ADVANCED PHYSICS 01
MARKING SCHEME

1 (a) The statement "The density of water is $(1000 \pm 0.5)\ kgm^{-3}$" indicates the following:

(i) Measured density : 1000 kgm^{-3} is the average density of water obtained through measurements (1.25)

(ii) Uncertainity : $\pm 0.5\ kgm^{-3}$ represents the margin of error associated with the measurement. This means that the true density of water could be anywhere between 999.5 and 1000.5 kgm^{-3}. (1.25)

Impact on the measurements.

This uncertainity has implication for the research:

- Precision: The measurements of water's properties (like volume or mass) might need to be adjusted based on the specific density value within the uncertainity range. (1.25)
- Error propagation: If he ~~y~~ use water density in calculations, the uncertainity will propagate to his final results, affecting their accuracy and requiring considerations in his analysis. (1.25)

(b) (i) According to ohm's law

$V = IR$,

$R = V/I$

Since workdone $W = qV$ where q is the charge, $R = W/qI = W/I^2t$

since $q = It$

Dimensions of work $[W] = [M^1L^2T^{-2}]$

Dimensions of $R = [R] = [M^1 L^2 T^{-2}][A^{-2} T^{-1}]$

$\therefore [R] = [M^1 L^2 T^{-3} A^{-2}]$ 2.5

(ii) Dimensions of kinetic energy $K = [M^1 L^2 T^{-2}]$

Dimensions of moment of inertia $(I) = [(2/5) M r^2]$

$[I] = [(2/5) M r^2] = [M L^2 T^0]$

Dimensions of angular speed $[\omega] = [\theta / t]$

$[\omega] = [M^0 L^0 T^{-1}]$

Applying principle of homogeneity in dimensions in the equation $K = k I^a \omega^b$

$[M^1 L^2 T^{-2}] = k([M L^2 T^0])^a ([M^0 L^0 T^{-1}])^b$

$[M^1 L^2 T^{-2}] = k[M^a L^{2a} T^{-b}]$

$a = 1$

$b = 2$

$K = k I \omega^2$ 2.5

2. Let u be the initial velocity of neutron before colliding with a nucleus and V the velocity after collision.

Kinetic energy before collision, $E_0 = \frac{1}{2} m u^2$

Kinetic energy of neutron after collision, $E_A =$

$E_A = \frac{1}{2} m v^2$ 01

The energy lost, $\Delta E = E_0 - E_A$

$= \frac{1}{2} m u^2 - \frac{1}{2} m V^2$

$= \frac{1}{2} m (u^2 - V^2)$

$= \frac{1}{2} m u^2 (1 - (V/u)^2)$

01

For the collision between heavy projectile (nucleus of mass M) and light target (neutron of mass m)

The velocity after collision is given by

$$V = \frac{(m-M)u}{m+M} \quad \text{or} \quad \frac{V}{u} = \frac{m-M}{m+M}$$ 01

$$\Delta E = \tfrac{1}{2}mu^2\left[1-\left(\frac{m-M}{m+M}\right)^2\right] \text{ but } \tfrac{1}{2}mu^2 = E_0$$

$$\Delta E = E_0\left[1-\left(\frac{m-M}{m+M}\right)^2\right]$$

$$\Delta E = E_0\left[\frac{(m+M)^2-(m-M)^2}{(m+M)^2}\right]$$

$$\Delta E = \frac{E_0}{(M+m)^2}\left[(m+M)+M-m)(m+M-m+M)\right.$$ 01

$$\Delta E = \frac{E_0}{(m+M)^2}(2M \times 2m)$$

$$\Delta E = \frac{4MmE_0}{(m+M)^2}$$ 01

(b) (i) ~~Newt~~ Rocket lift off relies on three key principles.

- Newton's third law of motion (action - reaction)
- Inside the rocket, fuel burns rapidly, creating hot, expanding gases. These gases are expelled downwards through the engine nozzle at high speeds. According to Newton's third law, this forceful downward thrust generates an equal 01

- Momentum Conservation.

As the exhaust gases leave the engine, they carry a significant amount of momentum downwards. To conserve momentum the overall momentum of the rocket system (rocket + gases) must increase upwards, leading to the rocket's acceleration. 01

- Over Coming gravity.

To escape earths gravitational pull; the rockets upward thrust (from principle 1) needs to be greater than the force of gravity pulling it down. This is why rockets have powerful engines and burn large amounts of fuel during lift off. 01

(b) (ii) When sand fall onto the balance, the effective reading on the pan will be the net weight of the accumulated sand plus the impact force produced by the flowing system.

