2003 TJC Prelim P2

Tan Zhi Yong 03S6A

(24)

2

Mr Jenson Ong

1 (a) (i) Explain the meaning of the term *base unit.* [1]

....

....

....

(ii) Give an SI unit and an estimate of the magnitude of each of the following physical quantities. (Marks will be awarded for the correct order of magnitude of each estimate, not for its accuracy.) [3]

	magnitude	unit
Resistance of a domestic filament lamp	10^3	Ω
Earth's magnetic field strength	10^{-5} 9.81	ms^{-2} T
Size of nucleus	10^{-15} 10^{-14}	m

1

(b) (i) The theory of gas flow through small diameter tubes at low pressures is an important consideration of high vacuum technique. One equation which occurs in the theory is

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

8.31

where *k* is a number without units, *r* is the radius of the tube, P_1 and P_2 are the pressures at each end of the tube of length *l*, *M* is the molar mass of the gas, *R* is the molar gas constant and *T* is the thermodynamic temperature. Use the equation to find the base units of *Q*. [3]

Units of $r^3 = m^3$
Units of $P = Nm^{-2}$
Units of $l = m$
Units of $M = kg\,mol^{-1}$
Units of $T = K$
Units of $R = ?$

Units of $Q = \frac{m^3 Nm^{-1}}{m}\sqrt{\frac{kg\,mol^{-1}}{K}}$

0

(ii) In using the equation given in (b)(i), the value of *r* is $(1.67 \pm 0.03) \times 10^{-4}$ m. What percentage uncertainty does this introduce into the value of *Q*? [2]

$\frac{\Delta Q}{Q} = 3\frac{\Delta r}{r}$

% uncertainty $= 3\left(\frac{0.03}{1.67}\right) \times 100\%$
$= 16.2\%$ (3s.f)

check!

1

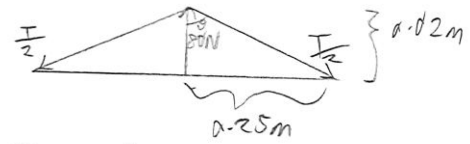
2 (a) State the two conditions for a rigid body to be in equilibrium under the action of coplanar forces. [2]

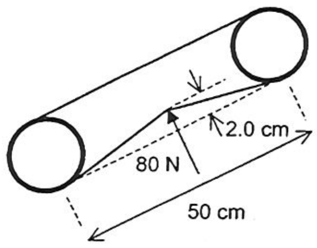
Net force is 0N about any direction

Net torque is 0Nm about any axis

1

(b) A mechanic tests the tension in a car fan belt by pushing its midpoint with a force of 80 N as shown in the diagram below. If the free length of the belt between the pulleys is 50 cm, what is the tension in the belt when the mechanic pushes on it? [4]





1

$2\frac{T}{2}\cos\theta = 80$

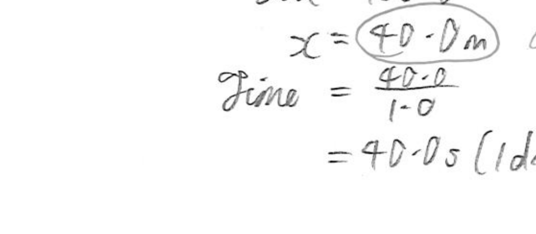
$T = 2\left(\frac{80}{\cos\theta}\right)$

$= 2\left(\frac{80}{\cos(\tan^{-1}(\frac{0.25}{0.02}))}\right)$

$= 2010\,N$ (3s.f)

α

(c) A uniform plank is 14.0 m long and is of mass 20 kg, being supported at **B** and **C**. Two boys X and Y are of masses 20 kg and 50 kg respectively. X starts to walk towards **A** and Y towards **D**. If the boys walk at 1.0 m s^{-1}, calculate the time when the plank begins to overturn. [4]



2

Taking moment about C,

$50g\,x = 20g(2.0) + 20g(x+4)$

$50x = 40.0 + 20x + 80$

$30x = 120.0$

$x = 40.0\,m$ check!

