2022 Mock Exams

Candidate Session Number

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JAMES SULLIVAN

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ST ANDREW'S CATHEDRAL SCHOOL

FOUNDED 1885

Year 12 IB Physics
Standard Level

Paper 2

2022 Semester 2 Examination
Wednesday 31 August 2022

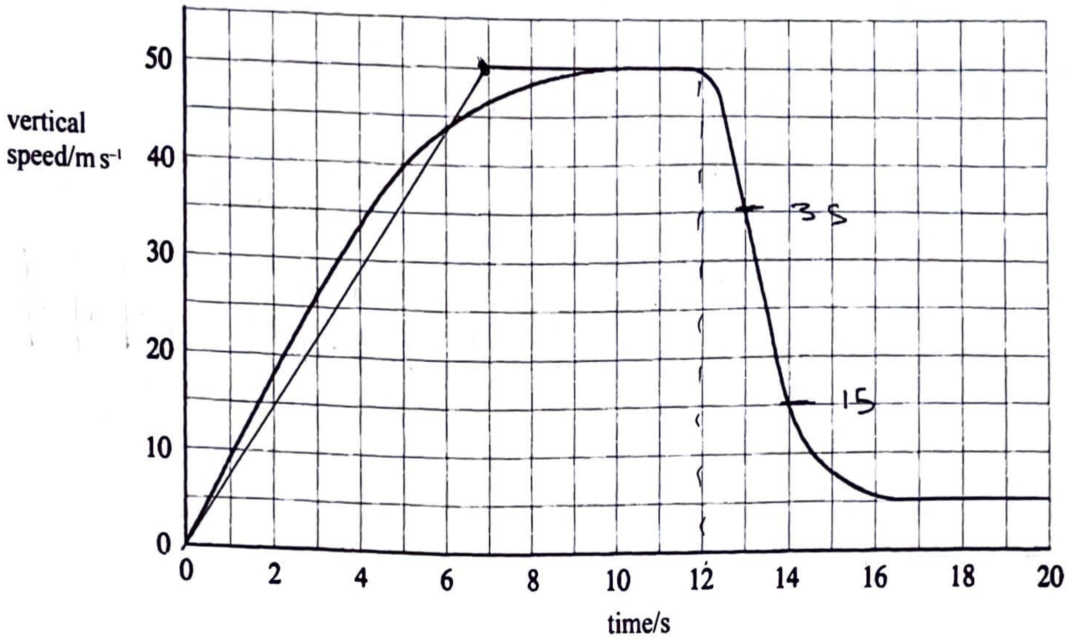
1 hour 15 minutes

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. The graph shows how the vertical speed of a parachutist changes during the first 20 s of her jump. To avoid air turbulence caused by the aircraft, she waits a short time after jumping before pulling the cord to release her parachute.



(a) Calculate the maximum acceleration experience by the parachutist. [2]

→ during parachute release ✓

→ $a = \Delta v / \Delta t = -20/1$

$= -20\ ms^{-2}$ ✓

2

(This question continues on the following page)

2

(b) Use the graph to estimate the vertical distance fallen by the parachutist before opening her parachute. Show your method and working clearly. [2]

$s = vt$ (area) = Triangle (7sec) + Box (7-12sec)

$\approx \frac{1}{2} \times 7 \times 50 + 5 \times 50$

≈ 425 m

NOTE: SEE MARKERS ON DIAGRAM

2

(c) At what speed must the parachutist fall so that the force acting on her due to air resistance is the same as the force provided by the parachute? Explain briefly. [1]

5 ms^{-1} $\therefore$ this is where she reaches terminal velocity

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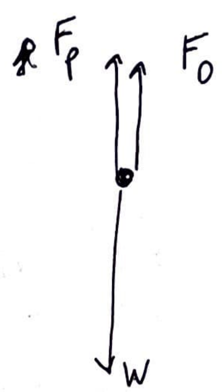

