29.08.22

ST ANDREW'S
CATHEDRAL
SCHOOL
FOUNDED 1885

Candidate Session Number

21	T	R	L	P	2	P	H	S	L

$\frac{39}{50}$ = 78%

Year 12 IB Physics
Standard Level

Paper 2

2021 Semester 2 Examination
Wednesday 18 August 2021

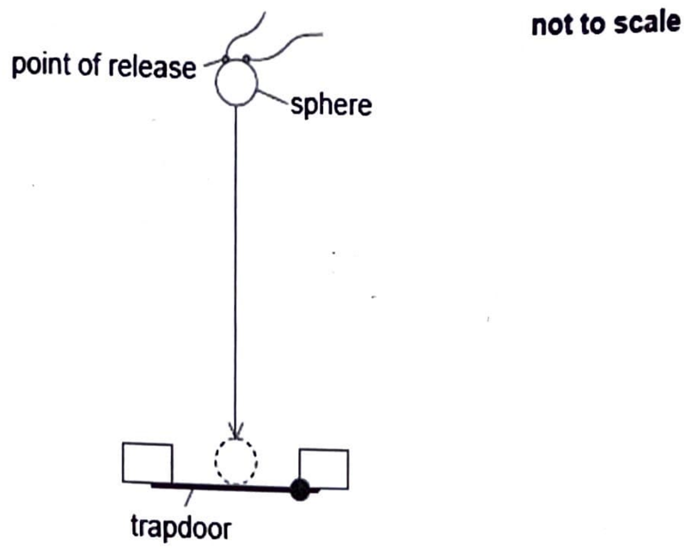
1 hour 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Give any equations used.
- Show ALL working including the substitution of values into equations.
- Answers must be written in the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**

Answer all questions. Answers must be written in the answer boxes provided.

1. To determine the acceleration due to gravity, a small metal sphere is dropped from rest and the time it takes to fall through a known distance and open a trapdoor is measured.



The following data are available.

Diameter of metal sphere = 12.0 ± 0.1 mm
Distance between point of release and trapdoor = 654 ± 2 mm
Measured time for fall = 0.363 ± 0.002 s

(a) Determine the distance fallen by the sphere, in m, including an estimate of the absolute uncertainty in your answer. [1]

~~$u = 0\ ms^{-1}$ $a = -9.81\ ms^{-2}$ $t = 0.363 \pm 0.002$~~ ~~DATA~~

$u = 0\ ms^{-1}$

~~$a = ?$~~

$s = 654 \pm 2$ mm

$S = (654 \pm 2) - (12.0 \pm 0.1)$

$= (642 \pm 2.1)$ mm $= 0.642 \pm 0.002$ m

1

(This question continues on the following page)

1

(Question 1 continued)

(b) Using the following equation [3]

$$\textit{acceleration due to gravity} = \frac{2 \times \textit{distance fallen by sphere}}{(\textit{measured time to fall})^2}$$

calculate the acceleration due to gravity including an estimate of the absolute uncertainty in your answer.

