2003 TJC Physics Prelim Paper Solutions

Paper 2

1ai) Base unit is a unit that can be accurately and easily reproduced and is unchanging with time. (It cannot be expressed as product or quotient of other base units.) [1]

1aii) [3]

	magnitude	unit
Resistance of a domestic filament lamp	10^3	Ω
Earth's magnetic field strength	10^{-5}	T
Size of nucleus	10^{-14}	m

1bi) [3]

$$[Q] = \left[\frac{kr^3(P_1 - P_2)}{l}\sqrt{\frac{M}{RT}}\right]$$

$$= \frac{(m^3)(kgm^{-1}s^{-2})}{m}\left(\frac{kg\,mol^{-1}}{kgm^2 s^{-2} K^{-1} mol^{-1} K}\right)^{\frac{1}{2}}$$

$$= kg\ s^{-1}$$

1bii) [2]

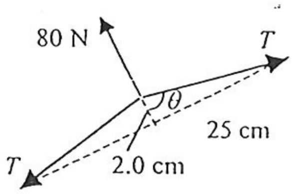
$$3\frac{\Delta r}{r} \times 100\% = 3\left(\frac{0.03}{1.67}\right) \times 100\%$$

$$= \pm 5.4\%$$

2a) - Net force in any direction is zero. i.e. $\sum F = 0$

- Net moment about any axis is zero. i.e. $\sum \tau = 0$ [2]

2b)



$$\tan\theta = \frac{25}{2.0} = 12.5 \Rightarrow \theta = \tan^{-1}(12.5)$$

$$2T\cos\theta = 80$$

$$T = \frac{40}{\cos\theta} = \frac{40}{\cos\left[\tan^{-1}(12.5)\right]} = 502\ \text{N}$$ [4]

2c) -Since boy Y is heavier than boy X, plank is likely to overturn clockwise.
-When plank is about to overturn, $F_X = 0$.
-Let x be the distance traveled by both in time t.
-Take moment about C,

$$50\ g\ x = 20\ g\ (2.0) + 20\ g\ (4.0 + x)$$ [4]

$$x = 4.0\ \text{m}$$

$$v = \frac{x}{t} \Rightarrow 1.0 = \frac{4.0}{t} \Rightarrow t = 4.0\ \text{s}$$

3ai) A satellite in this orbit is always directly over the same geographical location. The period of its orbit is the same as that of the Earth's rotation about its axis, i.e, 24 hrs. The angular velocity of this orbit and the Earth's rotation about its axis are equal. [1]

3aii) [3]

$$\frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$

$$r = \left(\frac{GMT^2}{4\pi^2}\right)^{1/3}$$

$$= \left[\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 3600)^2}{4\pi^2}\right]^{1/3}$$

$$= 4.23 \times 10^7\ \text{m}$$

3aiii) [2]
- The Earth rotates from West to East, thus giving the satellite an initial velocity in that direction.
- and the surface speed of the Earth is greatest at the equator. Thus launching the satellite from equator in eastward direction will save fuel.

3bi) [1]

$$\frac{GM_E m}{r^2} = \frac{mv^2}{r}$$

K. E. of satellite, $T = \frac{1}{2}mv^2 = \frac{GM_E m}{2r}$

3bii) [2]

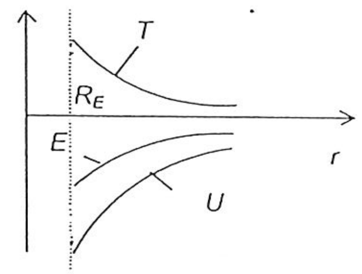
$$U = -\frac{GM_E m}{r}$$

Total energy $E = T + U$

$$= \frac{GM_E m}{2r} + \left(-\frac{GM_E m}{r}\right)$$

$$= -\frac{GM_E m}{2r}$$

3biii) [3]



3biv) - The satellite will move in smaller orbit
- with increasing speed or increasing kinetic energy. [2]

4ai) Simple harmonic motion refers to an oscillatory motion of a particle whose acceleration is directly proportional to its displacement from the equilibrium position and this acceleration is always directed towards that position. [2]

4aii) Damping occurs when an oscillatory system is subject to external dissipative forces, resulting in a gradual loss of energy. [1]

4bi) Vertical displacement of the mass from the equilibrium position. [1]

4bii) Display shows 4 complete cycles. [2]

Hence, frequency = $\frac{4}{2.0}$ = 2.0 Hz

4biii) Let the ratio of an amplitude to the preceding amplitude be k. [3]
Since the amplitude decays by half over 4 cycles, $k^4 = 0.5 \Rightarrow k = 0.5^{1/4}$
Since energy is proportional to square of amplitude,
Ratio of energy in a cycle to the preceding cycle = $k^2 = 0.5^{2/4} = 0.71$

OR

From graph $\left(\frac{A'}{A}\right)^4 = \frac{1}{2}$ where A' and A are two consecutive amplitudes .

Since energy is proportional to square of amplitude,

$$\frac{E'}{E} = \left(\frac{A'}{A}\right)^2 = \left(\frac{1}{\sqrt{2}}\right) = 0.71$$

4biv) [1]

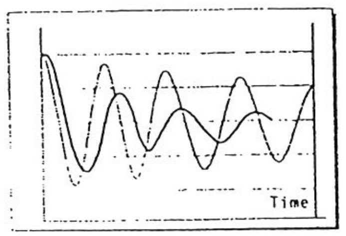


Fig 4.2

5a) [2]

$$V_A = \frac{1200}{1500 + 1200} \times 12 = 5.33\ \text{V}$$

$$V_B = \frac{1000}{1000 + 1000} \times 12 = 6.0\ \text{V}$$

5b) [2]

- since $V_A < V_B$, the output of the comparator will saturate at -12 V.

