = 0.0625$

Question 8

The diagram below shows a simple electrical generator consisting of a rotating wire loop in a magnetic field, connected to an external circuit with a light globe, a split-ring commutator and brushes. The direction of rotation is shown by the arrow.



Which one of the following best describes the function of the split-ring commutator in the external circuit?

A. It delivers a DC current to the light globe.

B. It delivers an AC current to the light globe.

C. It ensures the force on the side of the loop nearest the north pole is always up.

D. It ensures the force on the side of the loop nearest the north pole is always down.

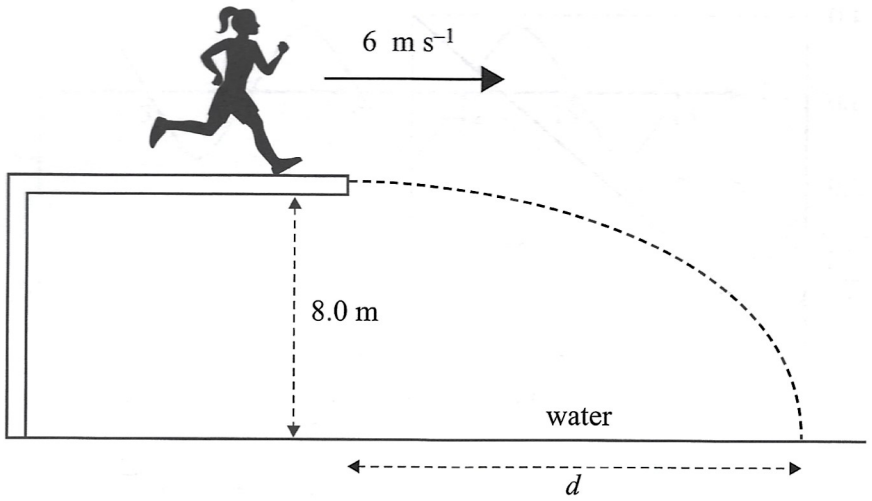
Generator → Current Induced.
Form AC.
→ Split ring AC → DC

Note: The FUNDAMENTAL purpose of a split-ring commutator in a generator is to deliver a DC output.

Use the following information to answer Questions 9 and 10.

Lucy is running horizontally at a speed of 6 m s^{-1} along a diving platform that is 8.0 m vertically above the water. Lucy runs off the end of the diving platform and reaches the water below after time t.

She lands feet first at a horizontal distance d from the end of the diving platform.



Question 9

Which one of the following expressions correctly gives the distance d?

A. $0.8t$

B. $6t$

C. $5t^2$

D. $6t + 5t^2$

Horizontally $a = 0$.

$6 = \frac{d}{t}$

$d = 6t$.

Question 10

Which one of the following is closest to the time taken, t, for Lucy to reach the water below?

A. 0.8 s

B. 1.1 s

C. 1.3 s

D. 1.6 s

Vertically $a = 9.8$

$x = 8 \quad u = 0 \quad t = ?$

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

$8 = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$

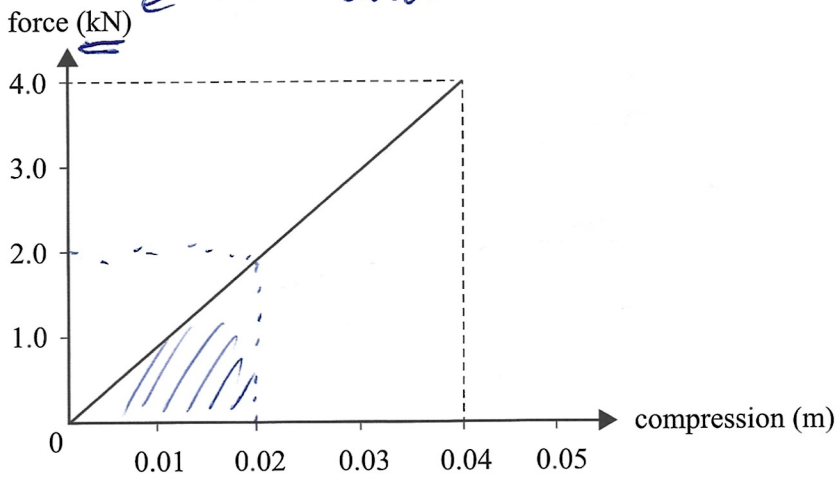
$8 = 4.9t^2$

$1.632 = t^2$

$t = 1.277$ sec.

Use the following information to answer Questions 11 and 12.

A force versus compression graph for a suspension spring is shown below.



← kilo Newton.

Question 11

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

A. $0.16\ \text{N m}^{-1}$

B. $1.0 \times 10^{2}\ \text{N m}^{-1}$

C. $1.6 \times 10^{2}\ \text{N m}^{-1}$

D. $1.0 \times 10^{5}\ \text{N m}^{-1}$

gradient

$k = \frac{4000}{0.04}$

$= 100{,}000$

Question 12

The spring is compressed to 0.02 m.

Which one of the following is closest to the potential energy stored in the spring?

A. 0.04 J

B. 0.20 J

C. 20 J

D. 40 J

$V_s = \frac{1}{2} k x^2$

$V_s = \frac{1}{2} \times 100{,}000 \times 0.02^2$

$= 20$

OR Area.

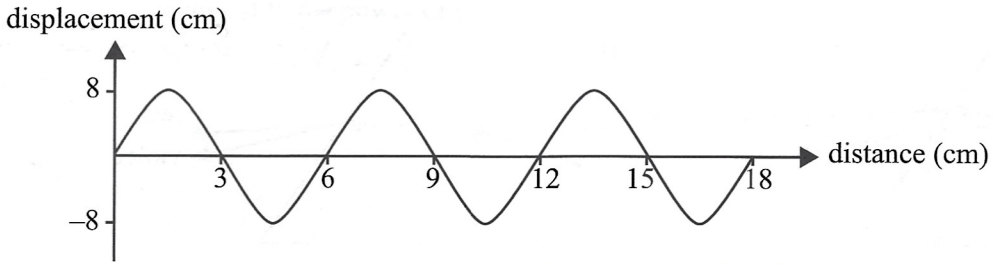
Triangle $= \frac{1}{2} b h$

$= \frac{1}{2} \times 0.02 \times (2 \times 10^3)$

$= 20$

Question 13

The diagram below shows part of a travelling wave.



From graph $\lambda = 6\text{cm} = 0.06\text{ m}$.

The wave propagates with a speed of 18 m s^{-1}.

Which of the following is closest to the amplitude and frequency of the wave?

A. 8 cm, 3.0 Hz

B. 16 cm, 3.0 Hz

C. 8 cm, 300 Hz

D. 16 cm, 300 Hz

↑ 8cm From graph

$v = \lambda f$

$18 = 0.06 f$

$f = 300$

Question 14

Different regions of the electromagnetic spectrum have distinct applications in society.

Which of the following best associates a particular region of the electromagnetic spectrum with a possible application?

Heat, See Stuff, Sterilisation, Medical

	Infra-red	Visible	Ultraviolet	X-rays
A.	thermal imaging ✓	water sterilisation	optical microscopy	medical imaging ✓
B.	water sterilisation	optical microscopy ✓	thermal imaging	medical imaging ✓
C.	optical microscopy	medical imaging	thermal imaging	water sterilisation
D.	thermal imaging ✓	optical microscopy ✓	water sterilisation ✓	medical imaging ✓

Note: Put a small summary image on your sheet of notes that summarizes the Electromagnetic Spectrum

Question 15

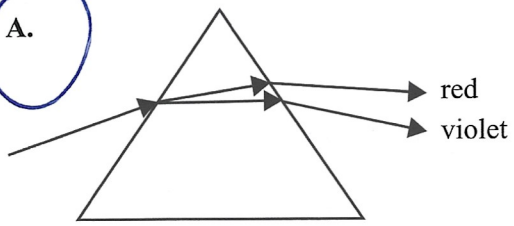
A Physics class is investigating the dispersion of white light using a triangular glass prism.

Which one of the following diagrams best shows the principle of dispersion?

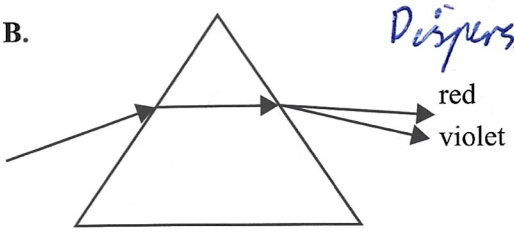
Violet Varies Violently

Dispersion will occur at both boundaries

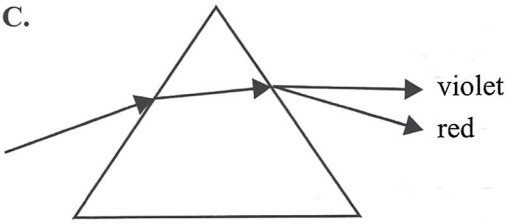
A.



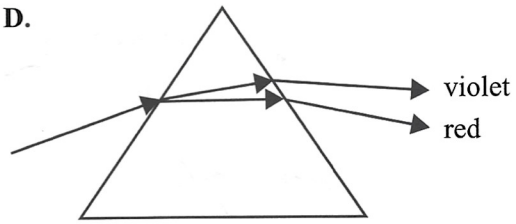
B.



C.



D.

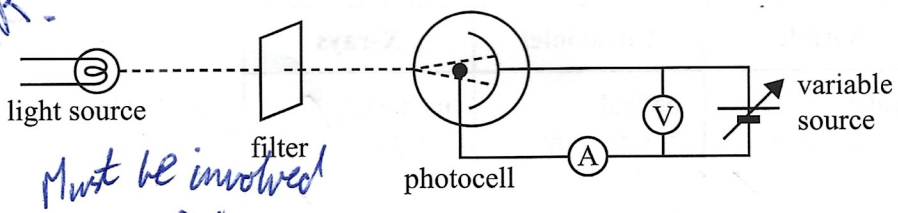


Question 16

The diagram below shows a circuit that is used to study the photoelectric effect.

Threshold Frequency.

B. True but not ESSENTIAL to the MEASUREMENT.



Must be involved

Which one of the following is essential to the measurement of the maximum kinetic energy of the emitted photoelectrons?

