30.08.22

Candidate Session Number

20	T	R	L	P	2	P	M	S	L

ST ANDREW'S CATHEDRAL SCHOOL
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$\frac{41}{50} = 82\%$

Year 12 IB Physics
Standard Level

Paper 2

2020 Semester 2 Examination
Wednesday 26 August 2020

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. A pyramid has a square base of side x and height h. The volume V of a square pyramid is given by the expression:

$$V = \frac{x^2 h}{3}$$

(a) h is measured with an uncertainty of 2% and x is measured to 4%. What is the percentage uncertainty in V? [2]

$\Delta V/V = 2 \times \Delta x/x + \Delta h/h$ ✓

$= 2 \times 4\% + 2\%$

$= 10\%$ ✓

(2)

(b) The volume of a square pyramid was calculated from measurements of x and h to be 8.275 m^3. Give the value of V including an uncertainty estimate. [1]

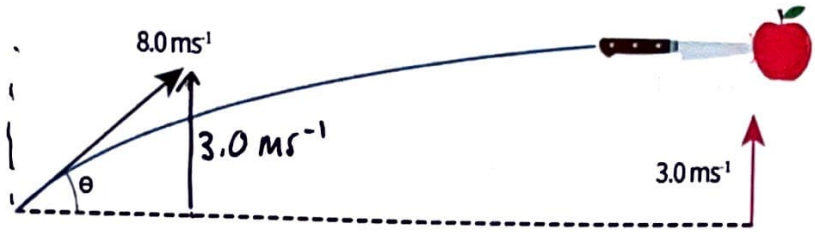
$V = \frac{x^2 h}{3} = 8.275\ m^3 \rightarrow \Delta V = V \times 10\% = 0.8275$

$\therefore V = 8.275 \pm 0.8275\ m^3 = 8.3 \pm 0.8\ m^3$ ✓

(1)

3/

2. In a circus trick, a knife-thrower throws a knife to hit an apple in mid-air.



The thrower releases the knife at the same time that the apple is thrown, and at the same height above the ground.

The apple is thrown vertically at 3.0 m s^{-1}. The knife is thrown at 8.0 m s^{-1}.

When the knife and apple collide, they are both at the highest points of their trajectories.

(a) How long after being thrown did the knife collide with the apple? [2]

DATA {apple}	$v = u + at$
$u = 3.0\ ms^{-1}$	$\therefore t = -u/a$
$v = 0\ ms^{-1}$	$= -3.0/-9.81$ ✓
$a = -9.81\ ms^{-1}$	$= 0.30581\ s$
$t = ?$	$\therefore t = 0.31\ s$ ✓

(2)

(b) At what angle from the horizontal, θ, was the knife thrown? [2]

DATA {knife}	eq 1: $u_V = 8.0 \sin\theta \rightarrow \theta = \sin^{-1}(u_V/8)$
$u = 8.0\ ms^{-1}$	eq 2: $u_V = V_0 - at = 0 - (-9.81)(0.30581)$
$V_V = 0\ ms^{-1}$	$= 3.0\ ms^{-1}$
$a_V = -9.81\ ms^{-1}$	$\therefore$ using (1): $\theta = \arcsin(3.0/8.0)$ ✓
$t = 0.30581\ s$	$\therefore \theta = 22°$ ✓