Time $= \frac{40.0}{1.0}$

$= 40.0\,s$ (1d.p)

3 A communication satellite is put into a geostationary orbit round the Earth.

(a) (i) State a *unique* feature of a geostationary orbit. [1]

The orbit is parallel to the Earth's equator.

explain 0

(ii) The mass of the Earth is 5.98×10^{24} kg. Find the radius of the geostationary orbit. [3]

$mr\omega^2 = \frac{GMm}{r^2}$

$\frac{4\pi^2 r^3}{T^2} = GM$

$r^3 = \frac{GMT^2}{4\pi^2}$

$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$

$= \sqrt[3]{\frac{6.67\times10^{-11}\times5.98\times10^{24}\times(24\times3600)^2}{4\pi^2}} = 4.23\times10^{7}\,m$

3

(iii) Explain why it is advantageous to launch a satellite at the equator in the eastward direction. [2]

It will be moving in the same direction as the Earth from west to east, thus the horizontal displacement is lower and less air resistance is encountered. 0

(b) (i) Show that the kinetic energy T of a satellite of mass m moving in a circular orbit of radius r round the Earth of mass M_E is given by $T = \frac{GMm}{2r}$. [1]

$T = \frac{1}{2}mv^2$

$= \frac{1}{2}m(r\omega)^2$

$= \frac{\omega^2 r^2 m}{2}$

$= \frac{4\pi^2 r^2 m}{2T^2}$

$= \frac{4\pi^2 r^2 m}{2\left(\frac{4\pi^2 r^3}{GM}\right)} = \frac{GMm}{2r}$ shown

1

(ii) Write down an expression, in terms of G, m, M_E and r, for the gravitational potential energy U of the satellite. Hence derive an expression for the total energy E of the satellite. [2]

$U = -\frac{GMm}{r}$

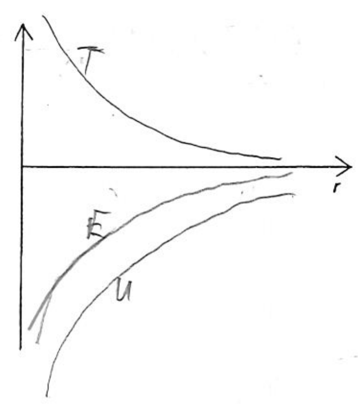
$E = U + T$

$= -\frac{GMm}{r} + \frac{GMm}{2r}$

$= -\frac{GMm}{2r}$

2

(iii) On the same axes, sketch graphs to show how E, T and U vary with orbit radius r of the satellite. [3]



2

(iv) Over a period of time, atmospheric friction reduces the energy of the satellite. Describe the effect of atmospheric resistance on the motion of the satellite. [2]

The satellite will increase in speed and decrease in height until it strikes the Earth.

1

4 (a) Explain the meaning of the following terms:

$a \propto -kx$

(i) *simple harmonic motion*

The acceleration of the object is directly proportional to its displacement from equilibrium and always in opposite direction to its motion.

2½

(ii) *damping* [3]

The gradual loss of energy of a system in periodic motion to its surroundings. due to

(b) Fig 4.1 shows a data logger used with a computer to demonstrate the oscillatory motion of a vertical mass-spring system. The movement of the mass is converted into electrical signals by a sensor, which is connected to the computer. Fig 4.2 shows the result displayed on the screen of the computer and sampled over a duration of 2.0 s.

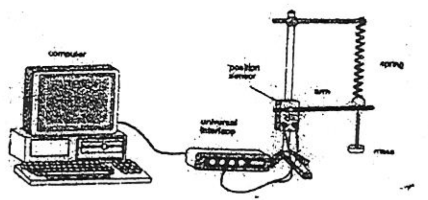
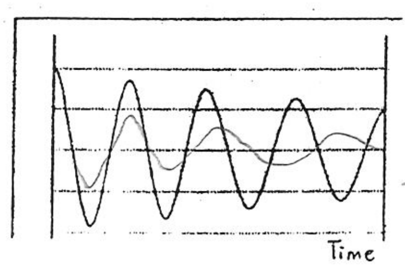


Fig 4.1



1

Fig 4.2

(i) What physical quantity of the motion is being represented by the vertical axis on the display in Fig 4.2? [1]

Wavelength.