- therefore the LED will be reversed-biased and will not light up.

5c)
- The resistance of the thermistor will increase to a very high value and V_A will be higher than V_B. The output of the comparator will then saturate at +12 V
- and the LED will be forward-biased and will light up.

5d) - The circuit can be used in cold countries to turn on heaters through relays at very low temperature. [1

6a) Electric potential is the work done per unit charge by an external agent in bringing a positive charge from infinity to the point. [

6bi) $U = \frac{Q^2}{4\pi\varepsilon_o r} = \frac{(8.0 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})1.0 \times 10^{-9}}$ [2

$= 5.75 \times 10^{-18}$ J

6bii) Electric potential energy = 0 when the charges are very far apart [3
Using conservation of energy,
$\Delta U = \Delta KE$

$5.75 \times 10^{-18} = 2\left(\frac{1}{2} m v^2\right) = mv^2 = 2.0 \times 10^{-27} v^2$

$v = 5.36 \times 10^4$ m s^{-1}

6c)
- for the system to be stationary, net electric force must be zero for each of the charges.
- net electric force is zero at Z as charges at X and Y are equal and opposite.
- for net electric force at X (or at Y) to be zero,

$F_{ZX} = F_{YX}$

$$\frac{Q^2}{4\pi\varepsilon_o r^2} = \frac{Qq}{4\pi\varepsilon_o(\frac{r}{2})^2}$$

-Q (X) —— $\frac{r}{2}$ —— q (Z) —— $\frac{r}{2}$ —— -Q (Y)

$$\Rightarrow q = \frac{Q}{4} = \frac{8.0 \times 10^{-19}}{4} = 2.0 \times 10^{-19}\ \text{C}$$ [4

-The magnitude of this charge is not possible as it is not an integral multiple of basic electronic charge (e = 1.60×10^{-19} C).

7a)
- Absorption line spectrum is produced by passing a beam of white light through a cool vapour. Or: Specific wavelengths corresponding to difference in the energy levels are absorbed by the atoms but re-emitted in all directions when atoms return to ground state and hence missing from the spectrum. [
- Emission line spectrum is produced by the excitation of the atoms in a vapour or gas. Or: It is produced by excited atoms in a discharge tube returning to ground state.
- Absorption line spectrum consists of dark lines on a coloured background.
- Emission line spectrum consists of coloured lines on a dark background.

7bi) Both spectra are produced by the transition of electrons in the same set of energy levels of the element. [1]

7bii) Emission lines are produced by transition between any two energy levels whereas absorption lines are produced only by transition between the lowest energy level and a higher level. [2]

7c) $\frac{hc}{\lambda} = E_2 - E_1$ [3]

$\lambda = \frac{hc}{E_2 - E_1}$

$\lambda_1 = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{3.38 \times 10^{-19} - 0} = 5.89 \times 10^{-7}$ m

$\lambda_2 = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{4.81 \times 10^{-19} - 0} = 4.14 \times 10^{-7}$ m

8a) $t_{½} = \frac{\ln 2}{\lambda}$ [2]

$= \frac{\ln 2}{4.18 \times 10^{-9}}$

$= 1.66 \times 10^8$ s

8b) $\frac{\lambda}{M_m} = \frac{5.59 \times 10^{-7}}{0.032} = 1.75 \times 10^{-5}\ \text{kg}^{-1}\,\text{s}^{-1}$ [2]

8ci) - Sodium has the greatest activity per unit mass. [3]

- Activity per unit mass = $\frac{A}{M} = \frac{\lambda N}{M} = \frac{\lambda N_A}{M_m}$

- Sodium has the largest ratio $\frac{\lambda}{M_m}$

8cii) $A = \frac{\lambda N_A}{M_m} \times M$

$= \frac{1.28 \times 10^{-5} \times 6.02 \times 10^{23}}{0.024} \times 2.0 \times 10^{-12}$ [2]

$= 6.42 \times 10^8$ Bq

8di) - It is worthwhile to store ^{24}Na and ^{32}P.

- Several half-lives would have elapsed for ^{24}Na and ^{32}P. Their activities would be greatly reduced. [3]

- The activities of ^{60}Co and ^{241}Am hardly change in 3 months.

8dii) This is to ensure that the activity of the radioactive waste has decreased to a safe level so that it does not cause environmental hazard or pollution. [1]

8e) - When ^{241}Am nuclei decay, 85% of α-particles emitted have higher energy of 8.78×10^{-13} J and 13% have energy 8.70×10^{-13} J. [3]

- 2% of α-particles are unaccounted for.

- When a ^{60}Co nucleus decays, a β-particle and two γ-ray photons are emitted.

8f) Energy produced in each decay = (0.496 + 1.87 + 2.13) × 10^{-13} = 4.496×10^{-13} J [4]

The required activity to produce the power

$= \frac{2000}{4.496 \times 10^{-13}} = 4.448 \times 10^{15}$ Bq

Volume of cobalt = $\frac{4.448 \times 10^{15}}{3.00 \times 10^6} \times 2.68 \times 10^{-9}$

$= 3.97\ \text{cm}^3$

~ End of Paper 2 solution ~