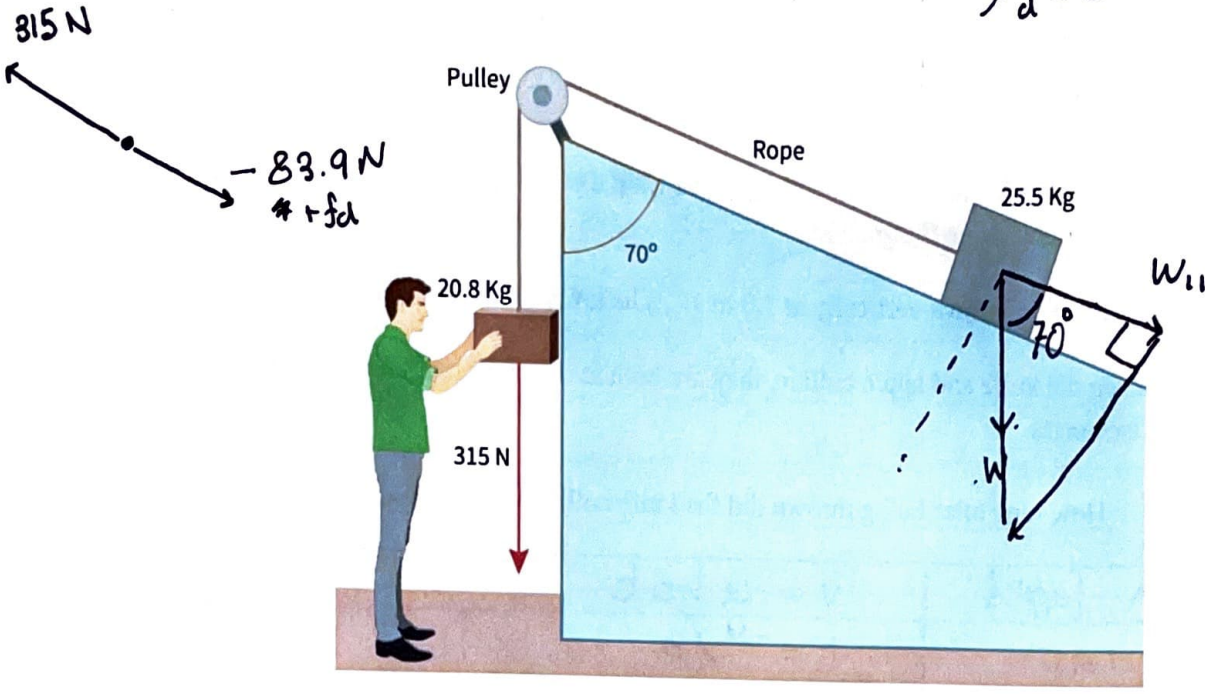
(2)

4/

3. A smooth pulley is used to drag a 25.5 kg mass up a ramp as shown in the diagram below. The coefficient of dynamic friction between the mass and the ramp is 0.410.

A second mass of 20.8 kg is attached to the end of the rope. A person pulls downwards with a force 315 N on the mass as shown in the diagram.

$\mu_d = 0.410$



(a) Calculate the component of the weight force of the 25.5 kg mass acting down the ramp. [1]

$W = 25.5 \times (-9.81) = -245.25\ N$ ×

$\therefore W_{11} = -245.25 \sin 30° = -83.9\ N$ $-212.40\ N$

$\sin 20$ $= -212\ N$ $85.6\ N$ (0)

(b) Determine the friction force acting on the 25.5 kg mass as it slides up the ramp. [2]

$315 = -(-83.9 + f_d) = 83.9 - f_d$

$\therefore f_d = 231.1\ N$ $255.9 \cdot 21 \cos 20$ ECF

$F_d = \mu_D R$ ✓ $= 0.410 \times -212\ N$

$= -87.1\ N$ ×

$96.4\ N$ (1)

(This question continues on the following page)

1/

(Question 3 continued)

(c) Determine the acceleration of the masses. [2]

DATA	ECF from a and b
$F_A = 315$ N	~~$F_{net} = 315$~~ $F_{net} = 315 + 20.8 \times 9.81 + (-87.1) + (-245.2\cos 70)$
$F_D = -87.1$ N	$= 348.068$ N
$m_1 = 20.8$ kg	$a = F_{net}/m_1 + m_2 = 348.068/20.8 + 25.5$
$m_2 = 25.5$ kg	$= 7.52$ m s^{-2}

①

④ A space probe of mass 1312 kg far from the Earth is travelling at 14.8 km s^{-1}. The probe fires its rockets to give a constant force of 156 kN for 220 seconds. During this time it burns 150 kg of fuel and accelerates in the same direction as its initial velocity.

