Physics Standard level Paper 2 Wednesday 28 October 2020 (afternoon)

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Formulae used in this paper

$F\,dt = m\,dV \Rightarrow F = V\frac{dm}{dt}$

$F_c = m\omega^2 r$

$f = \mu N$

$KE = \frac{3}{2}kT$

$Q = mL$

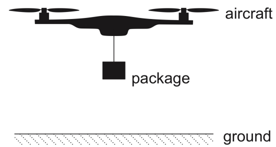
$\Delta\phi = \frac{2\pi}{\lambda}(\Delta x)$

$N = N_0\left(\frac{1}{2}\right)^n$, Total time $= n\,T_{1/2}$

IB PHYSICS SL PAPER-2 28 OCT-2020 SOLUTION

WITH EXPLANATION

1. A company delivers packages to customers using a small unmanned aircraft. Rotating horizontal blades exert a force on the surrounding air. The air above the aircraft is initially stationary.



The air is propelled vertically downwards with speed v. The aircraft hovers motionless above the ground. A package is suspended from the aircraft on a string. The mass of the aircraft is 0.95 kg and the combined mass of the package and string is 0.45 kg. The mass of air pushed downwards by the blades in one second is 1.7 kg.

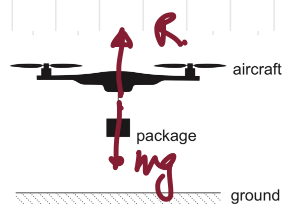
(a) (1) State the value of the resultant force on the aircraft when hovering.

↳ to stay in air in one place

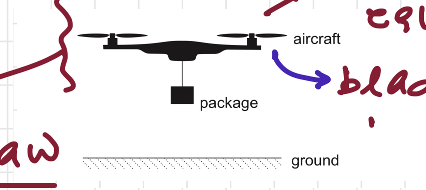
since $R = mg$

Net force $= R - mg$

$= 0\,N$



(ii)Outline, by reference to Newton's third law, how the upward lift force on the aircraft is achieved.



Air pushes the blades up with equal and opposite force

blades pushes the air down.

can be explained by Newton's third Law

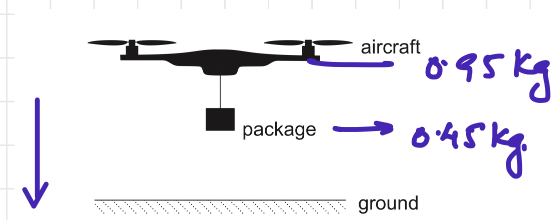
ACTION - REACTION

iii -Determine v. State your answer to an appropriate number of significant figures.

$F = ma \Rightarrow F = m\frac{dv}{dt}$

$F = v\frac{dm}{dt}$

F → weight of the aircraft and package.



aircraft → 0.95 kg

package → 0.45 kg

$\frac{dm}{dt} = \frac{1.7\ kg}{sec}$

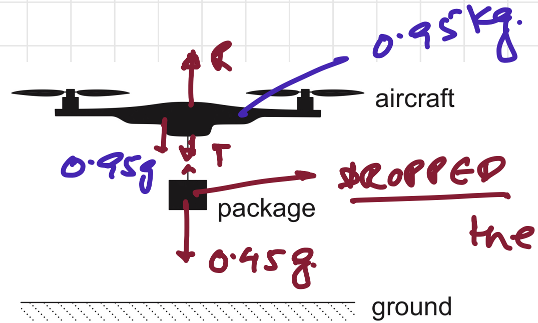
$(0.95 + 0.45)g = v\,(1.7)$

$v = \frac{(1.4)(9.8)}{1.7} = 8.07\ mt/sec = 8.1\ mt/sec$

(b) The package and string are now released and fall to the ground. The lift force on the aircraft remains unchanged. Calculate the initial acceleration of the aircraft