$E_{k\,Max} = hf - \phi$

↑ Connected to f_0

Stopping Voltage.

A. the level of brightness of the light source

B. the wavelengths that pass through the filter

C. the reading on the voltmeter when the current is at a minimum value

D. the reading on the ammeter when the voltage is at a maximum value

Question 17

Which one of the following is closest to the de Broglie wavelength of a 663 kg motor car moving at 10 m s^{-1}?

A. 10^{-37} m

B. 10^{-36} m

C. 10^{-35} m

D. 10^{-34} m

$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{663 \times 10}$

$= 1 \times 10^{-37}$

Question 18

A monochromatic light source is emitting green light with a wavelength of 550 nm. The light source emits 2.8×10^{16} photons every second.

Which one of the following is closest to the power of the light source?

A. 1.0×10^{-2} W

B. 3.3×10^{-11} W

C. 2.1×10^{9} W

D. 6.3×10^{16} W

$\leftarrow \times 10^{-9}$

$E = hf$ $\quad v = \lambda f$ $\quad f = \frac{v}{\lambda}$

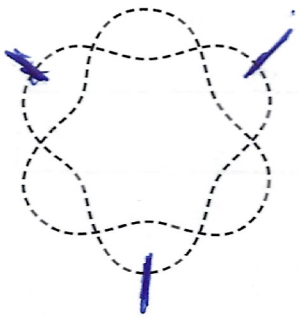
Total energy $= 2.8 \times 10^{16} \times 3.616 \times 10^{-19}$ $\quad E = \frac{hc}{\lambda}$

$= 0.0101$ J $\quad = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{550 \times 10^{-9}}$

$P = \frac{E}{t} = \frac{0.0101}{1} = 0.0101$ $\quad = 3.616 \times 10^{-19}$ each photon

Question 19

The diagram below shows one representation of a de Broglie standing wave for an electron in orbit around a hydrogen atom.



Count number of wavelengths in the standing pattern

Which one of the following values of n, the number of whole wavelengths, best depicts the de Broglie standing wave pattern shown in the diagram?

A. 2

B. 3

C. 4

D. 6

Question 20

One of Einstein's postulates for special relativity is that the laws of physics are the same in all inertial frames of reference.

Which one of the following best describes a property of an inertial frame of reference?

A. It is travelling at a constant speed.

B. It is travelling at a speed much slower than c.

C. Its movement is consistent with the expansion of the universe.

D. No observer in the frame can detect any acceleration of the frame.

An INERTIAL frame is NOT accelerating → VELOCITY constant

Note: If travelling in a circle speed is constant, but accelerating.

END OF SECTION A
TURN OVER

SECTION B

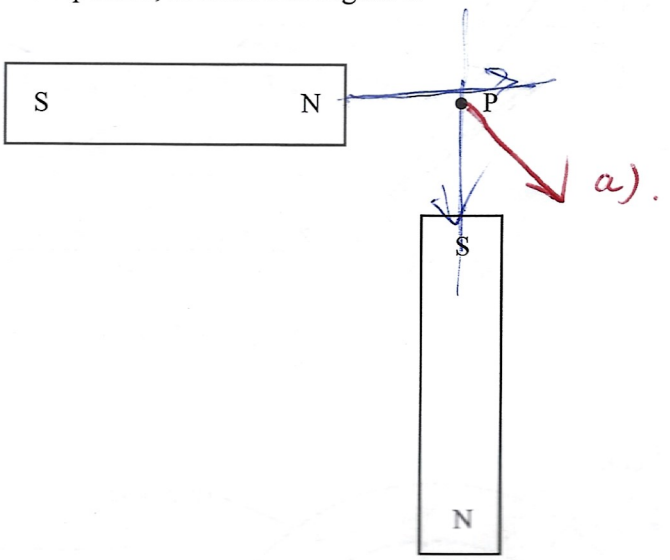
Instructions for Section B

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}.

Note this one, as there are a few Questions Requiring working out.

Question 1 (3 marks)

Two identical bar magnets of the same magnetic field strength are arranged at right angles to each other and at the same distance from point P, as shown in Figure 1.

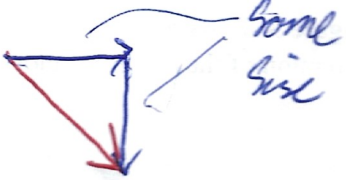


a).

out of N →

Into S ↓

Vector addition



Some Size

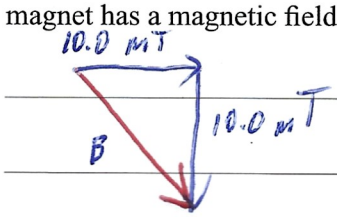
Figure 1

a. At point P on Figure 1, draw an arrow indicating the direction of the combined magnetic field of the two bar magnets.

1 mark

b. Calculate the magnitude of the combined magnetic field strength of the two bar magnets if each bar magnet has a magnetic field strength of 10.0 mT at point P.

2 marks



$B^2 = 10^2 + 10^2$

$B^2 = 200$

$B = \sqrt{200}$

$= 14.14$

OR

$B^2 = (10 \times 10^{-3})^2 + (10 \times 10^{-3})^2$

$= 2 \times 10^{-4}$

$B = \sqrt{2 \times 10^{-4}}$

$= 0.01414$

$= 14.14 \times 10^{-3}$

14.1 mT

DO NOT WRITE IN THIS AREA

Question 2 (4 marks)

A schematic side view of one design of an audio loudspeaker is shown in Figure 2. It uses a current carrying coil that interacts with permanent magnets to create sound by moving a cone in and out.

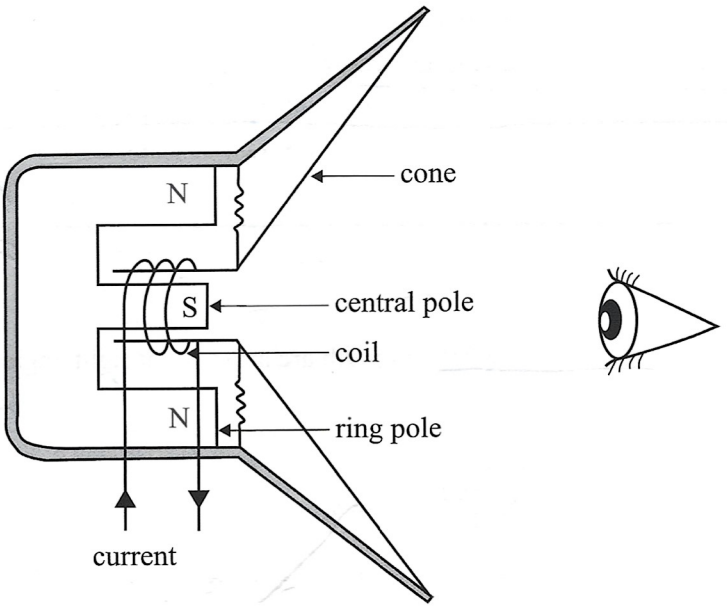


Figure 2

Figure 3 shows a schematic view of the loudspeaker from the position of the eye shown in Figure 2. The direction of the current is clockwise, as shown.

Examiners Report
Full marks for field lines due to Magnets.
If Field due to coil (i.e into page) was included - full marks were awarded.

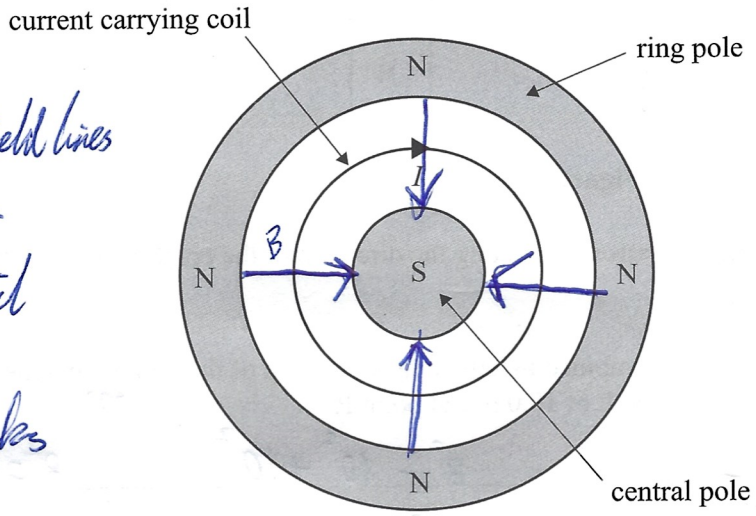


Figure 3

a. Draw **four** magnetic field lines on Figure 3, showing the direction of each field line using an arrow. 1 mark

↖ Due to Magnets?

SECTION B – Question 2 – continued

b. Which one of the following gives the direction of the force acting on the current carrying coil shown in Figure 3? 1 mark

Right Hand Push Rule.
Thumb → I
Fingers → B.
Palm → F

A.	left	**B.**	right
C.	up the page	**D.**	down the page
E.	into the page	**F.**	out of the page

E

c. The current carrying coil has a radius of 5.0 cm and 20 turns of wire, and it carries a clockwise current (I) of 2.0 A. Its magnetic field strength (B) is 200 mT.

Circular → Circumference

Calculate the magnitude of the force, F, acting on the current carrying coil. Show your working. 2 marks

$F = n I L B$

$= 20 \times 2.0 \times 0.314 \times 200 \times 10^{-3}$

$= 2.513$.

radius $= 5.0$ cm
$= 0.05$ m.

$L = 2\pi r$
$= 2 \times \pi \times 0.05$
$= 0.314$.

2.5 N

Note: the coil is circular
Thus the length of the wire in the field is the circumference of the circle.

- Show Working → Needed to get Full marks.
Question asks for Working

DO NOT WRITE IN THIS AREA

Question 3 (3 marks) ← Must show significant working.

To calculate the mass of distant pulsars, physicists use Newton's law of universal gravitation and the equations of circular motion.

The planet Phobetor orbits pulsar PSR B1257+12 at an orbital radius of 6.9×10^{10} m and with a period of 8.47×10^{6} s.

Assuming that Phobetor follows a circular orbit, calculate the mass of the pulsar. Show all your working.