0

(ii) Determine the frequency of oscillation of the mass-spring system. [2]

$f = \frac{4}{2.0}$

$= 2.00 Hz$ (3s.f)

2

(iii) By comparing the amplitudes of motion at the start and at the end of the 2.0 s duration, determine the ratio of energy in a cycle to the preceding cycle. (The energy of the oscillation is proportional to the square of the amplitude) [3]

$E \propto A^2$

0

Rate of energy loss is exponential in damping $T = 0.5 s$

$A = A_0 e^{-kt}$

After 2.0s,

$A = \frac{1}{2} A_0$

$\frac{1}{2} A_0 = A_0 e^{-2.0k}$

$\frac{1}{2} = e^{-2.0k}$

$k = 0.3466$

$A = A_0 e^{-0.3466t}$

$E = kA^2$

$= k A_0^2 e^{-t\ln 2}$

$\frac{E_2}{E_1} = \frac{kA_0^2 e^{-\ln 2}}{kA_0^2 e^{-0.5\ln 2}}$

$= e^{-1.5\ln 2}$

(iv) Sketch on Fig 4.2 another graph which you would expect when a piece of cardboard is attached to the base of the mass. [1]

5 The diagram in Fig. 5.1 shows an op-amp being used as a comparator. The LED emits light when the output from the op-amp is positive and high. The thermistor with resistance R_t used in the circuit is a negative temperature coefficient type and has a resistance of 1200 Ω at a temperature of 30 °C.

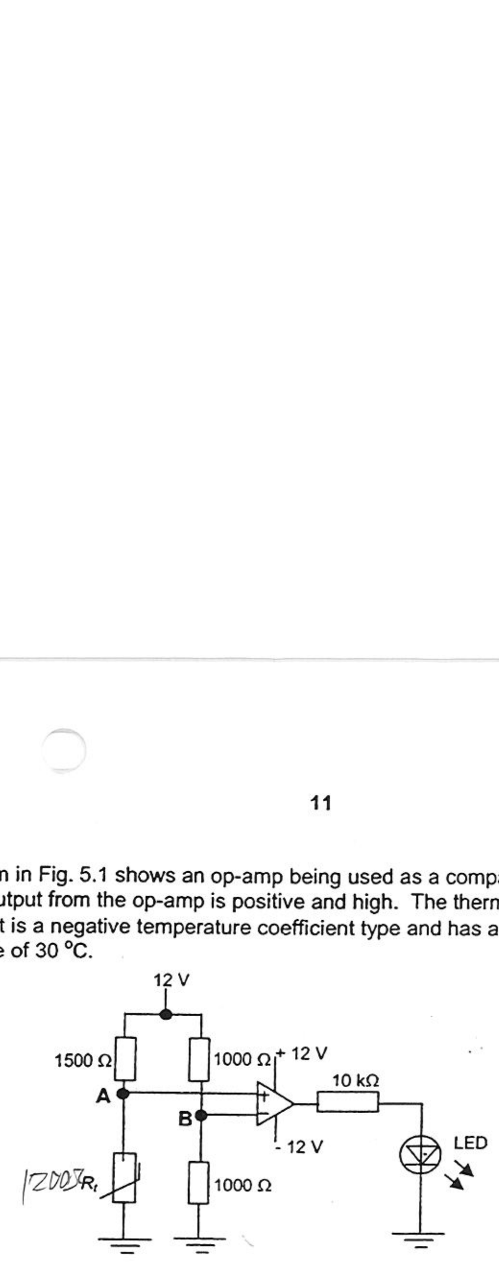


Fig. 5.1

(a) Determine the potentials at the points **A** and **B** when the temperature is 30 °C. [2]

$V_A = \frac{1500}{1500+1200}(12)$

$= 6.67 V$ (3s.f)

$V_B = \frac{1000}{1000+1000}(12)$

$= 6.00 V$ (3s.f)

1

(b) Hence determine whether the LED at the output of the comparator will light up. [2]

Since the potential differences of V_+ and V_- are large, output will be saturated and the LED will light up.

Since it is ~~for~~ reverse-biased

1

(c) Explain what will happen when the temperature drops to a very low value. [2]

When temperature drops to a low value, V_A will fall due to rise of R_t. The difference between V_A and V_B will become very small and output current is not saturated. The LED will become dimmer.