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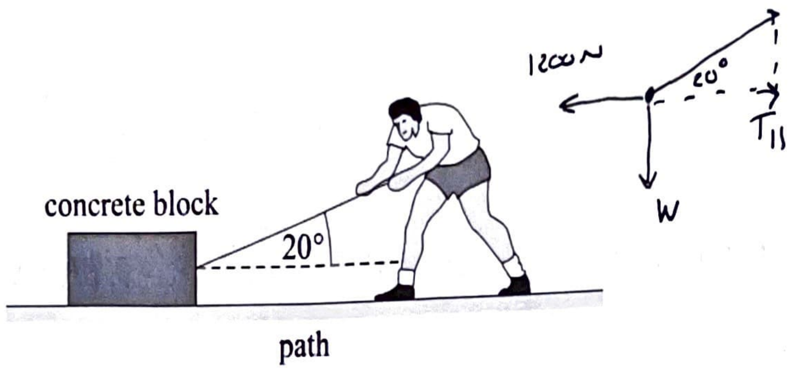
2. A man is participating in a 'strong man' competition. The event requires competitors to pull a concrete block along a horizontal path for 15 m. The frictional force between the block and the path while the block is moving is 1200 N.



(a) The rope is inclined at 20° to the horizontal. Calculate the tension in the rope while the block is being moved at a constant speed. [2]

$T_{\parallel} = -(-1200) = T\cos 20$

$\therefore T = +1277$ N ✓

2

(b) The coefficient of dynamic friction is 0.4. Determine the mass of the block. [3]

$F_f = \mu_d R$ $\rightarrow R = W + T_{\perp} = W + T\sin 20$ ✓

$\therefore F_f = \mu_d (W + T\sin 20) \rightarrow -1200 = 0.4(-m \times 9.81 + 1277\sin 20)$

$\therefore 9.81m = 3000 + 1277\sin 20$

$= 350$ kg ✓

3

Good!

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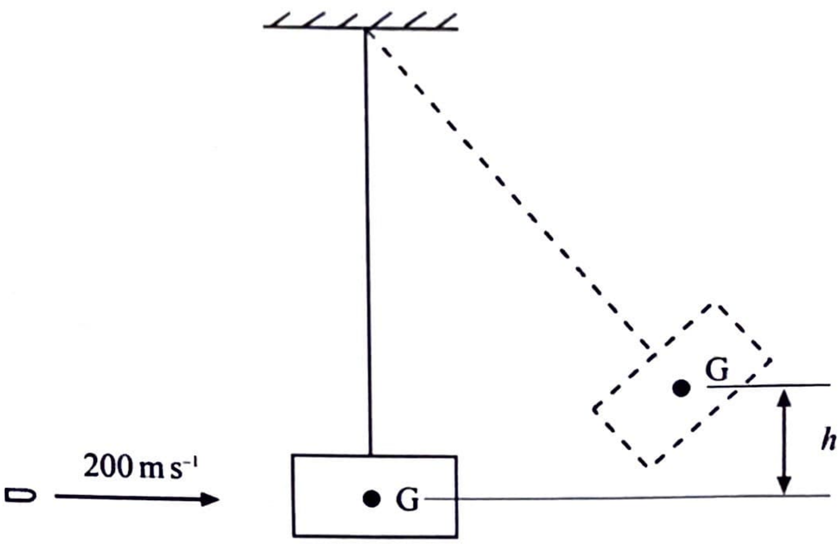
3. A block of wood of mass 0.39 kg is suspended at rest by a light string. A bullet of mass 0.01 kg moving at 200 m s^{-1} strikes the block and lodges within it.