$$a = \frac{2 \times 0.642}{0.363^2}$$

$$= 9.74433 \ ms^{-2}$$

$$\approx 9.744 ms^{-2}$$ ✓

$$\frac{\Delta a}{a} = \frac{\Delta s}{s} + 2 \times \frac{\Delta t}{t}$$

$$= \frac{0.002}{0.642} + 2 \times \frac{0.002}{0.363}$$

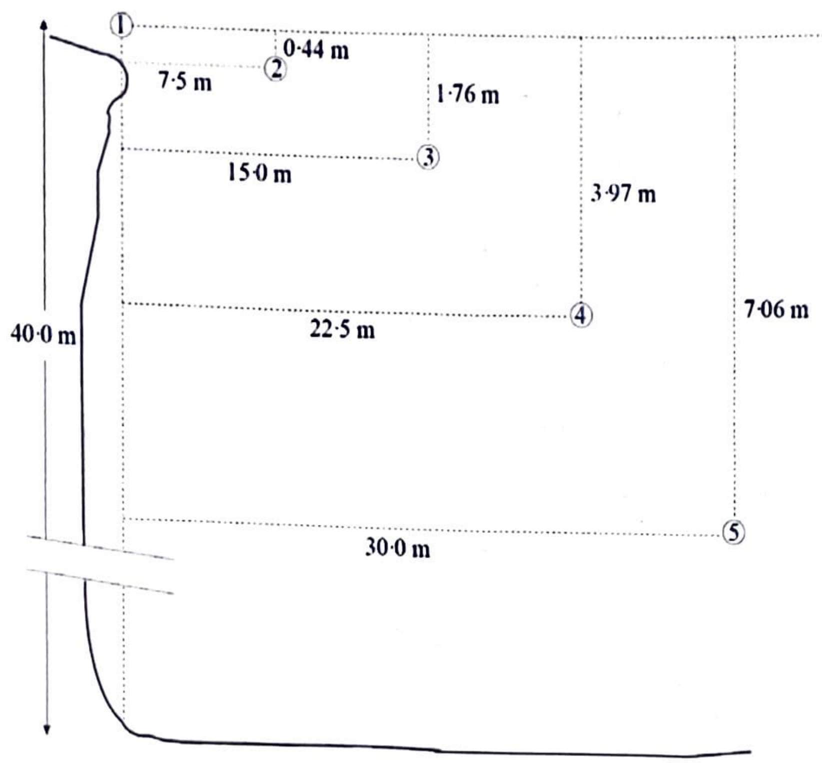
$$= 0.0141$$ ✓

$$\therefore a = 9.7\cancel{4} \pm 0.1 \ ms^{-2}$$ ✓

3

3/

2. A ball is thrown horizontally from the top of a cliff 40·0 m high. The position of the ball is shown at five points on its path. Position 1 is the point where it leaves the thrower's hand. The time interval in moving from any position to the next is 0·3 s. The diagram is not to scale. Air resistance is negligible.



(a) How far from the bottom of the cliff does the ball land? [2]

$S_v = -40.0$ m
$a_v = -9.81$ ms^{-1}
$u_v = 0$ ms^{-1}
$t = ?$

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

$\therefore \frac{1}{2}(-9.81)t^2 = (-40)$

$\therefore t \approx 2.86$ s

$\therefore$ If $S_H = 7.5$ m in 0.3 s, $(S_H)_T = \frac{2.86}{0.3} \times 7.5 = 71.5$ m

②

(b) At what speed does the ball hit the ground? [2]

$V_H = 7.5/0.3 = 25$ ms^{-1}

$V_v = (-9.81)(2.86)$

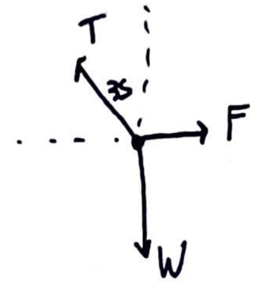
$= -28.0566$ ms^{-1}

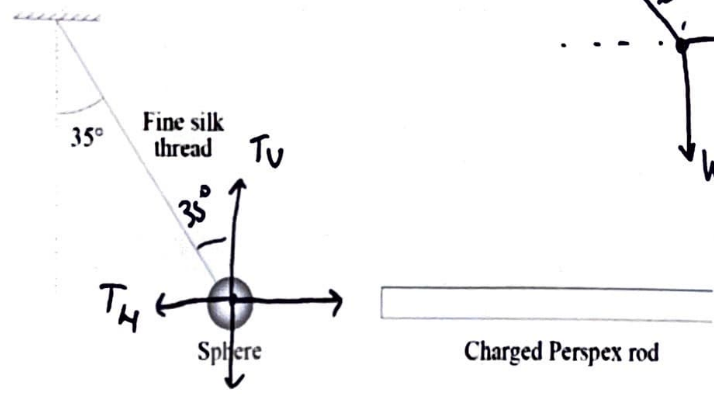
$\therefore V = \sqrt{25^2 + (-28.0566)^2} = 37.6$ ms^{-1}

②

4/

3. A small sphere of mass 2·00 x 10^{-3} kg is held in a fixed position by a fine silk thread and the force F due to a charged perspex rod, as shown in the diagram.