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

$$M = \frac{4\pi^2 R^3}{GT^2}$$

$$M = \frac{4 \times \pi^2 \times (6.9 \times 10^{10})^3}{6.67 \times 10^{-11} \times (8.47 \times 10^{6})^2}$$

$$= \frac{4 \times \pi^2 \times 3.29 \times 10^{32}}{6.67 \times 10^{-11} \times 7.17 \times 10^{13}}$$

$$= 2.64 \times 10^{30}$$

2.64×10^{30} kg

Alternate Method

Circular Motion

$F_c = \frac{4\pi^2 r m}{T^2}$.

$F_g = \frac{GMm}{r^2}$ as gravity holds it in the 'circle'

$F_c = F_g$

$\frac{4\pi^2 r m}{T^2} = \frac{GMm}{r^2}$

$\frac{4\pi^2 r^3}{GT^2} = M$.

Kepler's 3rd Law $\frac{R^3}{T^2}$ = Constant

The constant is $\frac{GM}{4\pi^2}$

M is mass of central body.

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

Question 4 (2 marks)

Liesel, a student of yoga, sits on the floor in the lotus pose, as shown in Figure 4. The action force, F_g, on Liesel due to gravity is 500 N down.

↑ due to - Earth's Mass.

F_g is Earth on Liesel

Newton's 3rd Law.

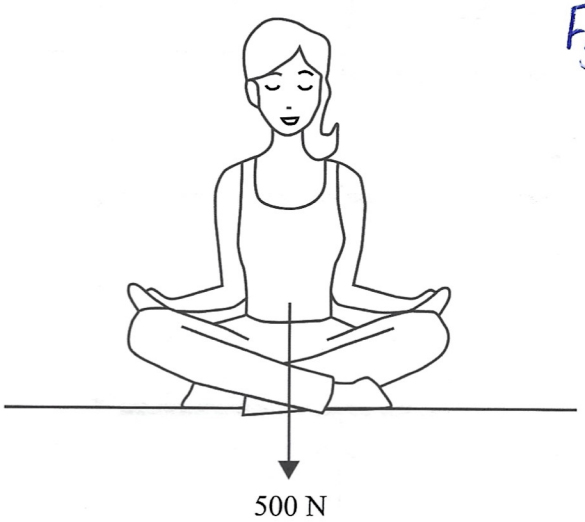


Figure 4

Identify and explain what the reaction force is to the action force, F_g, shown in Figure 4.

Newton's 3rd Law.

Reaction is Liesel on Earth.

500 N Upwards.

Note: These questions can be confused.

Newtons 3rd Law → since Action and Reaction are referred to.

The Action and Reaction MUST involve the SAME two objects

If one body exerts a force on a second, the second exerts an equal and opposite force on the first.

or Action Force of 1 on 2.

Reaction Force of 2 on 1, Same Size opposite direction

$(F_{1on2} = -F_{2on1})$.

Question 5 (9 marks)

Figure 5 shows a stationary electron (e^-) in a uniform magnetic field between two parallel plates. The plates are separated by a distance of 6.0×10^{-3} m, and they are connected to a 200 V power supply and a switch. Initially, the plates are uncharged. Assume that gravitational effects on the electron are negligible.

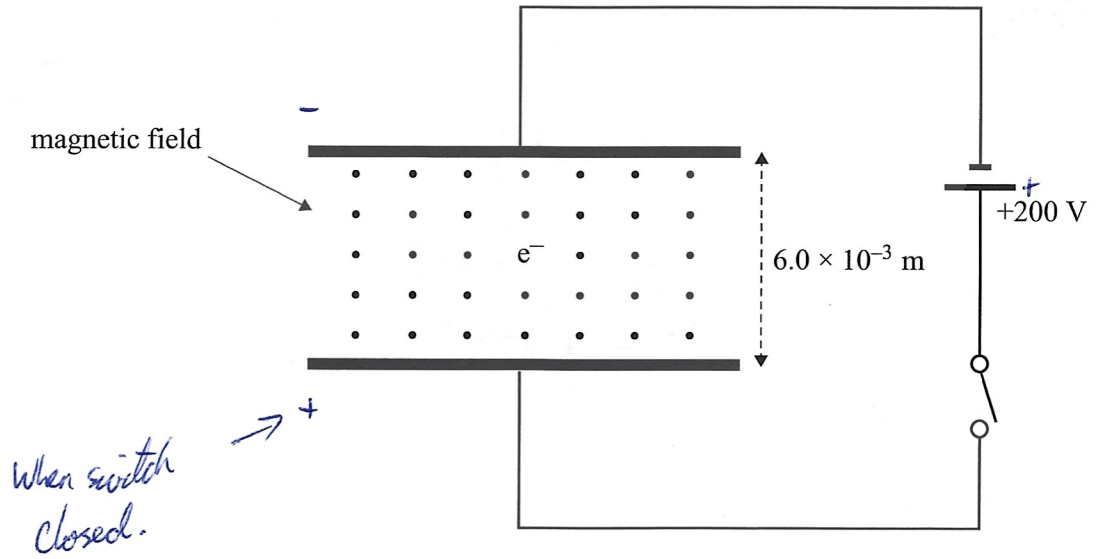


Figure 5

a. Explain why the magnetic field does not exert a force on the electron. Justify your answer with an appropriate formula. 2 marks

Electron is Stationary ie. $v = 0$.

$F = qvB$.

$v = 0$.

$\therefore F = 0$.

The switch is now closed.

b. Determine the magnitude and the direction of any electric force now acting on the electron. Show your working. 3 marks

$F = qE$

$= 1.6 \times 10^{-19} \times 0.033$

$= 5.33 \times 10^{-21}$

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

$= \frac{200}{6.0 \times 10^{-3}}$ = 3.3 X 10^4

$= 0.033$

3.3 X 10^4

-15

Before switch closed forces balance. After closing forces no longer balance → acceleration

5.33×10^{-21} N

Direction Down page.

c. Ravi and Mia discuss what they think will happen regarding the size and the direction of the magnetic force on the electron after the switch is closed.

Ravi says that there will be a magnetic force of constant magnitude, but it will be continually changing direction.

Mia says that there will be a constantly increasing magnetic force, but it will always be acting in the same direction.

Evaluate these two statements, giving clear reasons for your answer. 4 marks

→ $F_m = qvB$.

Ravi

$F = qE$, Charge and Electric Field constant, Thus the Electric Force is constant. Not Magnetic Force

Right Hand Push rule says Force is ⊥ to direction of movement. Thus the direction of movement will continually change.

Mia → Magnetic

For force to increase, v would need to increase. Since there is an Electric Force due to electric field, so v can increase and Magnetic force could increase.

Right Hand Rule. Direction of magnetic force ⊥ to direction of Travel. which changes. Thus direction of force changes.

Ravi correct on direction, incorrect on Force being Constant

Mia correct on Magnetic Force, incorrect on direction.

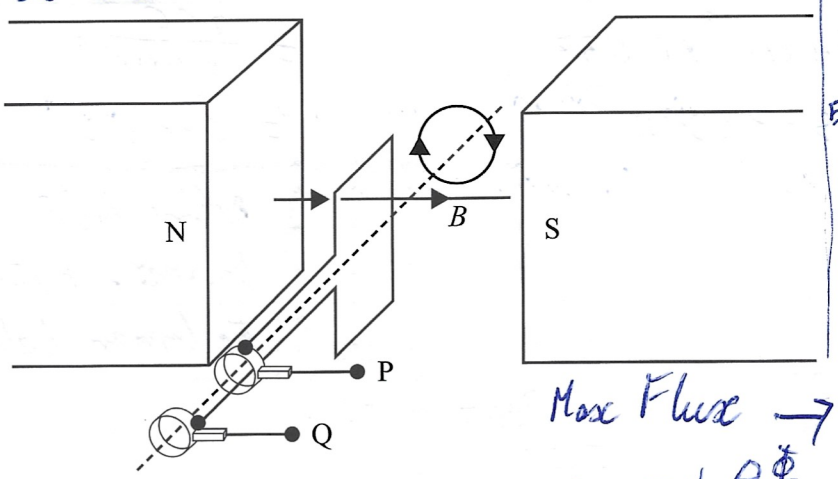
Question 6 (8 marks)

Figure 6 shows a simple AC generator. A mechanical energy source rotates the loop smoothly at 50 revolutions per second and the loop generates an RMS voltage of 4.25 V. The magnetic field, B, is constant and uniform. The direction of rotation is as shown in Figure 6.

$f = 50 \rightarrow T = \frac{1}{50} = 0.02$

$V_{RMS} = 4.25$

$V_p = \sqrt{2} \times 4.25 = 6.01$



Flux Φ t

EMF t

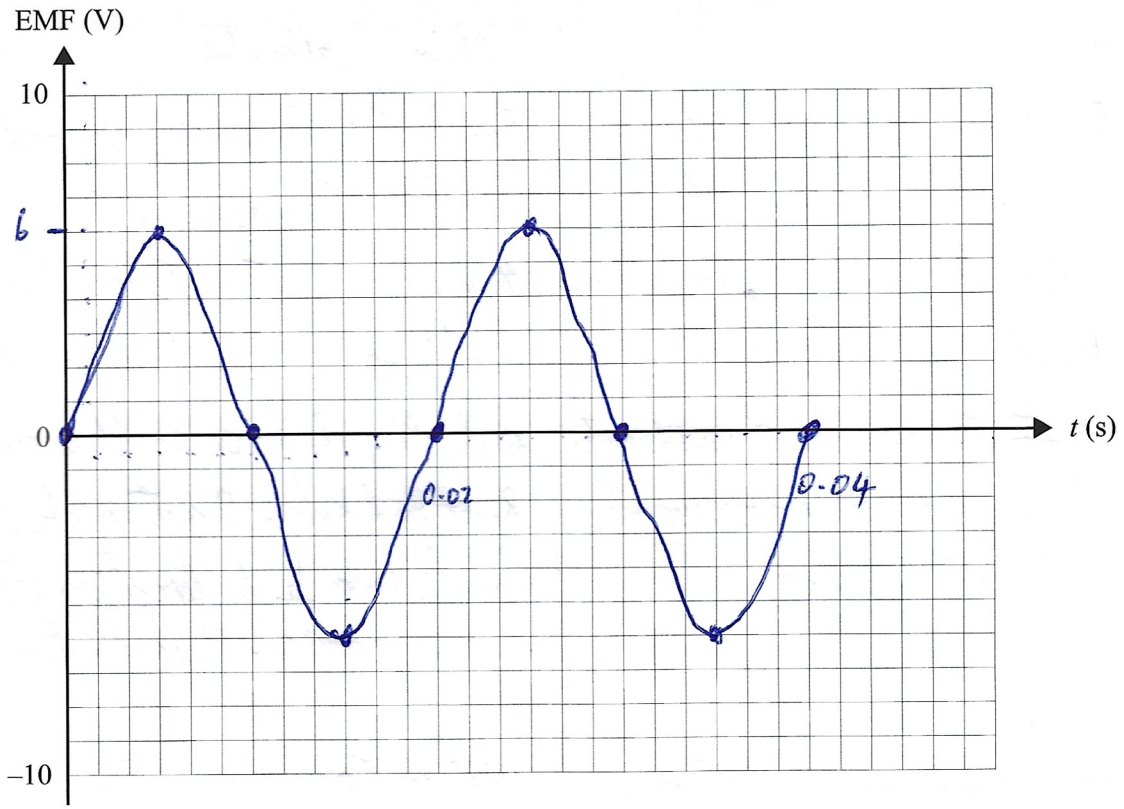
Max Flux → EMF = 0.