(a) Calculate the maximum speed of the block after being struck by the bullet. [2]

DATA	
$m_B = 0.01$ kg	$m_B u_B + m_W u_W = (m_B + m_W) V$
$m_W = 0.39$ kg	$\therefore \quad V = 5 \text{ ms}^{-1}$
$u_B = 200 \text{ ms}^{-1}$	→ this is max whic occurs
$u_W = 0 \text{ ms}^{-1}$	at displacement $= 0$

2

(b) During the collision of the bullet and block, kinetic energy is converted into internal energy that results in a temperature rise. Neglecting other energy losses, show that the amount of kinetic energy converted into heat energy is 195 J. [2]

$\Delta E_K = \frac{1}{2} m_B u_B^2 - \frac{1}{2}(m_B + m_W) V^2$

$= \frac{1}{2} \times 0.01 \times 200^2 - \frac{1}{2} \times 0.40 \times 5^2$

$= 195 \text{ J}$

2

(This question continues on the following page)

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(Question 3 continued)

(c) The material from which the bullet is made has a specific heat capacity of 250 J kg^{-1} K^{-1}. Assuming that all of the lost kinetic energy increases the internal energy of the bullet, calculate its temperature rise due to the collision. [2]

$\Delta T = Q/mc = 195/0.01 \times 250$

$= 78°C$ (k)

2

(d) The bullet lodges at the centre, G, of the block. Determine the vertical distance, h, that the block rises after the collision. Frictional forces are negligible. [2]

$E_p = mg\Delta h = E_k = \frac{1}{2}mv^2$

$\therefore \Delta h = \frac{1}{2}v^2 \div g$

$= \frac{1}{2}(5^2) \div 9.81$

$\therefore \Delta h \approx 1.27$ m

2

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$\nearrow P \qquad \nearrow V \qquad \nearrow n$

4. The graph shows how the pressure changes with volume for a fixed mass of an ideal gas in an insulated container. At **A** the temperature of the gas is 27 °C. The gas then undergoes two changes under different conditions, one from **A** to **B** and then one from **B** to **C**.

~~$T_1 \propto P/V = P/\tfrac{3}{7}V$~~

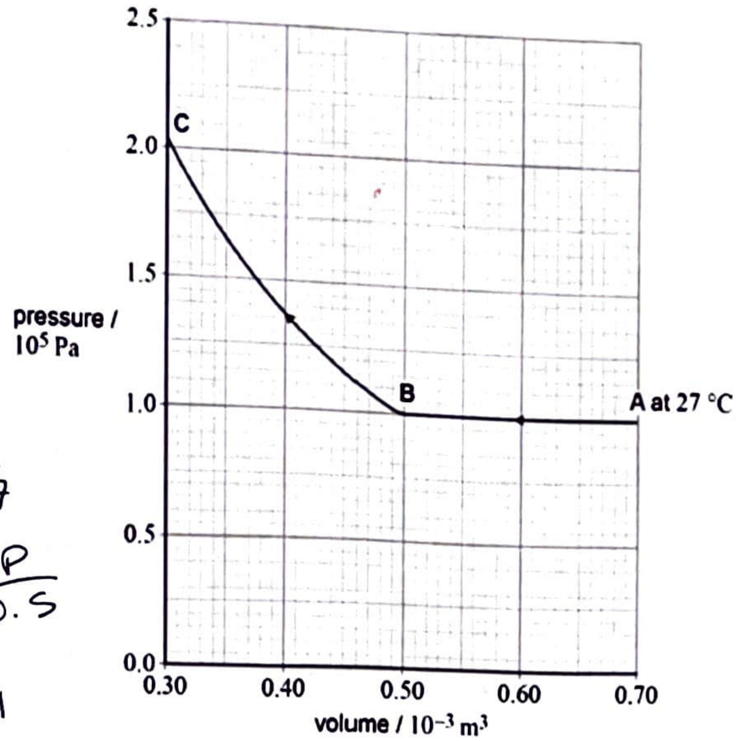
~~$T_2 \propto P/V = P/\tfrac{5}{7}V$~~

~~$\frac{P}{V} =$~~

~~$T \propto \frac{P}{V} = \frac{P}{0.7}$~~

~~$T_2 \propto \frac{P}{V_2} = \frac{P}{0.5}$~~

~~$V_2 = \frac{5}{7}V_1$~~



$V \downarrow \quad T \downarrow$

(a) Calculate the temperature of the gas at **B** after it has been compressed to 0.5×10^{-3} m^3. [2]