$R - 0.95g - T = 0.95a$

$T = 0$, when package and string are now released



DROPPED then $T=0$

$\uparrow a$

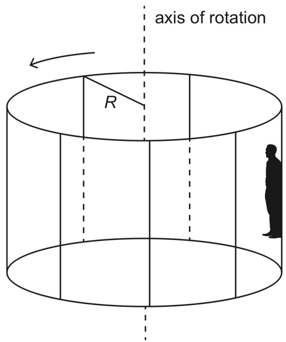
$1.4g - 0.95g = 0.95a$

$0.45g = 0.95a$

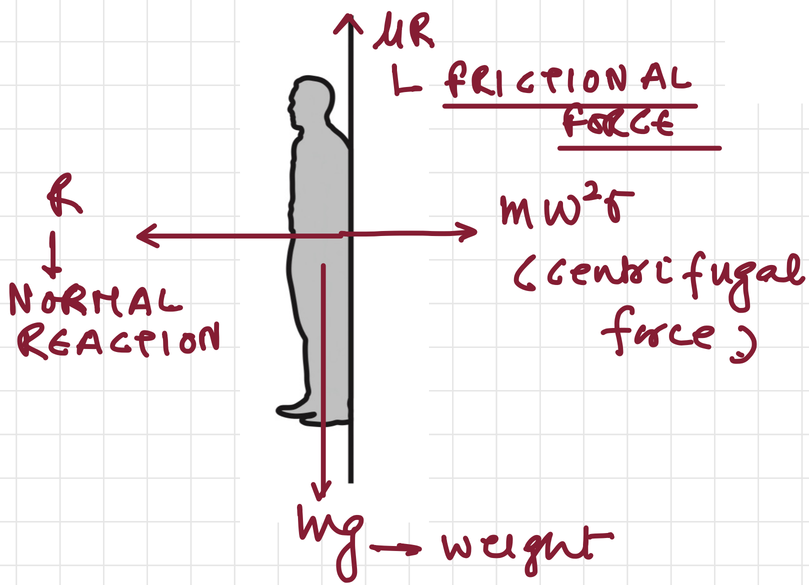
$$a = \frac{g(0.45)}{0.95} = \frac{9.8 \times 4.5}{0.95}$$

$= 4.6\ ms^{-2}$

2. The Rotor is an amusement park ride that can be modelled as a vertical cylinder of inner radius R rotating about its axis. When the cylinder rotates sufficiently fast, the floor drops out and the passengers stay motionless against the inner surface of the cylinder. The diagram shows a person taking the Rotor ride. The floor of the Rotor has been lowered away from the person.



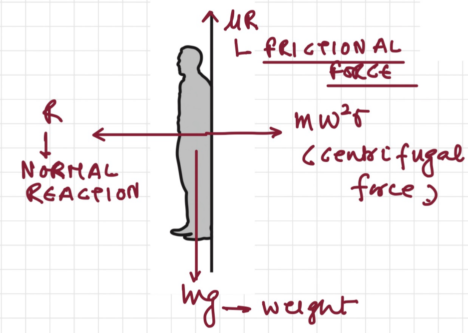
(a) Draw and label the free-body diagram for the person.



(b) The person must not slide down the wall. Show that the minimum angular velocity ω of the cylinder for this situation is

$$\omega = \sqrt{\frac{g}{\mu R}}$$

where μ is the coefficient of static friction between the person and the cylinder.



VERTICAL EQUILIBRIUM, $\Sigma F_y = 0$

$$\mu R = mg \quad \text{— (1)}$$

HORIZONTAL EQUILIBRIUM

$$\Sigma F_x = 0$$

$$R = m\omega^2 r \quad \text{— (2)}$$

$$\mu (m\omega^2 r) = mg \Rightarrow \omega^2 = \frac{g}{\mu r}$$

$$\omega = \sqrt{\frac{g}{\mu r}}$$

C) The coefficient of static friction between the person and the cylinder is 0.40. The radius of the cylinder is 3.5 m. The cylinder makes 28 revolutions per minute. Deduce whether the person will slide down the inner surface of the cylinder.

from part (b)

$$\omega_{min} = \sqrt{\frac{g}{\mu r}} = \sqrt{\frac{9.8}{0.40 \times 3.5}} = 2.65 \text{ rad/sec}$$

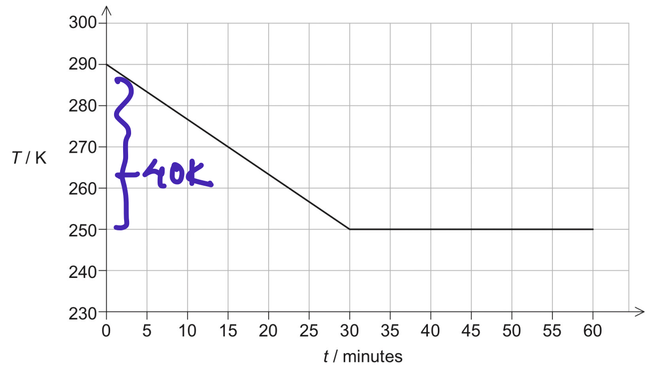
cylinder makes 28 revolutions per minute

$$\omega_{NEW} = 2\pi f = 2 \times \frac{22}{7} \times \frac{28}{60} = 2.93 \text{ rad/sec}$$

Since $\omega_{NEW} > \omega_{MIN}$

so does not slide down

3. A sample of vegetable oil, initially in the liquid state, is placed in a freezer that transfers thermal energy from the sample at a constant rate. The graph shows how temperature T of the sample varies with time t.