$EMF_{MAX} = -N \frac{\Delta\Phi}{\Delta t}$ → -ve change in Flux.

Figure 6

a. Sketch the output EMF between P and Q versus time, t, on the grid below, starting with the loop in the position shown in Figure 6. Show **at least two** complete revolutions, and include the maximum voltage on the vertical axis and a time scale on the horizontal axis. 4 marks

← Must label axes



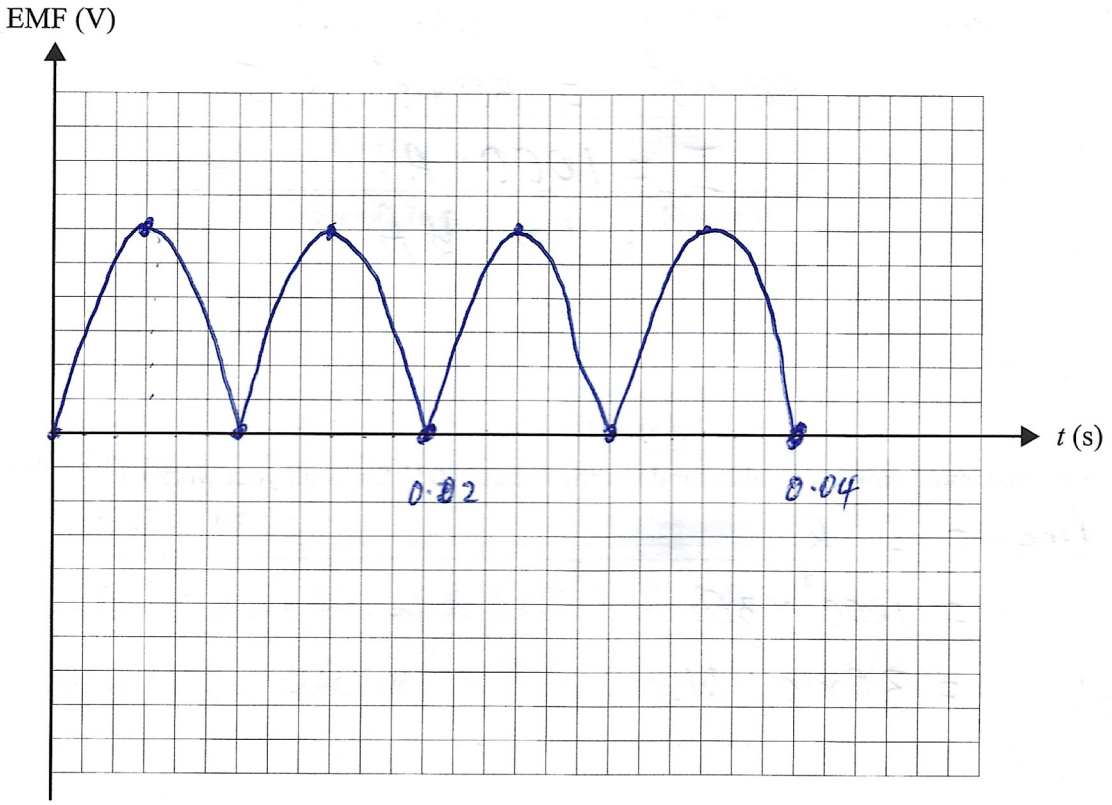
b. Describe the function of the slip rings shown in Figure 6. 1 mark

Maintain contact Electrical contact between loop and Wires would twist.

c. **i.** How could the AC generator shown in Figure 6 be changed to a DC generator? 1 mark

Addition of SPLIT RING COMMUTATOR.
Replacing the slip rings ← Must be this specific

ii. Sketch the output EMF versus time, t, for this DC generator for **at least two** complete revolutions on the grid below. Include a time scale on the horizontal axis. No scale is required for the vertical axis. 2 marks



Question 7 (7 marks)

The generator of an electrical power plant delivers 500 MW to external transmission lines when operating at 25 kV. The generator's voltage is stepped up to 500 kV for transmission and stepped down to 240 V 100 km away (for domestic use). The overhead transmission lines have a total resistance of 30.0 Ω. Assume that all transformers are ideal. → No Power loss in Transformer . Power loss in Transmission Wires.

a. Explain why the voltage is stepped up for transmission along the overhead transmission lines. 2 marks

Voltage Stepped up → Current Reducing
→ Reduce Power loss due to I^2R.
Voltage ↑ by factor 20 → Current ↓ by factor 20.
→ Power loss ↓ by factor $20^2 = 400$.

b. Calculate the current in the overhead transmission lines. Show your working. 2 marks

Ideal Transformer Power In = Power Out

$500 \times 10^6 = 500 \times 10^3 \times I$

$I = 1000$ A.

$= 1.0$ kA.

1.0 kA

c. Determine the maximum power available for domestic use at 240 V. Show all your working. 3 marks

Power loss $= I^2R$

$= 1000^2 \times 30$

$= 30 \times 10^6$ W.

Power at Domestic use $= 500 \times 10^6 - 30 \times 10^6$

$= 470 \times 10^6$

470 MW

Need to show both steps in the calculation to gain full marks.

Question 8 (11 marks)

On 30 July 2020, the National Aeronautics and Space Administration (NASA) launched an Atlas rocket (Figure 7a) containing the Perseverance rover space capsule (Figure 7b) on a scientific mission to explore the geology and climate of Mars, and search for signs of ancient microbial life.

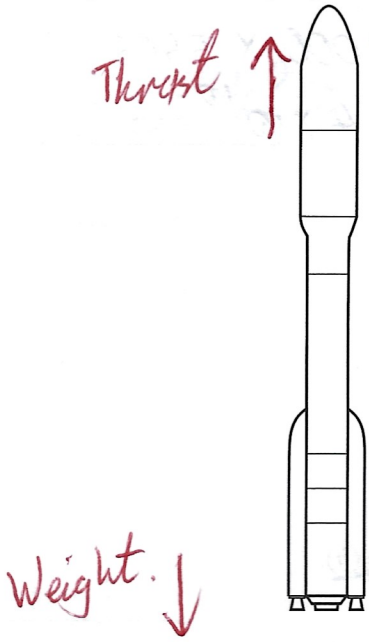


Figure 7a

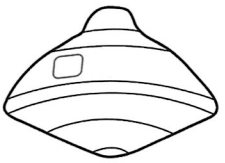


Figure 7b

a. At lift-off from launch, the acceleration of the rocket was 7.20 m s^{-2}. The total mass of the rocket and capsule at launch was 531 tonnes.

Calculate the magnitude and the direction of the thrust force on the rocket at launch. Take the gravitational field strength at the launch site to be $g = 9.80$ N kg^{-1}. Give your answer in meganewtons. Show your working. 3 marks

$\Sigma F = ma$

Thrust − Weight $= 531 \times 10^3 \times 7.20$

Thrust − $531 \times 10^3 \times 9.8 = 3823200$

Thrust − $5203800 = 3823200$

Thrust $= 9,027,000$

$= 9.03$ MN.

9.03 MN	Upwards.

On 18 February 2021, the Perseverance rover space capsule, travelling at 20 000 km h^{-1}, entered Mars's atmosphere at an altitude of 300 km above the surface of Mars. The mass of the capsule was 1000 kg.

b. Calculate the kinetic energy of the capsule at this point. Show your working. 2 marks

$v = 20\,000$ km/hr

$= 20\,000 \div 3.6$

$= 5555$ m/s

$E_K = \frac{1}{2} m v^2$

$= \frac{1}{2} \times 1000 \times 5555^2$

$= 1.054 \times 10^{10}$

1.54×10^{10} J

Figure 8 shows the gravitational field strength of Mars (g) versus altitude (h).