DATA

$p = 1.0 \times 10^5$ Pa

$V = 0.5 \times 10^{-3}$ m^3

FOR A? $pV = nRT \rightarrow n_A = pV/RT$

$= \frac{1 \times 10^5 \times 0.7 \times 10^{-3}}{8.31 \times 300}$

$= 0.0281$ mol

FOR B:

$T = pV/n_A R$

$= \frac{1.0 \times 10^5 \times 0.5 \times 10^{-3}}{0.0281 \times 8.31}$

≈ 214 K $= -58.7$ °C

2

(b) Deduce whether the temperature of the gas changes during the compression from **B** to **C**. [2]

$T_B \propto P_B V_B = 0.5$

$T_C \propto P_C V_C = 2 \times 0.3 = 0.6$

∴ as n is constant, T must change to facilitate the ratio above

2

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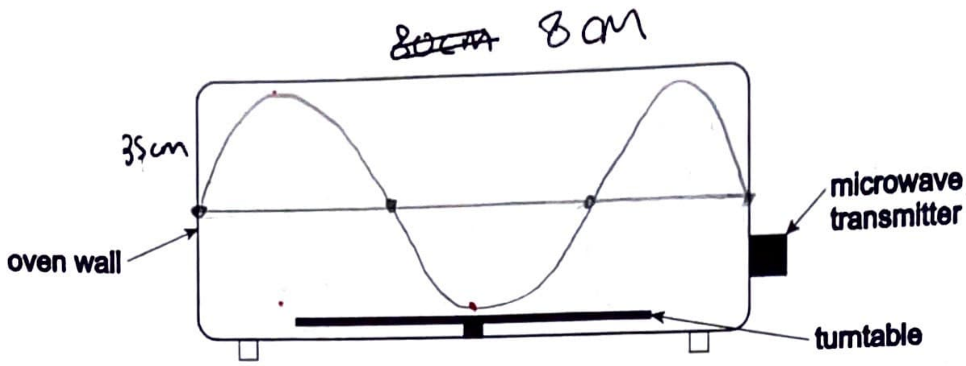
5. A student wants to use the standing waves formed inside a microwave oven to measure the frequency of the microwaves emitted by the transmitter.

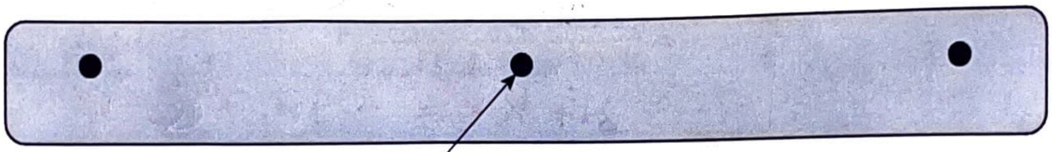


(a) Suggest how standing waves are formed in the microwave oven. [2]

→ Transmitter will produce a wave, directed accross the microwave ✓
→ That wave will reflect ✓ and superimpose ✓ with more waves produced by the transmitter. ✓

(2)

(b) The student removes the turntable and places a bar of chocolate on the floor of the oven. He then switches the oven on for about one minute. When the chocolate is removed the student observes that there are three small patches of melted chocolate with unmelted chocolate between them.



melted chocolate (actual size)

Suggest why the chocolate only melts in the positions shown. [1]

→ Those are the positions of antinodes. ✓
All ~~positi~~ positions with little-to-no melting are not situated directly under antinodes.