The following data are available.

Mass of the sample = 0.32 kg

Specific latent heat of fusion of the oil = 130 kJ kg−1 Rate of thermal energy transfer = 15 W

A 1)Calculate the thermal energy transferred from the sample during the first 30 minutes.

$$P = \frac{Q}{t} \Rightarrow Q = P(t)$$

$$= (15)(30 \times 60)$$

$$= (15)(1800) = 27000\,J$$

$$= 27\,kJ$$

II) Estimate the specific heat capacity of the oil in its liquid phase. State an appropriate unit for your answer.

$$Q = m \cdot c \cdot \Delta T$$

$$c = \frac{Q}{m(\Delta T)} = \frac{27 \times 10^3 \text{ J}}{(0.32)(40\text{K})} = 2 \times 10^3 \text{ J/kg}$$

B) The sample begins to freeze during the thermal energy transfer. Explain, in terms of the molecular model of matter, why the temperature of the sample remains constant during freezing.

$$KE = \frac{3}{2} kT$$

Substance freezes → Intermolecular PE decreases →

But $\overline{KE} = \frac{3}{2} kT$, will remain constant, since $KE \propto T$

T will remain constant

C) Calculate the mass of the oil that remains unfrozen after 60 minutes

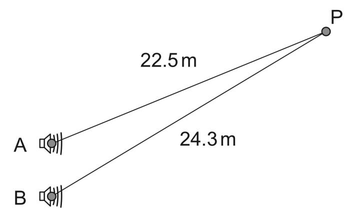
Energy removed $= P(t) = 15 \times 30 \times 60 = 27\text{ kJ}$

mass that freezes $\Rightarrow m = \dfrac{Q}{L} = \dfrac{27\text{ kJ}}{130\text{ kJ/kg}} = 0.21\text{ kg.}$

Remains unfrozen $= 0.32 - 0.21$

$= 0.11\text{ kg.}$

4. Two loudspeakers, A and B, are driven in phase and with the same amplitude at a frequency of 850Hz. Point P is located 22.5m from A and 24.3m from B. The speed of sound is 340ms .



Path difference

$= \Delta x = 24.3 - 22.5$

$= 1.8$

a) Deduce that a minimum intensity of sound is heard at P.

$\lambda = \frac{v}{f} = \frac{340}{850} = 0.4\,mt$

for destructive interference

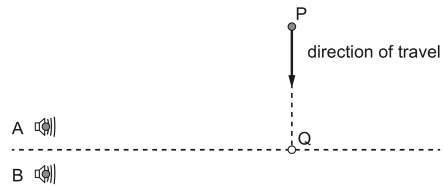
$\Delta x = (2n-1)\frac{\lambda}{2}$

$\lambda = \frac{2(\Delta x)}{(2n-1)} = \frac{2 \times 1.8}{(2n-1)} = \frac{3.6}{(2n-1)}$

put $n = 5$

$\lambda = \frac{3.6}{9} = 0.4$ — condition for destructive interference is satisfied — hence minimum intensity

(b) A microphone moves along the line from P to Q. PQ is normal to the line midway between the loudspeakers.

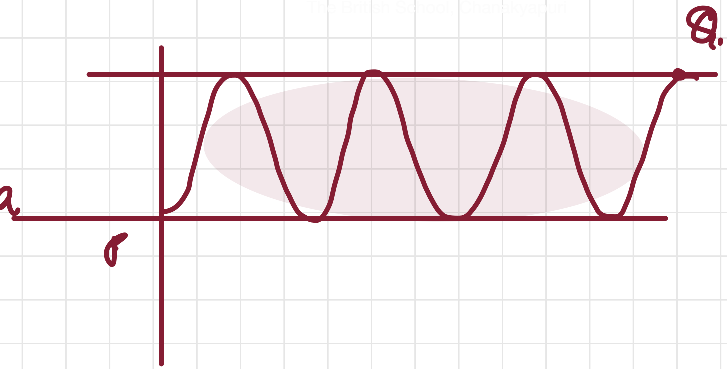


The intensity of sound is detected by the microphone. Predict the variation of detected intensity as the microphone moves from P to Q.