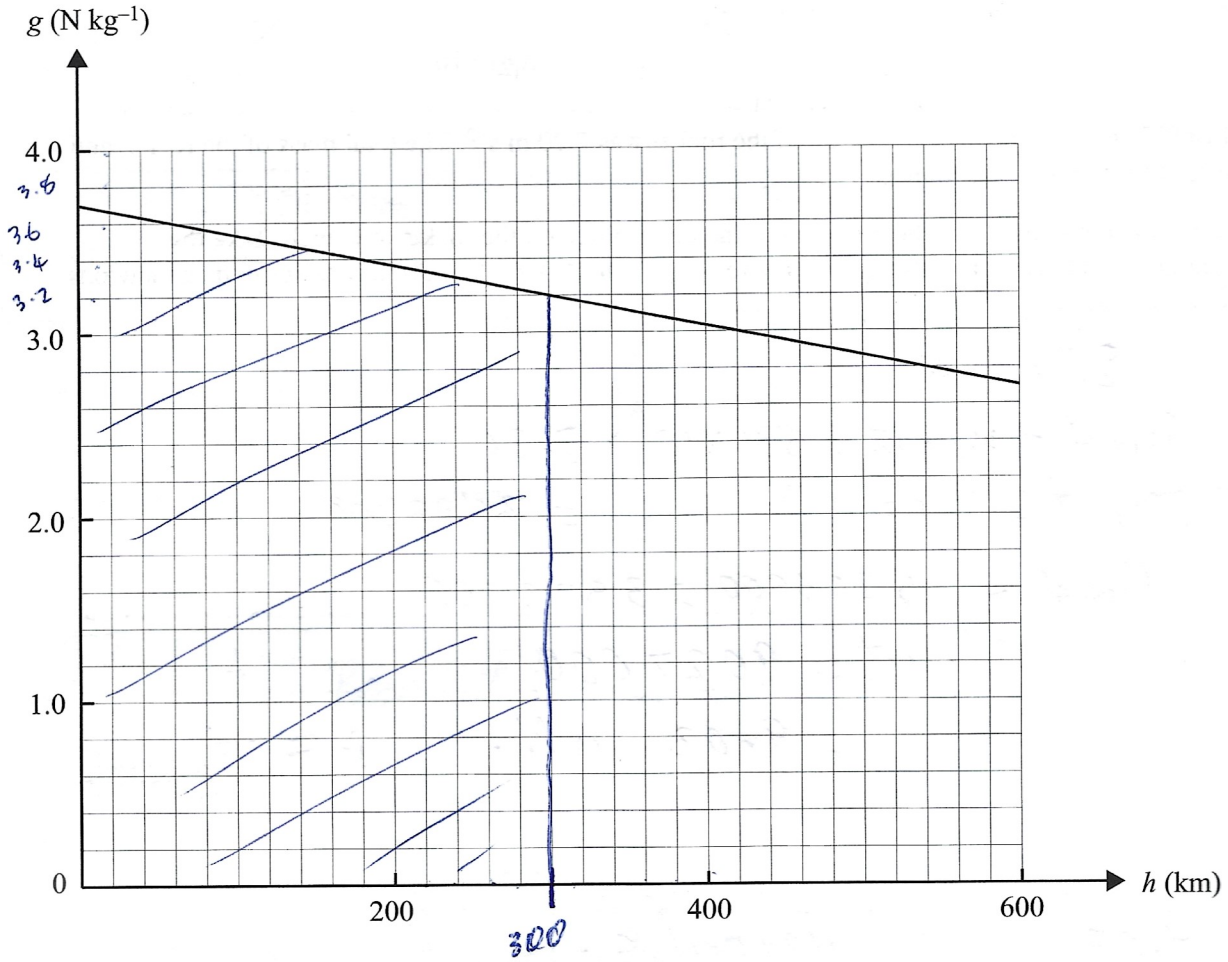


Figure 8

c. Calculate the gravitational potential energy of the capsule relative to the surface of Mars at an altitude of 300 km. Show your working. 3 marks

g Vs h graph → Area is Gravitational P.E. per kilogram.

Area $= \frac{1}{2}(3.2 + 3.7) \times 300 \times 10^3$

$= 1{,}035{,}000$

Gravitational P.E. $= 1\,035\,000 \times 1000$

$= 1{,}035{,}000{,}000$

$= 1.04 \times 10^9$.

Area of Trapezium $= \frac{1}{2}(a+b)h$.
Alternatively split into △ and □

1.04×10^9 J

d. The capsule used aerodynamic braking as it descended through Mars's atmosphere to reduce its speed from 20 000 km h^{-1} to 1600 km h^{-1}. The capsule was then at an altitude of 10 km above the surface of Mars and had ~1% of its original combined gravitational potential energy and kinetic energy remaining.

Describe how ~99% of the gravitational potential energy and kinetic energy of the capsule was transformed and dissipated as the capsule descended from an altitude of 300 km above the surface of Mars to an altitude of 10 km above the surface of Mars. No calculations are required. 3 marks

Gravitational P.E. → Kinetic Energy but slows down.

So Kinetic Energy → Heat Energy, Light, Sound (Friction due to atmosphere).

Thus the Gravitational P.E. and Kinetic Energy are ultimately converted to Heat Energy, light & Sound.

Note: Examiners Report includes Light + Sound. Given Space capsules have Heat Shields, Heat would be the most significant (probably)

Question 9 (10 marks)

Abbie and Brian are about to go on their first loop-the-loop roller-coaster ride. As competent Physics students, they are working out if they will have enough speed at the top of the loop to remain in contact with the track while they are upside down at point C, shown in Figure 9. The radius of the loop CB is r.

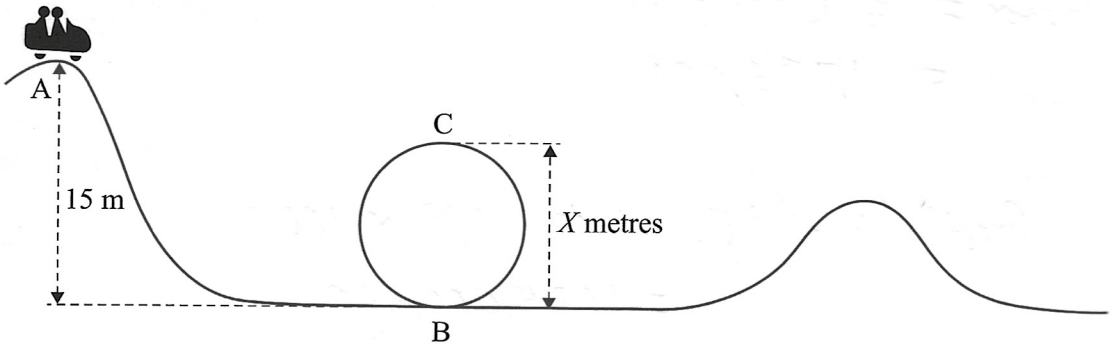


Figure 9

The highest point of the roller-coaster (point A) is 15 m above point B and the car starts at rest from point A. Assume that there is negligible friction between the car and the track.

a. What is the speed of the car at point B at the bottom of the loop? Show your working. 2 marks

$U_g \rightarrow E_K$ - Conservation of Energy.

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

$9.8 \times 15 = \frac{1}{2}v^2$

$294 = v^2$

$v^2 = 294$

$v = 17.15$

17.15 m s^{-1}

Must start with the forces acting.

b. By considering the forces acting on the car, show that the condition for the car to just remain in contact with the track at point C is given by $\frac{v^2}{r} = g$. Show your working. 2 marks

$F_C = W + N$

$\frac{mv^2}{r} = mg + 0$

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

$\frac{v^2}{r} = g.$

Normal Reaction = 0.

$\Rightarrow$ Centripetal Force = Weight

Note: * Motion is circular $\rightarrow$ Centripetal force.

* Centripetal force is provided by Gravitational and Normal reaction forces.

* Just in contact $\rightarrow$ Normal Reaction = 0.

c. What is the maximum height of the loop (X metres) that will ensure that the car stays in contact with the track at point C? Show your working. 3 marks

Need plenty of working

Total Energy at B = $m \times 9.8 \times 15 = 147m$

At C G.P.E = $m \times 9.8 \times x = 9.8mx$.

K.E. at C = $147m - 9.8mx$.

from b. $v^2 = gr$, and $r = \frac{x}{2}$.

$v^2 = \frac{9x}{2} = \frac{9.8x}{2} = 4.9x$

At C. $147m - 9.8mx = \frac{1}{2} m \times 4.9x$

$147 - 9.8x = 2.45x$

$147 = 12.25x$

$x = 12m$.

12 m

d. If friction is taken into account, will Abbie and Brian need to increase or decrease their predicted value for the radius of the loop? Explain your answer. 3 marks

Friction will convert some energy into heat.
Less energy (kinetic) at Point C, thus speed is less.
Thus the radius of the loop will need to DECREASE.
Since from Part b → $r = \frac{v^2}{g}$ ($\frac{v^2}{r} = g$) If $v \downarrow$ then $\frac{v^2}{g} \downarrow$ and $r \downarrow$

Need EXPLANATION. and significant.
Examiners report indicates the relationship $r = \frac{v^2}{g}$ is needed.

Question 10 (4 marks)

A new spaceship that can travel at $0.7c$ has been constructed on Earth. A technician is observing the spaceship travelling past in space at $0.7c$, as shown in Figure 10. The technician notices that the length of the spaceship does not match the measurement taken when the spaceship was stationary in a laboratory, but its width matches the measurement taken in the laboratory.

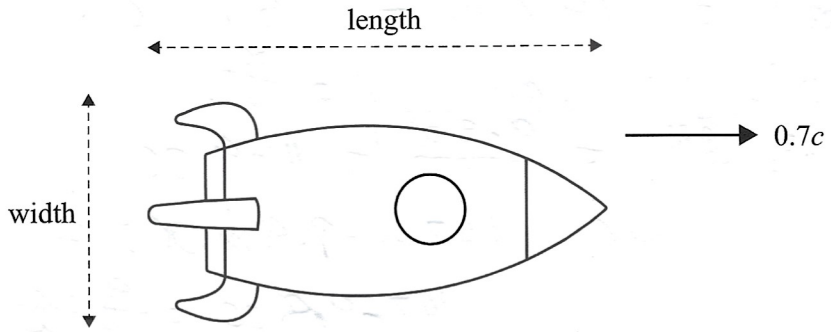


Figure 10

a. Explain, in terms of special relativity, why the technician notices there is a different measurement for the length of the spaceship, but not for the width of the spaceship. 2 marks

Length Contraction occurs only in the direction of Motion, which is what the technician is observing. Thus Length changes but Width does not.

b. If the technician measures the spaceship to be 135 m long while travelling at a constant $0.7c$, what was the length of the spaceship when it was stationary on Earth? Show your working. 2 marks

$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$= \frac{1}{\sqrt{1-\frac{(0.7c)^2}{c^2}}}$

$= \frac{1}{\sqrt{1-0.49}}$

$\gamma = \frac{1}{\sqrt{0.51}}$

$= 1.40$

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

$135 = \frac{L_0}{1.40}$

$L_0 = 189$

189 m

Note: * Lab. Technician measures CONTRACTED length
* Useful but not necessary - γ can never be less than 1.