Calculate final speed of the space probe. [2]

DATA	
$m = 1312$ kg	1) $a = F_{net}/m$ ~~$= 156/1312$~~ $= 0.1189$ km s^{-2}
$u = 14.8$ km s^{-1}	2) $v = u + at = 14.8 + 0.1189 \times 220$
$F_{net} = 156$ kN	$= 40.958$ km s^{-1}
~~$t = 220$ s~~	$= 41$ km s^{-1}
	CONTINUED IN ANSWER BOOKLET

①

5. A bicycle tyre of volume 3.1×10^{-3} m^3 contains air at a temperature of 18 °C.

A bicycle pump is used to put air into the tyre. The temperature of the air in the tyre increases to 26 °C and the pressure in the tyre increases to 360 kPa. The volume of the tyre does not change.

Assume that air behaves as an ideal gas.

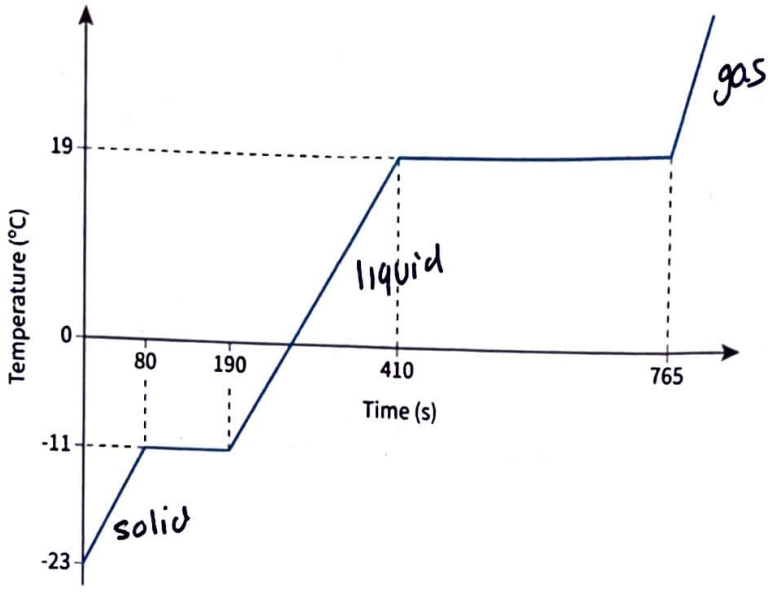
Determine the number of moles of air in the tyre after it has been inflated with the pump. [2]

DATA	
$V = 3.1 \times 10^{-3}$ m^3	$pV = nRT \rightarrow n = pV/RT$
$T_f = 26 + 273 = 299$ K	$n = (360 \times 10^3 \times 3.1 \times 10^{-3})/(8.31 \times 299)$
$P = 360 \times 10^3$ Pa	$= 0.449$ mol
$n = ?$	$= 0.45$ mol

②

4/

6. Heat energy is added to a substance of mass 0.24 kg at a rate of 0.82 kW. The following graph shows how the temperature of the substance changes.



(a) Determine the increase in internal energy of the substance while it is purely in the liquid phase. [2]

DATA

$t = 410 - 190$ s

$P = 0.82 \times 10^3$ W

$\Delta Q_{liquid} = \Delta t \times P$

$\Delta Q_{liquid} = (410-190) \times (0.82 \times 10^3)$

$= 1.8 \times 10^5$ J

(2)

(b) Determine the specific heat capacity of the liquid phase of this substance. [2]

$Q = mc\Delta T \rightarrow c = Q/m\Delta T$

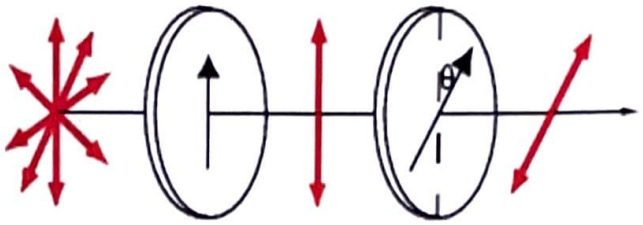
$= (1.8 \times 10^5)/(0.24)(19+11)$

$= 25000$ J kg^{-1} K^{-1}

(2)

4/

7. A narrow beam of unpolarised light of intensity 300 W m^{-2} is incident upon two polarisers which have an angle of θ between their planes (axes) of polarisation.