series of equally spaced out maxima and minima will be obtaind

maxima at → Q

minima at — P



C) When both loudspeakers are operating, the intensity of sound recorded at Q is I_0. Loudspeaker B is now disconnected. Loudspeaker A continues to emit sound with unchanged amplitude and frequency. The intensity of sound recorded at Q changes to I_A Estimate I_A/I_0

$I_A \propto A^2$

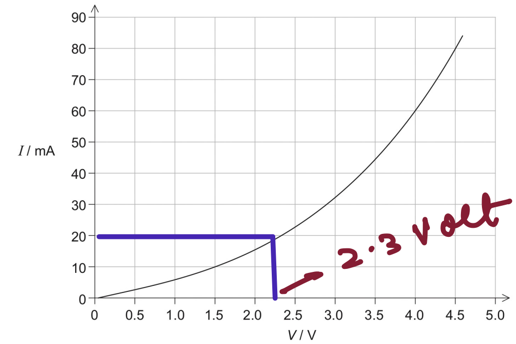
$I_0 \propto (2A)^2$

$\frac{I_A}{I_0} = \frac{1}{4}$

Intensity $\propto$ (Amplitude)^2

$I \propto A^2$

5. The graph shows how current I varies with potential difference V across a component X.

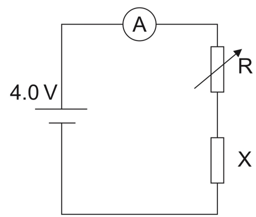


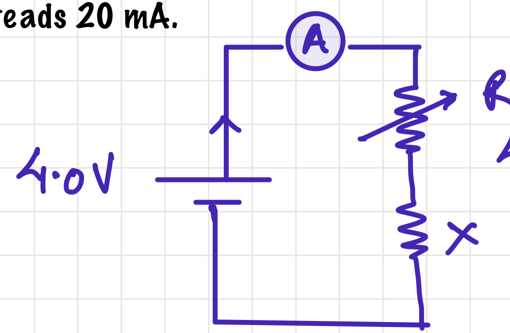
a) Outline why component X is considered non-ohmic.

current is not directly proportional to potential

hence - non ohmic

(b) Component X and a cell of negligible internal resistance are placed in a circuit. A variable resistor R is connected in series with component X. The ammeter reads 20 mA.





$4 = 20 \times 10^{-3} (R + X)$

$R + X = \frac{4}{20 \times 10^{-3}} = \frac{4000}{20} = 200\,\Omega$

i) Determine the resistance of the variable resistor.

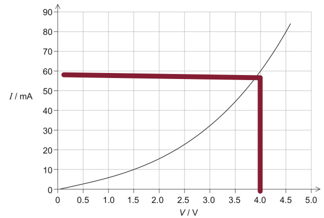
As per graph
2·3 volt across X, 1·7 volt across R

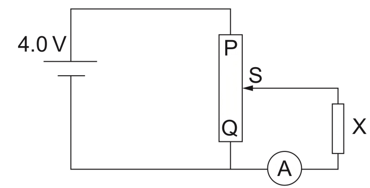
$R = \frac{1\cdot7}{\cdot020} = 85$ ohm

(ii) Calculate the power dissipated in the circuit.

$P = VI = 4\cdot0 \times 0\cdot020 = \cdot080$ watt

(c) Component X and the cell are now placed in a potential divider circuit.





(i) State the range of current that the ammeter can measure as the slider S of the potential divider is moved from Q to P.

when slider moves from Q to P then potential difference across X is 4volt and As per the graph current is 60 mA.

(ii) Describe, by reference to your answer for (c) (i), the advantage of the potential divider arrangement over the arrangement in (b).

main current will be greater than 20mA because total resistance decreases therefore overall diss power will be greater

$P = VI$

$= \downarrow$ → greater than before.

4.0volt

$P \uparrow$

6. (a) One possible fission reaction of uranium-235 (U-235) is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n$$

The following data are available.
Mass of one atom of U-235 = 235 u
Binding energy per nucleon for U-235 = 7.59 MeV
Binding energy per nucleon for Xe-140 = 8.29 MeV
Binding energy per nucleon for Sr-94 = 8.59 MeV

I) State what is meant by binding energy of a nucleus

The energy required to complete separate of nucleous in to its nucleons.