Question 11 (2 marks)

Figure 11 shows a system of two ideal polarising filters, F_1 and F_2, in the path of an initially unpolarised light beam. The polarising axis of the first filter, F_1, is parallel to the y-axis and the polarising axis of the second filter, F_2, is parallel to the x-axis.

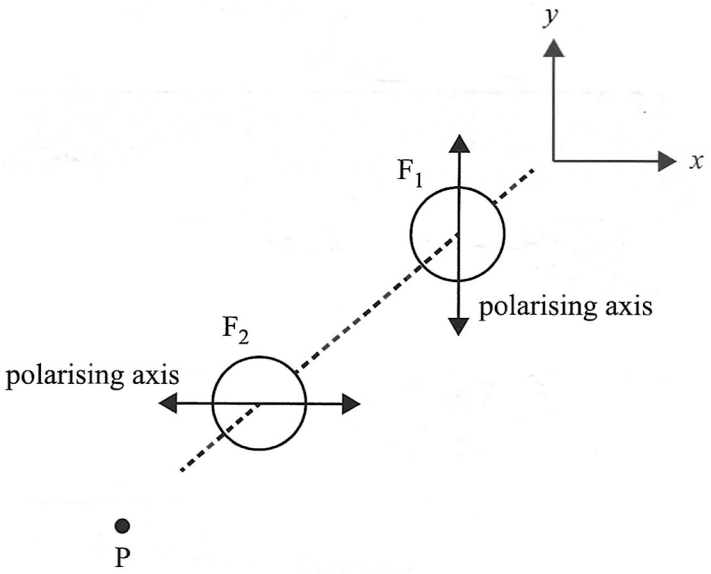


Figure 11

Will any light be observed at point P? Give your reasoning.

No light at P.

F_1 allows light polarised parallel to the y-axis through. Cuts out all other light.

F_2 allows light polarised parallel to the x-axis through. But light arriving from F_1 is polarised parallel to y-axis. This light is stopped. None passes through.

Note: Must relate Polarisation theory specifically to the situation given in the question.

Question 12 (5 marks)

A Physics teacher is conducting a demonstration involving the transmission of light within an optical fibre. The optical fibre consists of an inner transparent core with a refractive index of 1.46 and an outer transparent cladding with a refractive index of 1.42. A single monochromatic light ray is incident on the optical fibre, as shown in Figure 12.

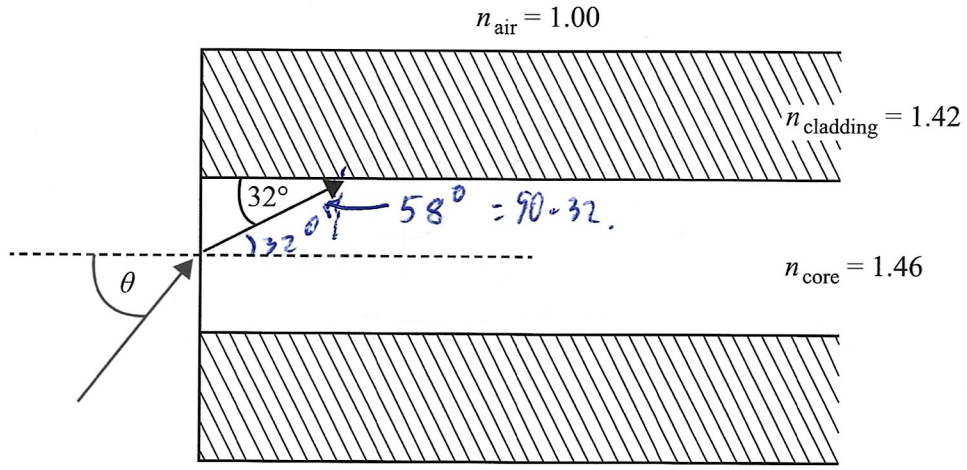


Figure 12

a. Determine the angle of incidence, θ, at the air–core boundary. Show your working. 2 marks

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law)

$1 \sin\theta = 1.46 \sin 32°$

$\sin\theta = 0.7736$.

$\theta = \sin^{-1}(0.7736) = 50.6857$

50.7 ° → Examiners Reports has 51° → Consistent with angle given (32°).

b. Will any of the initial light ray be transmitted into the cladding? Explain your answer and show any supporting working. 3 marks

$1.46 \sin 58 = 1.42 \sin\theta_{cladding}$

$\sin\theta_{cladding} = 0.871$

$\theta_{cladding} = 60.68°$

Light passes into cladding since it is possible to calculate a Refracted angle.

OR

$\sin\theta_{critical} = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1.42}{1.46}$

Critical Angle = 76.56°

Angle of incidence (58°) less than critical angle ⇒ light passes into cladding.

Preferred approach in Examiners Report.

Question 13 (4 marks)

In Young's double-slit experiment, the distance between two slits, S_1 and S_2, is 2.0 mm. The slits are 1.0 m from a screen on which an interference pattern is observed, as shown in Figure 13a. Figure 13b shows the central maximum of the observed interference pattern.

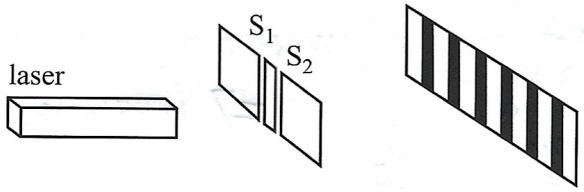


Figure 13a

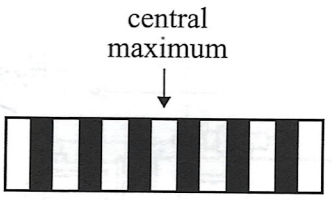


Figure 13b

a. If a laser with a wavelength of 620 nm is used to illuminate the two slits, what would be the distance between two successive dark bands? Show your working. 2 marks

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

$= \frac{620 \times 10^{-9} \times 1.00}{2.0 \times 10^{-3}}$

$= 0.0031$ m

0.31 mm

b. Explain how this experiment supports the wave model of light. 2 marks

Waves diffracted at each slit. Waves from S_1 and S_2 interfere at the screen. Path difference of whole wavelength → Constructive interference → Bright bands.

Path difference of $\frac{1}{2}$ wavelength → Destructive interference → Dark Bands.

Interference is wave behaviour, thus supports the wave model.

Note: Must relate the theory to the situation presented. Generic statements seldom score highly.

Question 14 (3 marks)

A distant fire truck travelling at 20 m s^{-1} to a fire has its siren emitting sound at a constant frequency of 500 Hz.

Chris is standing on the edge of the road. Assume that the fire truck is travelling directly towards him as it approaches and directly away from him as it goes past. The arrangement is shown in Figure 14.

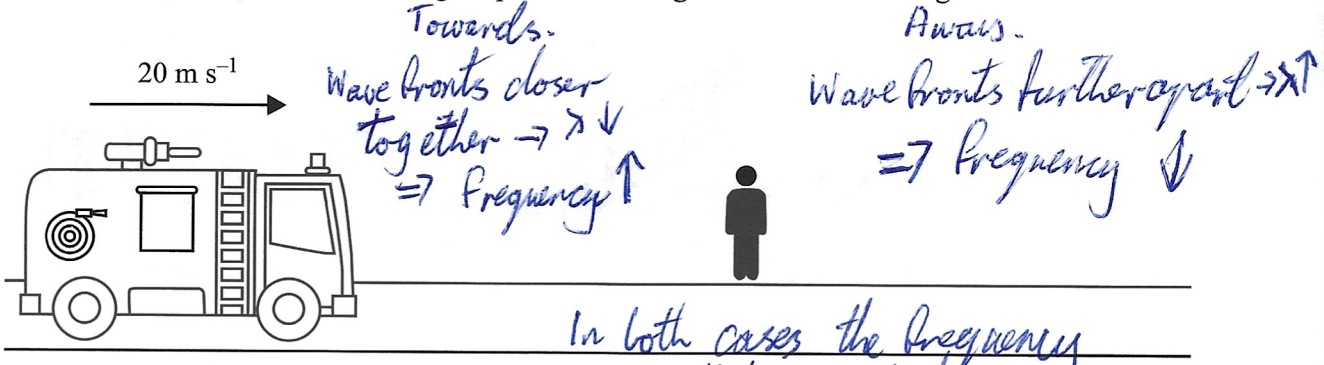
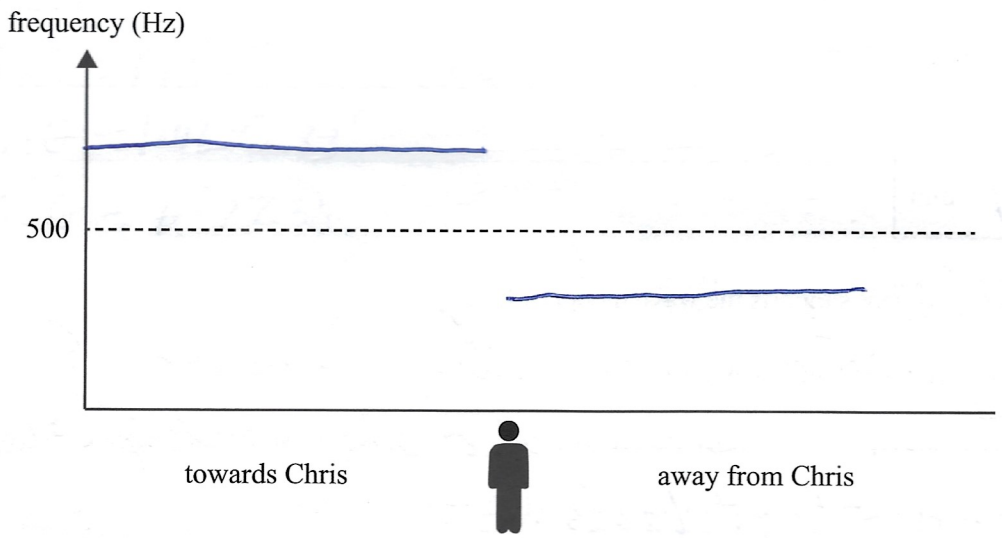


Figure 14

a. On the diagram below, sketch the frequency that Chris will hear as the truck moves towards him and then moves away from him. The 500 Hz siren signal is shown as a dotted line for reference. No calculations are required. 2 marks



b. Name the physics principle involved in Chris's experience. 1 mark

Doppler Effect.