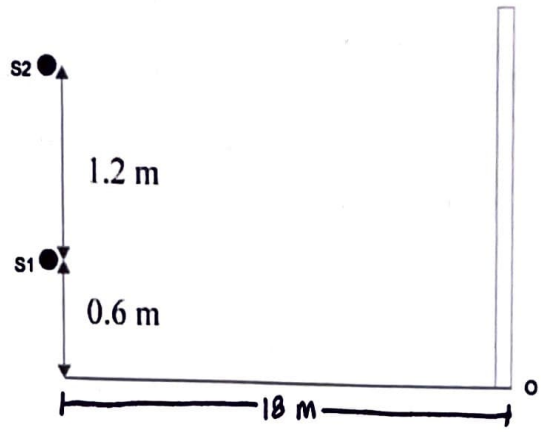
If the intensity of light emerging from the second polariser is 62 W m^{-2}, what is the value of θ, to the nearest degree? [2]

DATA	$I = I_0/2 \times \cos^2\theta$
$I_0 = 300\ W\,m^{-2}$	$\therefore \cos^2\theta = 2I/I_0$
$I = 62\ W\,m^{-2}$	$\therefore \theta = \arccos\left(\sqrt{2I/I_0}\right)$
$\theta = ?$	$= \arccos\left(\sqrt{2\times62/300}\right)$
	$= 49.99°$
	$= 50°$ (2 s.f)

(2)

2/

8. Below are two identical sources of sound of wavelength 0.108 m, placed a horizontal distance of 18 m from a wall. Source S1 is 0.6 m above the floor and source S2 is at a height of 1.2 m vertically above S1. (The diagram is not drawn to scale.)



(a) A microphone is moved up the wall starting from the floor. At what height will the volume of the sound be a maximum? Give a reason for your answer. [1]

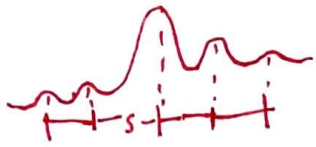
→ Max = ~~0.6~~ 0.6 + (1.2/2) = 1.2 m
→ This is because the peak constructive ~~interference~~ occurs in the centre of both slits (1)

(b) At what height will the volume of the sound be a minimum? [2]

$S = \lambda D/d = (0.108 \times 18)/1.2$
$= 1.62$ m
∴ minimum = $1.2 + 1.62$ (1)
$= 2.82$ m ×

$1.2 - \frac{1.62}{2} = 0.39$ m

"S" is the 'fringe spacing'



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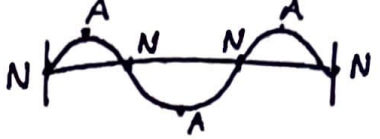


9. A standing wave of frequency 120 Hz is set up on a string of length 1.5 m fixed at both ends. It vibrates with 3 antinodes.

(a) What is the speed of waves travelling along the string? [2]

3 anti-nodes = 3rd harmonic → $\lambda = \frac{2}{2}L = 1\ m$ ✓

$\therefore V = f\lambda = 120 \times 1$ ✓

$= 120\ ms^{-1}$ (2)

(b) What is the lowest frequency at which a standing wave can be formed on the string? [1]

$f_1 = V/\lambda = V/2L = 120/2 \times 1.5$ (1)

$= 50\ Hz$ ~~Hz~~ (0)

$40\ Hz$ ✓

10. An electron orbits a proton at a distance of 10^{-15} m.

(a) What is the magnitude of the force between the proton and the electron? [2]

DATA

$r = 10^{-15}\ m$

$q_1 = 1.6 \times 10^{-19}\ C$

$q_2 = 1.6 \times 10^{-19}\ C$

$F = k\frac{q_1 q_2}{r^2} = (8.99 \times 10^9) \times \frac{(1.6 \times 10^{-19})^2}{(10^{-15})^2}$ ✓

$= 230\ N$ ✓ (2)

(b) Estimate the orbital speed of the electron. [2]