(1)

(This question continues on the following page)

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(Question 5 continued)

(c) Calculate, by making suitable measurements on the diagram, the frequency of the microwaves used by the oven. [2]

DATA ??	f_1 : $v = f_1\lambda$, $\lambda = 2L$
$L \approx 0.08\,m$ ✗	$\therefore f_1 = v/2L = 3\times10^8 / 0.16$ ✗
$v = 3\times10^8\,ms^{-1}$	$= 1.875\times10^9$ HZ
	Note : if scale factor of 10 is applied, ???
	$f_1 = 1.875\times10^8$ HZ

(1)

(d) State an assumption that you have made about the refractive index of air when calculating the frequency found in (c). [1]

→ $n = 1$ { refractive index in a vacuum } - this is a reasonable assumption to be made in air.

(1)

(e) Determine an uncertainty estimate for the microwave frequency found in (c). [2]

Uncertainty in ruler $= \pm 0.05$ cm
~~Propagati~~ $\Delta S/S = 0.05/8$ ECF
$= 6.25\times10^{-3}$
$\therefore \Delta f_1 = 6.25\times10^{-3} \times 1.875\times10^8$ ECF
$= \pm1.17\times10^6$ HZ $= \pm1\times10^6$ HZ

(1)

Why does $\Delta f = \frac{\Delta s}{s}\times f$?

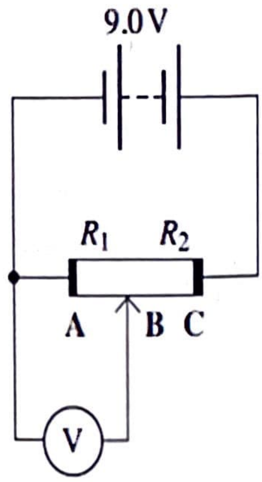
Show.

c) $\lambda = 12.5$ cm $f = \frac{c}{\lambda} = \frac{3.0\times10^8}{12.5\times10^{-2}}$
$= 2.4$ GHZ

e)

3

6. To test the potential differences in a potential divider circuit, a student sets up the circuit shown below. R_1 is the resistance of section AB and R_2 that of section BC of the potential divider. The battery has an emf of 9.0 V and negligible internal resistance.



(a) Calculate the voltmeter reading when $R_1 = 2.2\ \text{k}\Omega$ and $R_2 = 1.8\ \text{k}\Omega$. Assume that the voltmeter is ideal. [2]

→ $I = V/R = 9.0/(2.2+1.8)\times 10^3 = 2.25\ mA$

→ For just R_1, $V = IR = 2.25\times10^{-3} \times 2.2\times10^3$

$= 4.95\ V$

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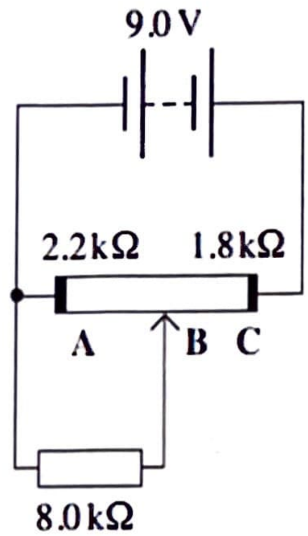
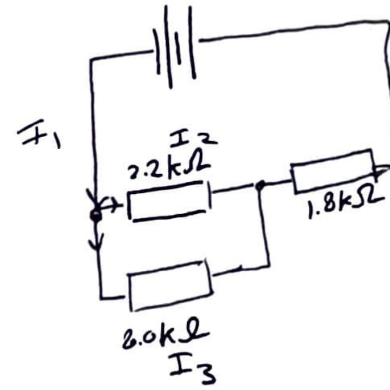
(Question 6 continued)

(b) A device having 8.0 kΩ resistance is connected in the circuit by replacing the voltmeter. The potential difference across this device can be adjusted by moving the sliding contact between A and C.