SECTION B – continued

Question 15 (3 marks)

A photoelectric experiment is carried out by students. They measure the threshold frequency of light required for photoemission to be 6.5×10^{14} Hz and the work function to be 3.2×10^{-19} J. f_0

Using the students' measurements, what value would they calculate for Planck's constant? Outline your reasoning and show all your working. Give your answer in joule-seconds.

$f_0 = 6.5 \times 10^{14}$ $W = 3.2 \times 10^{-19}$.

$E_{K\,MAX} = hf - \phi$

$0 = h \times 6.5 \times 10^{14} - 3.2 \times 10^{-19}$

$3.2 \times 10^{-19} = h \times 6.5 \times 10^{14}$

$h = \frac{3.2 \times 10^{-19}}{6.5 \times 10^{14}}$

$= 4.92 \times 10^{-34}$ Js

$= 4.9 \times 10^{-34}$ Js

OR.

$W = hf_0$

$3.2 \times 10^{-19} = h \times 6.5 \times 10^{14}$

$h = 4.92 \times 10^{-34}$ Js

$= 4.9 \times 10^{-34}$ Js

4.92×10^{-34} Js

Question 16 (2 marks)

Light can be described by a wave model and also by a particle (or photon) model. The rapid emission of photoelectrons at very low light intensities supports one of these models but not the other.

Identify the model that is supported, giving a reason for your answer.

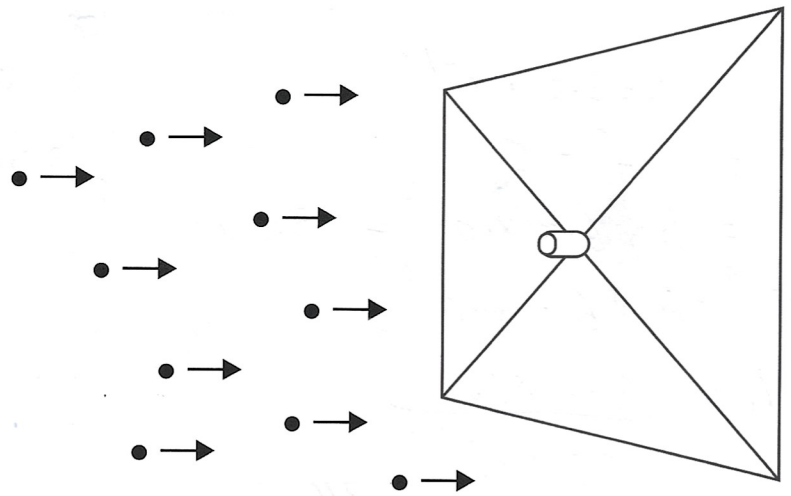
Model supported Particle.

* Particle (Photon) gives up all its energy and photo electron emmitted if the energy is above the work function. Doesn't rely on the number of Photons. Thus electron can be emmitted immediately by the first Photon
* Wave model predicts accumulation of energy over time, until enough is absorbed to emit an electron.

Note: Must be specific to the question. ie the rapid emmission at low intensity

Question 17 (4 marks)

A 'space sail' mounted on a tiny interstellar cylindrical probe relies on the momentum of photons from a nearby star to exert a propulsive force, as shown in Figure 15.



$v = \lambda f$

$\lambda = \frac{v}{f}$ for Photons $\lambda = \frac{c}{f}$

Figure 15

No energy loss (handy)

The photons strike the sail at 90° to its surface and reflect elastically. Scientists need to calculate the force exerted by the photons, which have a frequency of 7.0×10^{15} Hz.

a. Show that the momentum of a 7.0×10^{15} Hz photon is equal to 1.55×10^{-26} kg m s^{-1}. 1 mark

must have correct working

$$p = \frac{h}{\lambda} = \frac{hf}{c} = \frac{6.63 \times 10^{-34} \times 7.0 \times 10^{15}}{3 \times 10^{8}} = 1.547 \times 10^{-26}$$

$$= 1.55 \times 10^{-26} \text{ kg m s}^{-1}$$

b. 2.0×10^{18} photons of this frequency strike the space sail every second.

Calculate the force that the reflecting photons exert on the space sail. Show your working. Give your answer correct to two significant figures. 3 marks

$I = F_{ave} \Delta t$ Reflect $\Rightarrow \Delta p = 2 \times 1.55 \times 10^{-26}$ $\Delta t = 1$ sec.

$I = \Delta p$ $= 3.11 \times 10^{-26}$ each Photon

Total $\Delta p = 3.11 \times 10^{-26} \times 2 \times 10^{18}$

$= 6.2 \times 10^{-8}$

$\Delta p = I = F_{ave} \Delta t$

$6.2 \times 10^{-8} = F_{ave} \times 1$

$F_{ave} = 6.2 \times 10^{-8}$

6.2×10^{-8} N

Note: $\Delta p = p_f - p_i$. In this case since the Magnitudes are the same and directions opposite (elastic collision)

$\Delta p = 2 \times p$

Question 18 (5 marks)

Scientists are conducting experiments to compare the circular diffraction patterns formed by X-ray photons and electrons when they pass through small circular apertures. The X-ray photons have an energy of 100 eV and pass through an aperture of diameter 1.24 μm. The electrons are moving at 5.0×10^5 m s^{-1}.

a. Show that the de Broglie wavelength of the electrons is equal to 1.46×10^{-9} m. 1 mark

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

$= \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 5.0 \times 10^5}$ $= \frac{6.63 \times 10^{-34}}{4.55 \times 10^{-25}} = 1.46 \times 10^{-9}$ m

b. The scientists want an aperture for the electrons that forms diffraction patterns with the same spacing as the diffraction patterns formed by the X-ray photons.

Calculate the diameter of the aperture that the scientists should choose. Show your working. 4 marks

Diffraction $\rightarrow \frac{\lambda}{w}$

X-rays

$E = 100$ eV.

$E = hf$. $v = \lambda f \rightarrow f = \frac{v}{\lambda}$

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

$100 = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{\lambda}$

$\lambda = 1.242 \times 10^{-8}$

$\frac{\lambda}{w} = \frac{1.242 \times 10^{-8}}{1.24 \times 10^{-6}}$

$= 1.00 \times 10^{-2}$.

Electrons

Want $\frac{\lambda}{w} = 1.00 \times 10^{-2}$

Same as for the X-rays.

$1.00 \times 10^{-2} = \frac{1.46 \times 10^{-9}}{w}$.

$w = 1.46 \times 10^{-7}$ m.

1.46×10^{-7} m

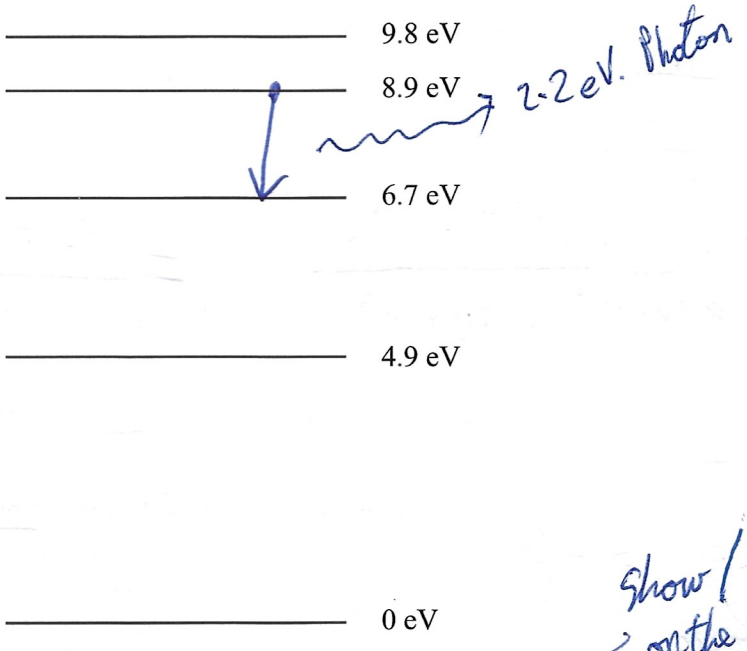
Note: * Same spacing in diffraction pattern $\Rightarrow \frac{\lambda}{w}$ is the same for both.

* 4 marks $\rightarrow$ ~ 4 steps in the calculation.

* Working must be shown.

Question 19 (4 marks)

A simplified diagram of some of the energy levels of an atom is shown in Figure 16.



Energies in eV.
∴ use eV version of Planck's Constant

Show / Draw on the diagram?

Figure 16

a. Identify the transition on the energy level diagram in Figure 16 that would result in the emission of a 565 nm photon. Show your working. 2 marks

$E_{photon} = \frac{hc}{\lambda}$

$= \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{565 \times 10^{-9}}$

$= 2.19\text{8}$

$= 2.2$ eV.

Need 2.2 eV difference in energy levels.

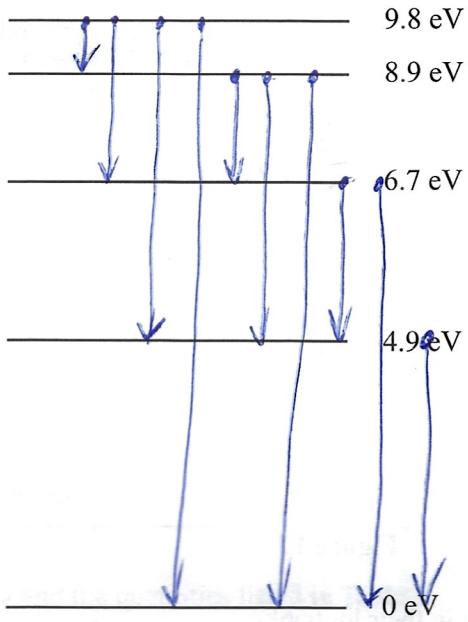
8.9 − 6.7 = 2.2 eV.

From 8.9 eV level to the 6.7 eV level.

SECTION B – Question 19 – continued

b. A sample of the atoms is excited into the 9.8 eV state and a line spectrum is observed as the states decay. Assume that all possible transitions occur.