Net Force = Weight of accumulated sand + The force produced due to falling sand at given time 0.5

$$F = mg + v\,dm/dt$$

where F = Total pan reading

mg = Weight of the accumulated sand

$v\frac{dm}{dt}$ = Impact force due to rate of the sand.

We assume that the weight of the instantaneous falling sand is negligible compared to the total reading. Now, velocity of sand at the impact is calculated as. 0.5

$$V^2 = u^2 + 2ah$$

But $u = 0$, then $V^2 = 2gh$

So $V = \sqrt{2gh} = \sqrt{2 \times 10 \times 0.2} = 2\,m/s$

and the total mass accumulated in the pan is calculated as follows

$m = \frac{dm}{dt} \times$ total time

$m = 5\times10^{-3} \times 10 = 0.05kg$ (0.5)

Hence, the total reading in the pan will be

$F = (0.05\times10) + (2\times5\times10^{-3})$

$F = 0.51N$ (0.5)

3 (a) (i)

Periodic motion	Simple harmonic M
(i) The displacement of the object may or may not be in the direction of the restoring force (01)	(i) The displacement of the object is always in the opposite direction of the restoring force
(ii) May or may not be oscillatory (01)	(ii) The motion is always oscillatory
(iii) examples are the motions of hand of a clock, motion of wheels of a car (01)	(iii) example, simple pendulum, motion of a spring

(ii) let the periodic time of each pendulum be

$T_1 = 2\pi\sqrt{\frac{L_1}{g}}$ and $T_2 = 2\pi\sqrt{\frac{L_2}{g}}$

Thus $T_1 = 2\pi\sqrt{\frac{0.4}{10}} = 1.257s$

$T_2 = 2\pi\sqrt{\frac{0.6}{10}} = 1.539s$

The two pendulums will be in phase when one exceed the other by a complete cycle, that let $t = nT_1 = (n-1)T_2$

$n = T_2/T_2-T_1$

$$n = \frac{T_2}{T_2 - T_1}$$

$$n = \frac{1.539}{1.539 - 1.257} = 5.46$$

Therefore $t = nT_1 = (n-1)T_2$

$t = 5.46 \times 1.257 = (5.46-1)1.539$

$t = 6.86$ Sec 0.3

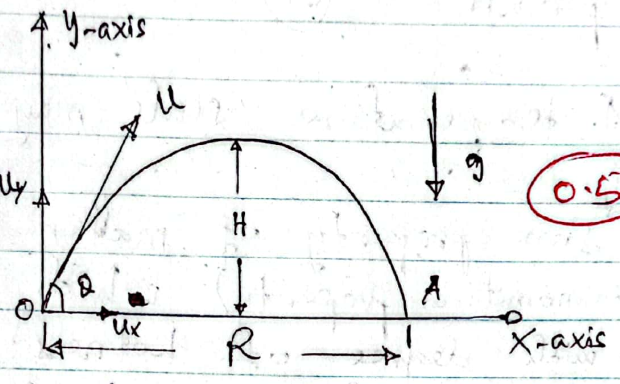
3 (b) The period of the dogs bouncing which determines how high it reaches, depends on both the spring constant (stiffness) and the dogs mass. A stiffer spring (higher k value) will lead to faster, shorter bounces, while a heavier dog will experience slower, higher bounces. You need to adjust the spring constant and dog's mass to achieve the desired bounce height. 0.4

4 (a) (i) Air resistance acts as a drag force opposing the ball's motion in both directions. However it has a greater impact on the horizontal component due to the balls slow speed in the direction compared to its initial launch velocity. This gradually slows down the horizontal movement, causing the ball to curve and eventually land. 2.5

(ii) Trajectory is the path a projectile follows in its flight 1.25

Range of a projectile is the distance between the point of projection and the point where the trajectory meets any plane through the point of projection. (1.25)

(b) Consider the following diagram.



(0.5)

(i) Using the first equation and considering vertical motion

$$V_y = U_y - gt \quad (01)$$

$$V_y = U\sin\theta - gt$$

The velocity changes sign at maximum height where $V_y = 0$.

$$\therefore 0 = U\sin\theta - gt$$

hence $t = \dfrac{U\sin\theta}{g}$ (01)

(ii) Using the second equation of motion and considering vertical motion

$$S_y = U_y t - \tfrac{1}{2}gt^2 \quad (0.5)$$

For maximum height, $t = \dfrac{U\sin\theta}{g}$

$$H = U\sin\theta\left(\frac{U\sin\theta}{g}\right) - \tfrac{1}{2}g\left(\frac{U\sin\theta}{g}\right)^2 = \frac{(U\sin\theta)^2}{g}\left(1-\tfrac{1}{2}\right) \quad (01)$$

$$H = \frac{U^2\sin^2\theta}{2g} \quad (01)$$

5 (a) (i) Temperature is the measure of the average kinetic energy of molecules or atoms of a substance WHEREAS heat is the form of energy which flows from one point to another due to temperature difference between two points. 01