DATA

$F = 230\ N$

$m_e = 9.110 \times 10^{-31}\ kg$

$r = 10^{-15}\ m$

$v = ?$

$v^2 = Fr/m_e \rightarrow v = \sqrt{Fr/m_e}$

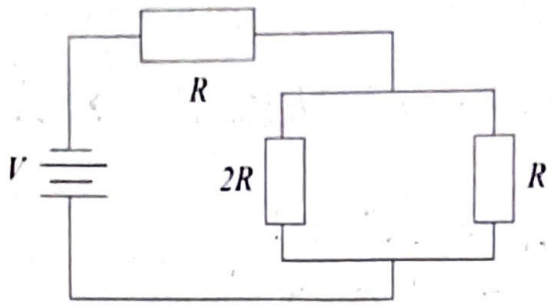
$v = \sqrt{\frac{230 \times 10^{-15}}{9.110 \times 10^{-31}}}$ ✓

$= 5.0246 \times 10^8\ ms^{-1}$ ✓

$= 5.02 \times 10^8\ ms^{-1}$ (2)

7/

11. The circuit below has $V = 100$ V and $R = 100\ \Omega$ and the battery has negligible internal resistance.



(a) Determine the total resistance of the circuit. [2]

$R_T = R + \frac{1}{(1/2R + 1/R)}$

$= 100 + \frac{1}{(1/200 + 1/100)}$

$= 167\ \Omega$

(2)

(b) What is the power output in the circuit? [2]

DATA

V = 100 V

R = 167 Ω

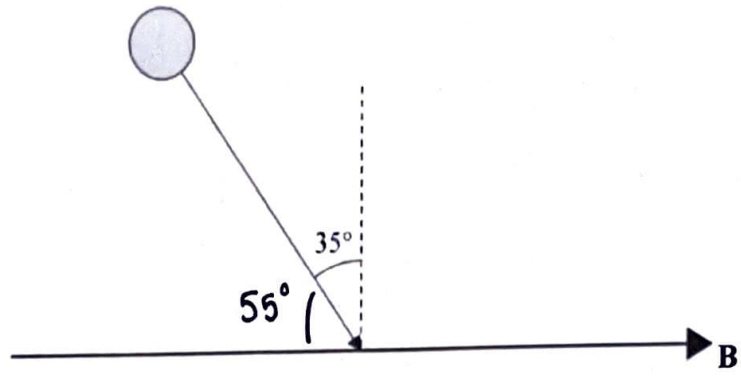
$P = V^2/R = 100^2/167$

$= 59.9$ W

(2)

4/

12. A helium nucleus $^{4}_{2}He^{2+}$ of mass 6.696×10^{-27} kg enters a uniform magnetic field B at an angle of 35° as shown below.



If the magnetic field strength is 0.36 nT and the nucleus is moving at 2350 m s^{-1}, what is its acceleration? [2]

DATA $q = 2\times1.6\times10^{-19}$

$B = 0.36\times10^{-9}$ T

$v = 2350\ ms^{-1}$

$m = 6.696\times10^{-27}$ kg

$\theta = 55°$

$F = ma = qvB\sin\theta$

$\therefore a = \dfrac{2\times1.6\times10^{-19}\times2350\times0.36\times10^{-9}\sin55°}{6.696\times10^{-27}}$

$= 33.1\ ms^{-2}$

2

2/

13. In a nuclear fusion reaction, a nucleus of deuterium (hydrogen-2) fuses with a nucleus of helium-3 to produce helium-4 and a proton.

$$^{2}_{1}H + ^{3}_{2}He \rightarrow ^{4}_{2}He + ^{1}_{1}H$$

watch out for binding energy

The following are the binding energies per nucleon of the nuclei involved:

Binding energy per nucleon $^{2}_{1}H$ = 1.112287 MeV
Binding energy per nucleon $^{3}_{2}He$ = 2.572681 MeV
Binding energy per nucleon $^{4}_{2}He$ = 7.073915 MeV

(a) How much energy is released per fusion by this reaction? [2]