(a) Calculate the tension in the thread. [2]

$T_v = -W = -(2.00\times10^{-3})\times(-9.81) = 0.01962$ N ✓

~~FH~~ $= \cos 35°\ T$

$\therefore T = \frac{0.01962}{\cos 35°} = 2.4\times10^{-2}$ N

①

(b) Calculate the magnitude of the electrostatic force F. [1]

$F = T \sin 35 = 0.01962 \sin 35$

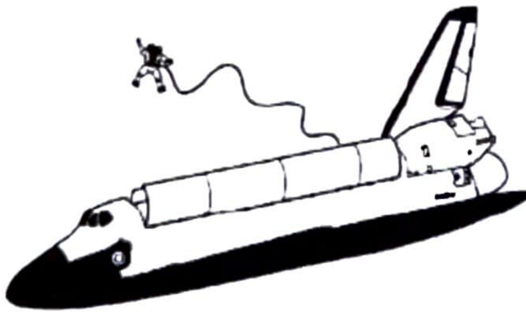
$= 0.011$ N ✗

$F = T\sin 35 = 2.4\times10^{-2}\times\sin 35$

$= 1.4\times10^{-2}$ N

1/

4. The diagram below shows an astronaut undertaking a spacewalk. The astronaut is tethered by a rope to a spacecraft of mass 4.0×10^4 kg. The spacecraft is moving at constant velocity before the astronaut pushes away from it.



The astronaut and spacesuit have a total mass of 130 kg. The change in velocity of the astronaut after pushing off is 1.80 m s^{-1}.

(a) Determine the change in velocity of the spacecraft. [2]

~~$(uM)_A + (uM)_S = (UM)_A + (Um)_S$~~

~~$\therefore u(4\times10^4 + 130) = 130(1.80) + v(4\times10^4)$~~

$p_i = (4\times10^4 + 130)(u) = 40130u$

$p_f = 130(u+1.8)$

×

(b) The astronaut pushes on the side of the spacecraft for 0.60 s. Calculate the average power developed by the astronaut. [2]

$P = \frac{\Delta E_k}{t} = \frac{\frac{1}{2} m \Delta v^2}{t}$

$= \frac{\frac{1}{2}(130)(1.80)^2}{0.60} + \frac{\frac{1}{2}(4\times10^4)(-5.85\times10^{-3})^2}{0.60}$

$= 351\,W + 1\,W = 352\,W$

✓

a) $\Delta P_{AST} = m\Delta v = 130 \times 1.80 = 234$

$\therefore 234 = -\Delta P_{spc} = m\Delta v = -234$

$\therefore \Delta v = -234 / 4\times10^4$

$= -5.85\times10^{-3}$ ms^{-1}

0/

5. In an experiment to determine the efficiency of a 240 V, 2000 W electric kettle, a student boiled water and recorded the following results.

Mass of water	1.2 kg
Initial temperature of water	25 °C
Time taken to reach 100 °C	3 minutes 30 seconds

The following data are available.

Specific heat capacity of water = 4.186 kJ kg^{-1} K^{-1}
Specific latent heat of vaporisation of water = 2.257 MJ kg^{-1}

(a) Determine the amount of energy absorbed by the water. [1]

$Q = mc\Delta T = 1.2 \times 4186 \times 75$
$= 376740$ J
$\approx$ ~~377~~ ~~377 kJ~~ 377 kJ ✓ 1

(b) Determine the amount of electrical energy supplied to the kettle. [1]

3 min 30 s = 210 s
2000 W × 210 s = 420000 J
= 420 kJ ✓ 1

(c) Calculate the efficiency of the kettle. [1]

$e = 377/420$
$= 0.8976$
$\approx 89.8\%$ ✓ 1

(This question continues on the following page)

3/

(Question 1 continued)

(d) Determine the time required for the kettle to boil dry *after it is switched on* if it operates at the efficiency calculated in (c).