Calculate the potential difference across the 8.0 kΩ device when the sliding contact B is in the position shown. [3]

1) $R_T = 1.8\times10^3 + \dfrac{1}{1/(2.2\times10^3) + 1/(8.0\times10^3)}$ ✓

$= 3.525\times10^3\,\Omega$ ✓

2) $I_1 = 9.0/3.525\times10^3 = 2.553$ mA ✓

3) $2.2/8.0 = 11/40$ → Current through $8k\Omega$ resistor $= 11/40 \times 2.553\times10^{-3} = 0.702\times10^{-3}$ ✗ (2)

∴ $V = IR = 0.702\times10^{-3} \times 8.0\times10^3$

$= \cancel{5616.6\text{ V}} \approx = 5.6$ V

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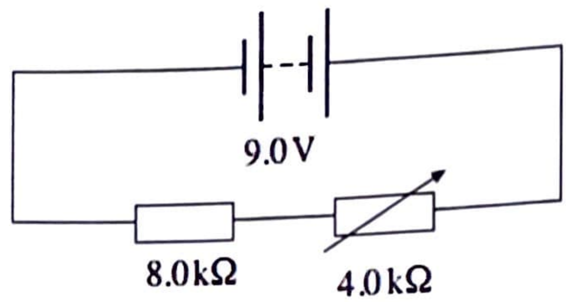
(Question 6 continued)

(c) The 8.0 kΩ device is now connected in a circuit with a 4.0 kΩ variable resistor.



State an advantage of the potential divider shown in (b) over the use of a variable series resistor to control the potential difference across the 8.0 kΩ device. [1]

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P.D

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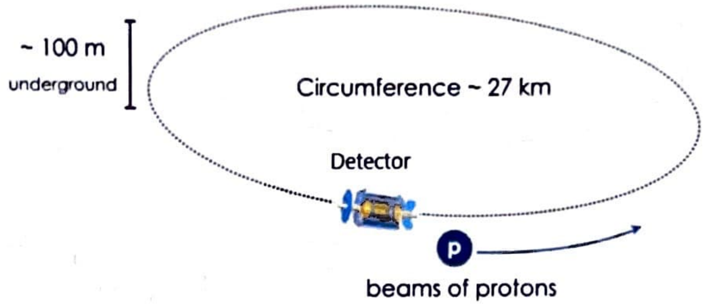
7. The Large Hadron Collider (LHC) uses magnetic fields to confine fast-moving charged particles travelling repeatedly around a circular path. The LHC is installed 100 m underground in a circular tunnel of circumference 27 km.



(a) The charged particles travelling around the LHC may be protons. Calculate the net force acting on a proton when travelling in a circular path of circumference 27 km at one-tenth of the speed of light in a vacuum. [2]

DATA	1) $C = 2\pi r = 27 \times 10^3 \rightarrow r = 4297$ m
$C = 27 \times 10^3$ m	2) $F = mv^2/r = \frac{1.673\times10^{-27} \times (\frac{1}{10}\times 3\times10^8)^2}{4297}$
$v = \frac{1}{10} \times 3 \times 10^8$ ms^{-1}	$= \cancel{3.50\ N}$
$M_p = 1.673 \times 10^{-27}$ kg	$= 3.50 \times 10^{-16}$ N

2

(b) Calculate the magnetic flux density that would be required to produce this force. [2]

$F = qvB \rightarrow B = F/qv$

$= (3.5 \times 10^{-16}) / (1.6 \times 10^{-19} \times \frac{1}{10} \times 3 \times 10^8)$

$= 7.29 \times 10^{-5}$ T

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$s = 27 \times 10^3$ m
$v = \frac{1}{10} \times 3 \times 10^8$

(Question 7 continued)

(c) Calculate the frequency of the protons' motion when moving around the LHC at one-tenth of the speed of light in a vacuum. [2]

$T^2 = 4\pi^2 r^2 / v^2 = (4\pi^2 \times (4297)^2)/(\frac{1}{10} \times 3 \times 10^8)^2$

$= 8.099308374 \times 10^{-7}\ s^2$

$\therefore T = 8.9996 \times 10^{-4}$ s

$\therefore T \approx 9.0 \times 10^{-4}$ s ✓

$\therefore f = \frac{1}{T} = \frac{1}{9.0 \times 10^{-4}} = 1.1 \times 10^3$

1

(d) Protons are classified as *hadrons*.