(ii) A temperature scale may be established by

- Some property of matter is selected (thermometric property) which varies continuously with degree of hotness. 01
- Two standard degrees of hotness (fixed points) are chosen and values are assigned to them. 01
- The fundamental interval is determined and the value of temperature θ is given by

$$\theta = \left(\frac{X_\theta - X_0}{X_{100} - X_0}\right) \times 100^\circ C$$ 01

(b) (i) Mercury in glass thermometer. This gives direct reading 02

(ii) Constant volume gas thermometer. This is very accurate. 02

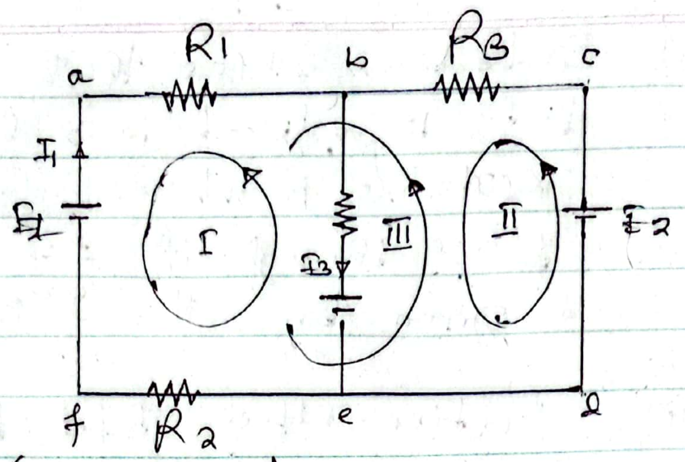
(iii) Thermo couple thermometer. This responds quickly to rapidly changing temperatures. 02

6 (a) (i) Joule's law, states that
"Heat H produced in a conductor of resistance R when a current I flows through it for a time t is given by $H = I^2Rt$" 2.5

(ii) Peltier effect, states that
" When a current I passes through a junction of two different conductors (or semiconductors), heat Q is absorbed or evolved at the junction, the heat Q is given by $Q = \Pi It$ where
Q is the heat absorbed or evolved
Π is the peltier coefficient (in. Volts)
I is the current
t is the time for which the current flows. 2.5

(b) (i) According to Kirchhoff's laws, in an electrical circuit, the total power entering the circuit is equal to the total power exiting the circuit.
Consider a circuit consisting of an ideal voltage source with emf E and a resistance R.
Power in the emf source $(P_s) = -VI$
Power in the resistance $(P_r) = I^2R = IV$
$\therefore P_s + P_r = 0$ 0.2

7 6 (b) (ii)



Loop I (afeba) we have

$-I_1R_1 - I_1R_2 - I_3R_4 + E_1 - E_3 = 0$ —— (i) (01)

loop II (bcdeb) we have

$-I_2R_3 + I_3R_4 - E_2 + E_3 = 0$ —— (ii) (01)

loop III (afedcba) we have

$-I_1R_1 - I_2R_3 - I_1R_2 - E_2 + E_1 = 0$ —— (iii) (01)

Junction equation at b gives

$I_1 - I_2 - I_3 = 0$

7 (a) (i) Is the wavelength between 8 μm and 12 μm at which the atmosphere is almost transparent so the emissivity is very small. (02)

(ii) Hydraulic Conductivity is the measure of the soil's ability to permit water to flow through its pores or voids.

Factors affecting hydraulic Conductivity are · size of the pores and distribution of the pores. (02)

(b) Using the Darcy's Law for one dimensional flow

$$Q_w = -K\frac{d\psi}{dx} = -K\frac{dh}{ds}A$$ (02)

Where A is the cross-sectional area

of the manometers, Q_w is the discharge rate and K the hydraulic Conductivity in the s direction. Then

$$K = -Q_w \frac{1}{A}\frac{ds}{dh}$$

$$= (-1.9\,cm^3 min^{-1}) \times \left[\frac{1}{\pi (9cm)^2}\right]\left[\frac{28cm}{-14cm}\right]$$ 02

$K = 0.015\ cm/min = 2.5 \times 10^{-4} cm/s$ 02

The sign of $\frac{ds}{dh}$ is negative because as s increases, h decreases.