[3]

latent energy required = $mL = 1.2 \times 2.257 \times 10^6$

$= 2.708 \times 10^6$ J

$\therefore \frac{Q}{t} = 2000 \times 89.8\%$

$\therefore t = \frac{2.708 \times 10^6 + 377 \times 10^3}{2000 \times 89.8\%}$

$= \cancel{1508}$ s 1718 s

3

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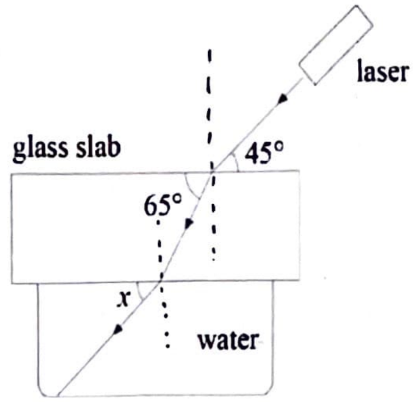
7. A student passed a beam of laser light of wavelength 633 nm through a glass slab into some water. She recorded the information shown in the diagram below.



$\lambda = 633 \times 10^{9}$ m

(a) Show that the refractive index of glass for the laser light is 1.67. [2]

$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} \rightarrow \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$

DATA
$n_1 = 1 ; n_2 = ?$
$\theta_1 = 45° ; \theta_2 = 25°$

$\therefore n_2 = \frac{\sin 45}{\sin 25}$
$= 1.67$

2

(b) Determine the wavelength of the laser light in the glass slab. [1]

$\frac{\lambda_2}{\lambda_1} = \frac{n_1}{n_2} \rightarrow \lambda_2 = 633 \times 10^{9} \times \frac{1}{1.67}$
$= 379$ nm

1

(c) The water has a refractive index of 1·33. Calculate the angle *x*. [2]

$\theta_1 = 25°$ $\theta_2 = 90 - x = ?$
$n_1 = 1.67$ $n_2 = 1.33$.
$\sin\theta_2 = \sin\theta_1 \times {}^{1.67}/_{1.33} = \sin 25 \times {}^{1.67}/_{1.33}$
$= 0.530656$
$\therefore \theta_2 = 32.0498° \rightarrow x = 90 - 32.0498 = 57.95°$

2

5/

8. Light, with intensity I_0, passes through a sheet of Polaroid material that reduces the light intensity to $0{\cdot}5\ I_0$. The optical axis of the Polaroid material is vertical. The light then passes through a second sheet of Polaroid material with its face parallel to that of the first.

(a) At what angle should the optical axis of the second sheet (relative to the optical axis of the first sheet) be placed to reduce the intensity of the light to 30% of I_0? [2]

$I_1 = I_0 \times 1/2$

$I_2 = \left(\frac{1}{2} I_0\right) \cos^2\theta = \frac{3}{10} I_0$

$\therefore \cos^2\theta = \frac{6}{10}$

$\therefore \theta = \cancel{\cos}\ \arccos\left(\sqrt{6/10}\right)$

$\therefore \theta = 39.2°$

2

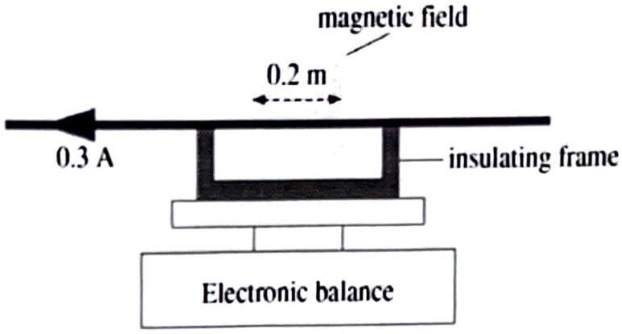
(b) People who go fishing prefer to wear polarising sunglasses because they say it helps them to see the fish below the surface of the water more clearly. Outline the physical principle that could be used to support this belief. [1]

Reflection: they will only see light that has come back out of the water as the reflected light (which is horizontally polarised), is removed by the glasses

1

3/

9. A copper rod is placed on a wooden frame, which is placed on an electronic balance. A length of 0.2 m of the rod passes at right angles to a horizontal magnetic field.