(i) What distinguishes hadrons from other subatomic particles? [1]

→ Hadrons consist of only quarks ✓ (either as baryons or mesons)

1

(ii) Hadrons fall into two subgroups. Name each subgroup and describe the general structure of each. [2]

Subgroup 1 Baryon ✓ 3 quarks ✓ (or 3 antiquarks),

Subgroup 2 Meson : ✓ 1 quark, 1 antiquark ✓

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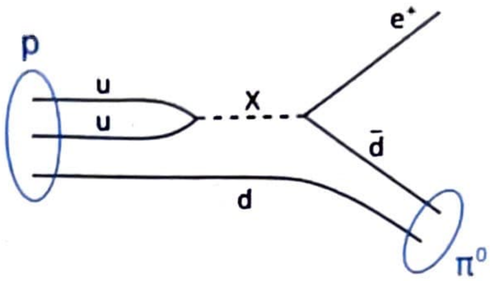
(Question 7 continued)

(e) It is suggested that protons could decay into π^0 particles via the weak interaction.



Determine whether this process is feasible. [2]

Charge : $+1 \rightarrow +1 + 0$ ✓ ✓

Baryon : $\frac{1}{3} + \frac{1}{3} + \frac{1}{3} \rightarrow 0 + \frac{1}{3} - \frac{1}{3}$ ✗ ✓

∴ not feasible as baryon number is not conserved ✓

2

/2

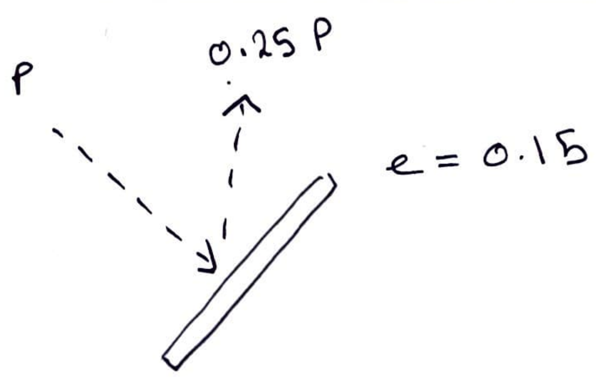
8. A photovoltaic solar panel is fitted to a spacecraft. The spacecraft is in a near Earth orbit where the solar panel receives energy at a rate of 3500 J s^{-1} when sunlight is incident perpendicularly on its surface. The albedo of the solar panel is 0.25 and its overall efficiency is 15%. Solar energy that is absorbed by the panel but not converted into electricity is radiated as heat energy. Show that the rate at which heat energy is radiated by the panel is 2.1 kW when it is in thermal equilibrium. [3]

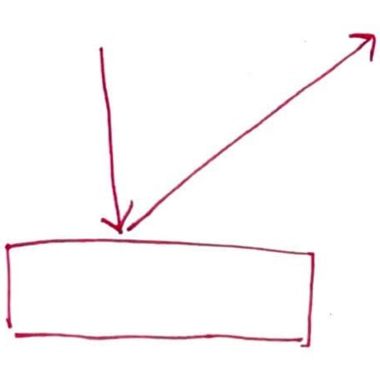
1) Power ~~incident~~ absorbed = $3500 \times (1-\alpha) = 2625$ W ✓ (1)

2) $P_{WASTED} = 2625 \times (1-e) = 2625 \times 0.85 = 2231.25$ W

3) ~~$P_{IN} = P_{OUT}$~~ $P_{WASTED} = P_{ABSORBED}$

~~$e\sigma AT^4$~~ $\therefore 2231.25 =$





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