II) Outline why quantities such as atomic mass and nuclear binding energy are often expressed in non-SI units.

At nuclear level mass and energy have very small values in kg, J, etc.

III) Show that the energy released in the reaction is about 180 MeV.

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$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n$$

235×7.59

RHS

140×8.29
$+ 94\,(8.59)$

ENERGY RELEASED $= (140 \times 8.29 + 94(8.59)) - 235 \times 7.59$
$= 184\ \text{MeV} \simeq 180\ \text{MeV}$

(b) A nuclear power station uses U-235 as fuel. Assume that every fission reaction of U-235 gives rise to 180 MeV of energy.
(i) Estimate, in J kg−1, the specific energy of U-235.

$$\frac{180 \times 10^{6} \times 1.6 \times 10^{-19}\ \text{J}}{235 \times 1.66 \times 10^{-27}\ \text{kg}} \simeq 7.4 \times 10^{13}\ \text{J/kg}$$

II) The power station has a useful power output of 1.2 GW and an efficiency of 36 %. Determine the mass of U-235 that undergoes fission in one day.

$$\eta = \frac{\text{useful}}{\text{toral power input}} \Rightarrow \text{Total power input} = \frac{\text{useful}}{\eta}$$

$$\text{Total power input} = \frac{1.2 \times 10^9}{0.36} = 3.3 \times 10^9 \text{ watt}$$

$$\text{mass} = \frac{3.33 \times 10^9 \text{ J/sec}}{7.4 \times 10^{13} \text{ J/kg}} = \frac{24 \times 36000}{1 \text{ day}} = 3.9 \text{ kg}$$

C) A sample of waste produced by the reactor contains 1.0 kg of strontium-94 (Sr-94). Sr-94 is radioactive and undergoes beta-minus (β−) decay into a daughter nuclide X. The reaction for this decay is

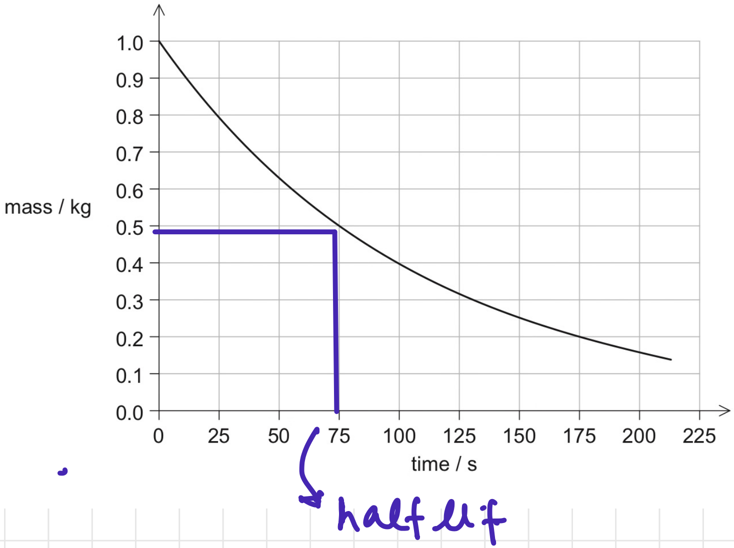
$$^{94}_{38}\text{Sr} \rightarrow \text{X} + \overline{\nu}_e + e.$$

(i) Write down the proton number of nuclide X.

$$^{94}_{38}Sr \longrightarrow {}^{94}_{39}X + \bar{\nu}_e + {}_{+1}e^{0}$$

39 ← ANSWER

The graph shows the variation with time of the mass of Sr-94 remaining in the sample.



II) State the half-life of Sr-94.

Initial mass = 1 kg

mass after 75 sec (as per the graph)

= 0.5 kg

Hence half life = 75 sec

III) Calculate the mass of Sr-94 remaining in the sample after 10 minutes

$N = N_0 \left(\frac{1}{2}\right)^n$ $N_0 = 1\,kg$

Total time $= n\,(T_{1/2})$

$10 \times 60 = 75\,(n)$

$n = \frac{600}{75} = 8$

$N = 1 \left(\frac{1}{2}\right)^8$

$= \frac{1}{256}\,kg$

$= \frac{1000}{256} = 3.9\,gm$

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WITH EXPLANATION

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