When a current of 0.3 A is passed through the rod the reading on the balance increases by 7.5×10^{-4} kg. What is the strength and direction of the magnetic field? [3]

- DIRECTION : OUT OF THE PAGE ✓
- $F = BIL$ $\{F = ma = 7.5 \times 10^{-4} \times 9.81 = 7.3575 \times 10^{-3}\}$

$\therefore 7.3575 \times 10^{-3} = B \cdot 0.3 \cdot 0.2$ ✓

$\therefore B = 0.122625\ T$

$\therefore B \approx 0.123\ T$ ✓

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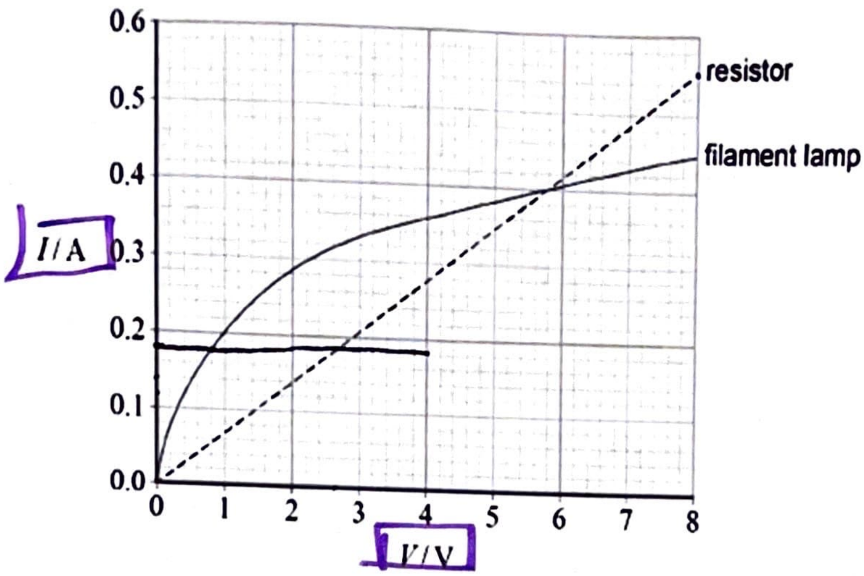
10. The graph below shows the current–potential difference (I–V) characteristics for a resistor and a filament lamp.



(a) Determine the resistance of the resistor. [1]

$V = IR \rightarrow R = V/I = 8/0.55$

$= 14.5\ \Omega$

(1)

(b) The resistor and the filament lamp are connected in series with a supply of variable emf and negligible internal resistance. Determine the emf that produces a current of 0.18 A in the circuit. [2]

At 0.18A, $V = 0.8 + 2.6$

$= 3.4V$

$= \mathcal{E}$

(2)

3

11. Data related to the Earth and its orbital motion around the Sun are given below.

Mean orbital radius = 1.5×10^{11} m
Orbital period = 365.24 days
Mass of the Earth = 5.97×10^{24} kg

(a) Determine the net force acting on the Earth. [2]

$$g = \frac{F}{M} = \frac{4\pi^2 r}{T}$$ ✓

$$\therefore F = (5.97\times10^{24})\left(\frac{4\pi^2(1.5\times10^{11})}{(365.24\times24\times60\times60)^2}\right)$$

$$= 1.12 \times 10^{30} \text{ N}$$ ✗

DATA
$r = 1.5\times10^{11}$ m
$T = 365.24$ days
$M = 5.97\times10^{24}$ kg

1

(b) Estimate the mass of the Sun. [1]

$$F = G\frac{Mm}{r^2} \rightarrow M = \frac{Fr^2}{GM_o}$$ ECF

$$= \frac{1.12\times10^{30}(1.5\times10^{11})^2}{6.67\times10^{-11}\times5.97\times10^{24}}$$