8. (a) (i) Peak voltage 2.0
- the maximum voltage reached during one Complete cycle of the AC waveform

(ii) Root mean square value (voltage)/current
- Is the dc voltage that dissipates the same amount of power as the average power dissipated by the alternating current/voltage. 2.5

(b) (i) Relation $V_{RMS} = \sqrt{2}\, V_{peak}$. 01

(ii) A resistor, $R = 10\Omega$ is connected to a 230V, 50HZ supply. determine the peak voltage, the current flowing and the power dissipated in the resistor.

230 V = R.M.S Voltage

Peak Value $= \sqrt{2} \times 230 = 325.3V$ 03

$I = V/R = 230/10 = 23A$ 03

$P = I^2R = 23^2 \times 10 = 5290W = 5.29KW$ 03

9 (a) (i) - Thermal generation 01
- optical generation 01
- Electrical generation 01
- chemical generation. 01

(ii) The process where by electrons that have been excited into the conduction band have a tendency to lose energy by falling into holes in the valence band. 01

(b) (i) Reasons.
Low reverse leakage current
Good temperature stability
Low cost
High reverse breakdown voltage
Large forward current

Low reverse leakage current 01
- Reverse current in silicon flows in order of nano amperes compared to germanium in which the reverse current flows in order of micro amperes; because of this, the ~~effect~~ accuracy of non-conduction of Ge-diode in reverse bias falls down, whereas Si diode retains its property to greater extent (allows negligible amount of current to flow)

Good temperature stability 01
- Si can withstand temperature ~~up to~~ typically 140°c to 180°c where as Ge is temperature sensitive only up to 70°C

Low Cost (01)

- Silicon is easy and inexpensive to obtain and process where as Ge is a rare material found in Copper, Lead or Silver deposits.

* High reverse breakdown voltage (01)

- Si has 70-100V breakdown voltage where as Ge has around 50V

Large forward Current (01)

- Si is much better for high current applications as it has very high forward current in a range of tens of amperes, where as Ge diodes have very small forward current in a range of micro amperes.

(b) (i) The maximum current flowing through the zener diode

$$I_Z = I_{max} = \frac{P_{max}}{V} = \frac{3W}{6V} = 0.5A$$ (2.5)

The minimum value of the series resistor

$$R_S = \frac{V_s - V_Z}{I_Z} = \frac{15V - 6V}{0.5A} = 18\Omega$$ (2.5)

10 (a) (i) • Data transmission at long distance may result in undesirable signal disturbances (0.5)

- Analog signals are prone to generation loss (0.5)
- Analog signal are prone to noise and distortion, as opposed to digital signal

which have much higher immunity (0.5)

- Analog signals are generally lower quality signals. (0.5)

(ii) • Receiving antenna (0.5)

- functions opposite to a transmission antenna and receives the amplitude-modulated wave (radio waves) and to the radio amplifier.

• Radio amplifier (0.5)

- Used to amplify the radio wave received by the antenna.

• Intermediate frequency stage (IF) (0.5)

- The intermediate frequencies of the amplified signals are filtered and amplified before feeding it to the demodulator this makes the process of demodulation easier.

• Demodulator (detector) (0.5)

- A device or circuit used to extract ~~or~~ the desired signal from the carrier wave

• Audio amplifier (0.5)

- A component that amplifies the low power electric signals that have become low after IF stage and the process of demodulation

• Loud speaker (0.5)

- Converts the audio signal into sound wave.

10 (b) (i) Is an electronic device which consist of many transistors, it can perform mathematical operations and its output voltage is direct proportional to the input voltage. 02

(ii) Because it has zero voltage. 02

$$A = \frac{-R_2}{R_1} = \frac{-15}{1} = -15$$

$$A = \frac{V_o}{V_{in}}$$

$V_o = A V_{in} = -15 \times 10mV = -150 mV$ 01

$$I_L = \frac{V_o}{R_L} = \frac{-150 \times 10^{-3}}{4 \times 10^{3}} = -3.75 \times 10^{-5} A = -37.5 mA$$ 01

$$I_1 = I_2 = \frac{10 \times 10^{-3}}{10^{3}} = 1 \times 10^{-5} = 10 mA$$ 02

$I_o = I_2 - I_L = 10 - (-37.5) = 47.5 mA$ 01

$$\text{Power gain} = \frac{P_{out}}{P_{in}}$$

$$A_L = \frac{I_L V_o}{I_1 V_{in}} = \frac{-37.5 \times 10^{-6} \times -150 \times 10^{-3}}{10 \times 10^{-6} \times 10 \times 10^{-3}} = 56.25$$ 01

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