What is the total number of lines in the spectrum? Explain your answer. You may use the diagram below to support your answer. 2 marks



9

10 options. From 9.8eV level 0.9, 3.1, 4.9, 9.8
From 8.9eV level 2.2, 4.0, 8.9
From 6.7eV level 1.8, 6.7.
From 4.9eV level 4.9

Same energy.

9 Different ones.

Question 20 (17 marks)

Two Physics students, Jerome and Priya, set out to investigate centripetal force.

Figure 17 shows the experimental set-up and the apparatus that the students use. In reality, the students find that the cord is not quite horizontal but dips downward slightly due to the gravitational force acting on the rubber stopper. Their teacher explains that they can safely ignore this effect when collecting their experimental results.

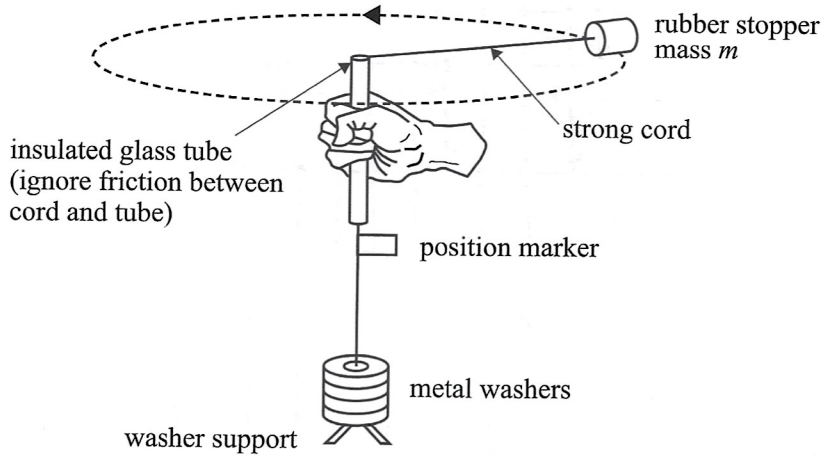


Figure 17

Jerome and Priya note the following data in their logbook.

radius of circle	0.75 m
mass of each metal washer	30 g
initial number of washers	10

Priya holds the glass tube and sets the rubber stopper rotating in a horizontal circle.

She maintains a constant radius of the circle by keeping the position marker at a fixed position just below the bottom of the glass tube.

Jerome uses a stopwatch to measure the time for 20 rotations of the rubber stopper, repeating this measurement three times. He notes all the data collected in their logbook.

The experiment is then repeated four more times with two extra metal washers added before each new trial is undertaken.

a. Why did the students take repeated time measurements during the experiment? 1 mark

To reduce the effect of Random Errors.

Alternative answer that were accepted

reduce uncertainty

improve reliability

b. The tension in the cord supplies the centripetal force that the rubber stopper needs to rotate in a circle.

What is the cause of this tension? 1 mark

Force of Gravity on the WASHERS
ie. the weight of the washers.

c. The gravitational force acting on the metal washers is given by Mg, where M is the total mass of the washers and g is the gravitational field.

Table 1

Symbol	Symbol represents
π	a constant
m	mass of rubber stopper
R	radius of rotation
T	period of rotation

Develop an equation between Mg and the quantities listed in Table 1. 3 marks

$F_c = \frac{mv^2}{R}$ but $v = \frac{dist}{time}$

$= \frac{circumference}{Period}$

$= \frac{2\pi R}{T}$

F_c Provided by Washers

$\Rightarrow F_c = W_{washers}$

$= Mg.$

$Mg = \frac{m}{R}\left(\frac{2\pi R}{T}\right)^2$

$= \frac{m\ 4\pi^2 R^2}{R\ T^2}$

$Mg = \frac{m\ 4\pi^2 R}{T^2}$

Jerome and Priya record some of their results in Table 2. The students are told by their teacher that they can use $g = 10\ \text{N kg}^{-1}$ for their calculations.

d. Fill in the blank columns in Table 2. 4 marks

Table 2

Line number	Total mass of washers, M (kg)	Gravitational force acting on washers, Mg (N)	Average time for 20 rotations (s)	Period, T (s)	$\frac{1}{T^2}$ (s^{-2})
1	0.30	3.0	14.0	$\frac{14}{20}$ 0.7	2.04
2	0.36	3.6	12.8	0.64	2.44
3	0.42	4.2	11.8	0.59	2.87
4	0.48	4.8	11.0	0.55	3.31
5	0.54	5.4	10.4	0.52	3.70

Examiners Report
Says 3.30
but. $\frac{11}{20} = 0.55$.

$\frac{1}{0.55^2} = \frac{1}{0.3025}$

$= 3.3057$

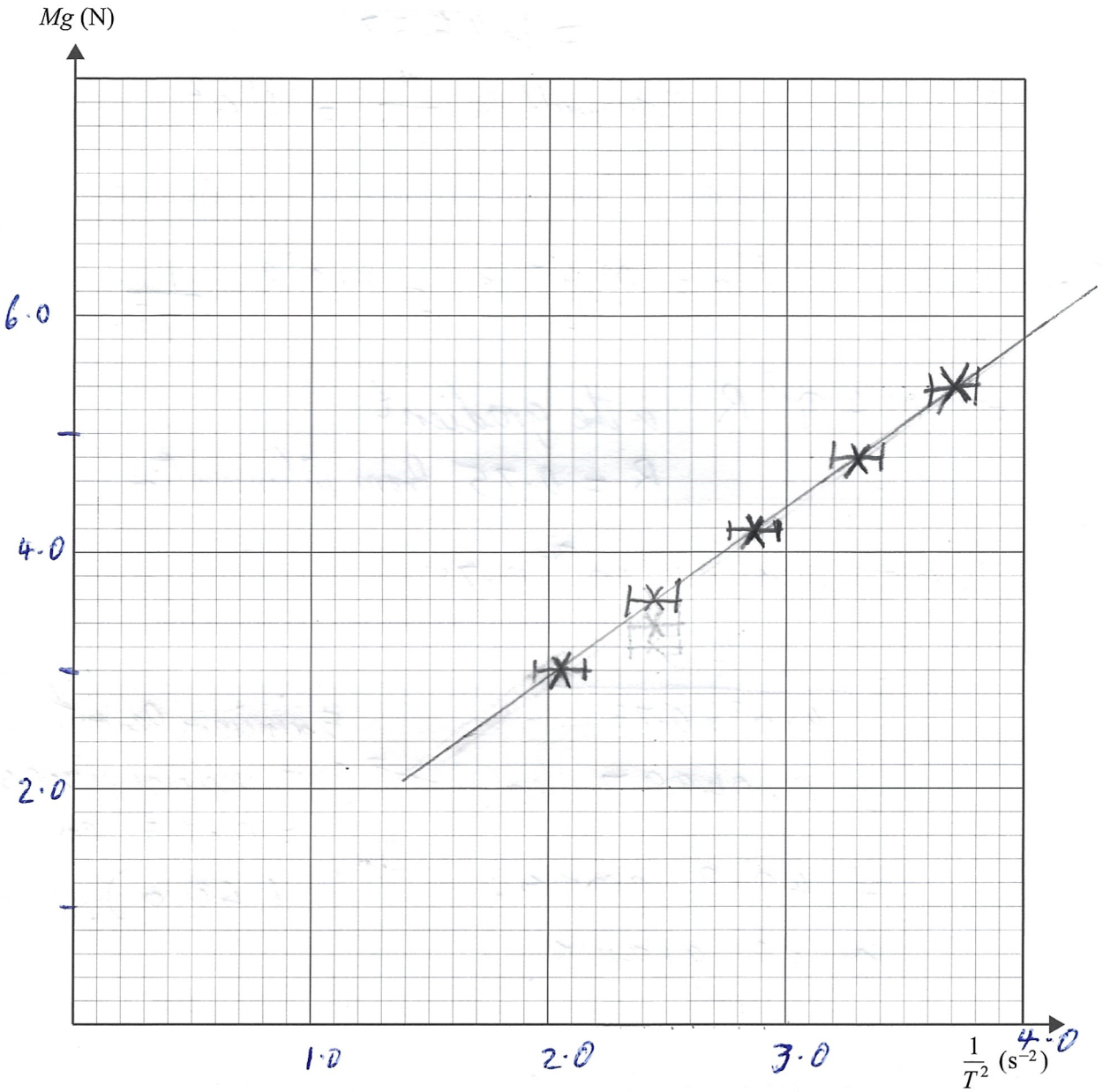
$= 3.31$ correctly Rounded to 2 decimal places

DO NOT WRITE IN THIS AREA

e. Using your values in Table 2, plot a graph of Mg on the y-axis against $\frac{1}{T^2}$ on the x-axis on the grid provided below. On your graph:

- draw a straight line of best fit through the plotted points
- include uncertainty bars ($\pm$ x-direction only) of $\pm$ 0.1 s^{-2}.
  (Uncertainty bars in the y-direction are not required.)

4 marks



Note: The first point is (2.04, 3.0).
The answer in the examiners report has this plotted at (2.0, 3.0). ie Rounded $\frac{1}{T^2}$ to One D.P.
Interesting given the examiners report has $\frac{1}{T^2}$ to Two D.P. in the table

f. Calculate the gradient of the graph plotted in **part e.** 2 marks

Some 'Wiggle Room' → on the line of best fit

Need 2 Points. First and Last look to be on the line of best fit.

$$m = \frac{5.4 - 3.0}{3.70 - 2.04}$$

$$= 1.4457$$

1.4

Units would be $\frac{N}{s^{-2}} = Ns^2$

g. Using the gradient calculated in **part f.**, show that m, the mass of the rubber stopper, is approximately 50 g. 2 marks

From Part C. $Mg = \frac{m 4\pi^2 R}{T^2} = m 4\pi^2 R \times \frac{1}{T^2}$.

$\Rightarrow m 4\pi^2 R$ is the gradient

$R = 0.75$ from information

$$1.45 = m \times 4 \times \pi^2 \times 0.75$$

$$m = \frac{1.45}{4 \times \pi^2 \times 0.75}$$

$= 0.04897$ kg.

$= 48.9$ grams.

≈ 50 grams.

Examiners Report → Two decimal places.

$= 0.05$ kg

(50 g).

Note: Some 'wiggle room' as the answer relies on the one found in part f.

END OF QUESTION AND ANSWER BOOK