$m_i = 1.112287 + 2.572681 = 3.684968$ MeV
$m_f = 7.073915 + 1.007276 = 8.081191$ MeV
$\therefore \Delta m = 4.396223 \times 10^{6}$ eV
$\therefore E = 4.396223 \times 10^{6} \times 1.6 \times 10^{-19}$ ✗ ⓪
$= 1.32 \times 10^{9}$ J $= 7.03 \times 10^{-13}$ J

(b) What is the total mass difference between the nuclei before and after the reaction? [2]

$\Delta m = 4.396223 \times 1.661 \times 10^{-27} \times 10^{6}$
$= 7.30 \times 10^{-21}$ kg ✗ ⓪

a) $E_i = 2 \times 1.112287 + 3 \times 2.572681 = 9.942617$ MeV
$E_f = 4 \times 7.073915 = 28.29566$ MeV
$\therefore \Delta E = 18.353043$ MeV

b) $\Delta E = 18.353043 \times 10^{6} \times 1.6 \times 10^{-19} = 2.93649 \times 10^{-12}$ J
$\therefore m = E/c^2 = (2.93649 \times 10^{-12}) / (3 \times 10^{8})^2$
$= 3.26 \times 10^{-29}$ kg ✓

14. A possible nuclear reaction involving pions is shown below.

$$\pi^+ \rightarrow \pi^0 + \pi^- + 2\pi^+$$

Pions are mesons consisting of two quark flavours, up and down.

(a) What is the quark composition of a π^- pion? [2]

$\pi^- = \bar{u}d$

{charge $= -\frac{2}{3}e - \frac{1}{3}e = -1$} (2)

(b) Show, by referring to three conservation laws, that this reaction is theoretically possible. [2]

Charge : $+1 \rightarrow 0 - 1 + 2\times 1$ ✓

Baryon : $0 \rightarrow 0 + 0 + 0$ ✓

Strangeness : $0 \rightarrow 0 + 0 + 0$ ✓ (2)

4/

15. The Sun's surface temperature is approximately 5780 K.

(a) Which wavelength is emitted with the highest intensity? [2]

DATA

$T = 5780\,K$

$\lambda_{MAX} = ?$

$\lambda_{MAX} = \dfrac{2.90 \times 10^{-3}}{5780}$

$= 5.02 \times 10^{-7}\ m$ ✓

(2)

(b) The Sun's power output is 3.9×10^{26} W. What is the intensity of the Sun's radiation at the position of Earth's orbit, a distance of 1.5×10^{11} m from the Sun? [2]

$A_{sphere} = 4\pi r^2$

$\therefore P_E = (3.9 \times 10^{26}) / 4\pi (1.5 \times 10^{11})^2$ ← $I = P/A$

$= 1379\ W\,m^{-2}$

$\approx 1400\ W\,m^{-2}$ ✓

(2)

4/

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Candidate name: / Nom du candidat: / Nombre del alumno:

Please write question numbers in the following format: / Veuillez numéroter les questions en utilisant la présentation suivante: / Sírvase escribir los números de las preguntas en el siguiente formato:

1 2 3 4 5 6 7 8 9 10

8 8

DATA	$\Delta p = F\Delta t$ (1)
$m = 1312\ kg$	
$u = 14.8\ kms^{-1}$	$\Delta p = -mu + [(m-\Delta m)v]$
$F_{net} = 156\ kN$	$= -mu + (m-\Delta m)v$
$t = 220\ s$	$= -1312 \times 14.8 \times 10^3 + (1312-150)v$
$\Delta m = 150 kg$	$= -19417.6 \times 10^3 + 1162v$ (2)

8 8

(2) → (1) ×

$10^3 x - 19417.6 + 1162v = 156 \times 220$

$\therefore v = 12.8\ ms^{-1}$

$\therefore v_f = 27.624\ kms^{-1}$

$\Delta p = F\Delta t = (m-\Delta m)v - mu$

$\therefore 156 \times 10^3 \times 220 = (1312-150)v - 1312 \times 14.8 \times 10^3$

$\therefore v = 46245\ ms^{-1}$

$= 46.2\ kms^{-1}$

8 8