$$= 6.33\times10^{37} \text{ kg}$$ ✓

1

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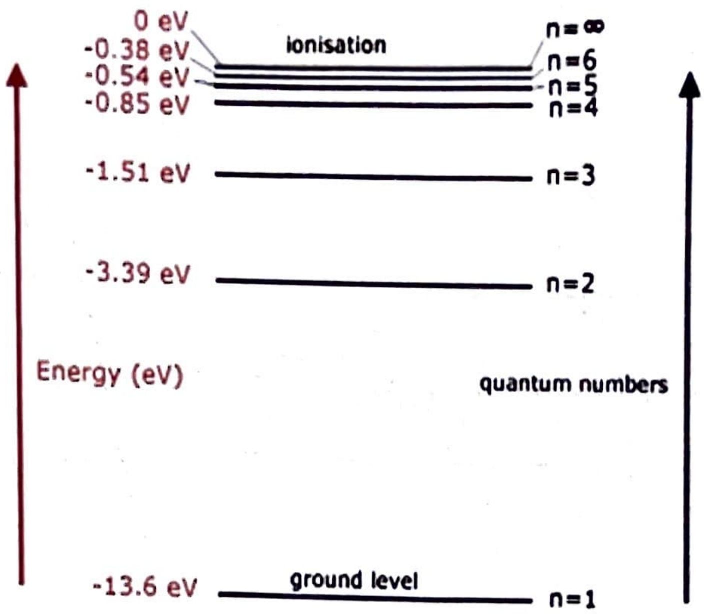
12. An energy level diagram for the hydrogen atom is shown below.



A photon of wavelength 489 nm is emitted from an excited hydrogen atom. The emerging photon is caused by a transition between two energy states. Determine the initial and final energy states n_i and n_f of this transition. [3]

$E = hf = \cancel{hc/\lambda} = hc/\lambda$

$= 6.63\times10^{-34} \times \frac{3\times10^{8}}{489\times10^{-9}}$

$= 4.0675\times10^{-19}$ J

$\therefore E = \frac{4.0675\times10^{-19}}{1.60\times10^{-19}} = 2.5422$ eV

$\therefore n_i = -0.85$ eV $\quad n_f = -3.39$ eV

$n = 4 \quad n = 2$

3

3/

13. The table below may be useful in answering the questions which follow.

particle	baryon number	lepton number	strangeness
π^-	0	0	0
p	1	0	0
$\bar{p}$	−1	0	0
e^-	0	1	0
e^+	0	−1	0
$\bar{\nu}_e$	0	−1	0

A particle X, which is a strange particle, decays in the following way:

$$X \rightarrow \pi^- + p$$

(a) Explain whether X is a meson, a baryon or a lepton. [1]

~~BARYON~~

~~S = Strange particle = quark~~

Baryon number : $p = 1$, $\pi^- = 0$ $\rightarrow$ $X = 1$ ✓

①

(b) State with justification the kind of interaction involved in this decay. [2]

- Weak interaction
- strangeness is not conserved

②

(c) State the approximate time interval for the decay of particle X to occur. [1]

weak $\Rightarrow$ long lifetime $\approx 10^{-10}$ s

⓪

3/

14. The fusion of two nuclei of deuterium ${}^2_1H$ to give one nucleus of helium ${}^3_2He$ may one day be used in nuclear power generation. The equation for this reaction is

$$ {}^2_1H + {}^2_1H \rightarrow {}^3_2He + {}^1_0n $$

The following data are available.

Mass of deuterium nucleus = 2·01355 u
Mass of helium nucleus = 3·01492 u
Mass of neutron = 1·00867 u

(a) Determine the energy (J) released in each fusion reaction. [2]

LHS = 2·01355 × 2 = 4.0271 u
RHS = 3.01492 + 1.00867 = 4.02359 ✓
∴ ΔM = RHS - LHS = 3.51×10^{-3} u
∴ ~~E = $3.51 \times 10^{-3} \times 1.661 \times 10^{-27}$ = 5.83×10^{-30} J~~
= 5.83×10^{-30} kg → $E = 5.83 \times 10^{-30} (3 \times 10^8)^2 = 1.749 \times 10^{-24}$ J ✗

1

(b) Assume that this fusion reaction could be used in a nuclear power station producing 1 GW of electrical power with an overall efficiency of 40%. Determine the mass of deuterium used per year. [3]

1 GW = 1×10^9 W
∴ Qyear = $1 \times 10^9 \times 60 \times 60 \times 24 \times 365$
= 3.1536×10^{16} J

40% efficiency ✗

∴ Mdeterium = $\frac{3.1536 \times 10^{16}}{1.749 \times 10^{-24}}$ ✓
= 1.80×10^{40} kg

ECF

1

2/