0

(d) Suggest a use for this circuit. [1]

Fire alarm. ✗ 0

6 (a) With reference to a point in an electric field, define the term *electric potential*. [1]

Electric potential at a point in an electric field refers to the amount of work needed to bring a unit positive charge from infinity to that point. 1/2

(b) Two identical negatively charged particles **X** and **Y**, each of mass 2.0 x 10^{-27} kg and charge -8.0 x 10^{-19} C are held at a distance 1.0 x 10^{-9} m apart. $N = kg\,m\,s^{-2}$ $= kg\,m\,s^{-3}$

(i) Find the electric potential energy stored in the system. [2]

$EPE = \frac{Q_0}{4\pi\epsilon_0 r^2}$ ✗ 0

$= \frac{2(-8.0\times10^{-19})}{4\pi(8.85\times10^{-12})(1.0\times10^{-9})^2}$

$= 1.44\times10^{10}\ J\ (3s.f)$

(ii) If the charges are released, they will move apart. Calculate their speeds when they are very far apart. [3]

When they are very far apart, all EPE will be converted to KE

$2\times\frac{1}{2}mv^2 = \frac{1}{2}EPE$ 1

$2.0\times10^{-27}v^2 = 1.439\times10^{10}$

$v = 2.68\times10^{18}\ ms^{-1}\ (3s.f)$ ✗

Since particles are of same mass and have equal momentum, their speeds are identical but velocities are in opposite direction

$\therefore$ speeds $= 2.68\times10^{8}\ ms^{-1}\ (3s.f)$

(c) Now another charge **Z** of equal mass is placed in the middle of **XY** so that the system of charges is stationary. Find the sign and the magnitude of **Z**. Comment on the magnitude of this charge. [4]

Charge of Z must be opposite to charges of X & Y to oppose their repulsive forces 0

$Z = -(-8.0\times10^{-19})\times2$ ✗

$= +1.60\times10^{-18}\ C\ (3s.f)$

The $|Z|$ is twice that of X or Y so the net force exerted on each charge is 0N.

7 (a) Distinguish between *absorption line spectrum* and *emission line spectrum*. [4]

In absorption line spectrum, light is shone through a thin layer of the element and the resultant light is viewed. There will be gaps in the visible light spectrum emitted due to absorbtion of those light wavelengths by electrons of the element. ✗ 0

(b) (i) Explain why the lines in the absorption line spectrum match some of those in the emission line spectrum produced by the same element. [1]

....

....

(ii) Explain why, for a given element, the number of lines in an emission line spectrum is normally greater than the number of lines in the absorption line spectrum. [2]

....

....

....

....

(c) Fig. 7.1 shows three of the lowest energy levels of an atom. A beam of white light is passed through the cool vapour of the atoms. Find the wavelengths in the white light which are absorbed by the atoms. [3]

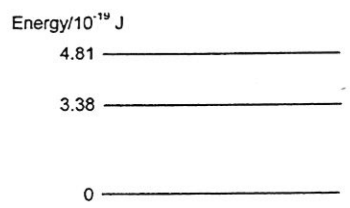


Fig 7.1

8 The table gives the half-lives of four radioactive nuclides together with some of the decay constants. The fifth column lists the significant emissions from the nuclides together with their energies. The total number of each of the emissions as a percentage of the total number of nuclei which decay is also given.

nuclide	*half-life/s*	*decay constant/s*$^{-1}$	$\frac{\lambda}{M_m}$ / kg^{-1} s^{-1}	*emissions* *type*	*emissions* *energy*/× 10^{-13} J	*emissions* *percentage*
Americium ^{241}Am	1.48 × 10^{10}	4.68 × 10^{-11}	1.94 × 10^{-10}	α	8.78	85
				α	8.70	13
Cobalt ^{60}Co		4.18 × 10^{-9}	6.97 × 10^{-8}	β	0.496	100
				γ	1.87	100
				γ	2.13	100
Phosphorus ^{32}P	1.24 × 10^{6}	5.59 × 10^{-7}		β	2.74	100
Sodium ^{24}Na	5.42 × 10^{4}	1.28 × 10^{-5}	5.33 × 10^{-4}	β	9.60	100
				γ	2.19	100
				γ	4.11	100

(a) Calculate the half-life of ^{60}Co. [2]

(b) Calculate the ratio $\frac{\lambda}{M_m}$ for ^{32}P where λ is the decay constant and M_m the molar mass of the nuclide. [2]

(c) (i) Which of the nuclides has the greatest activity per unit mass? Explain your answer. [3]

....

....

....

(ii) Calculate the activity of a mass of 2.0×10^{-12} kg of the nuclide which you have named in (i). [2]

(d) (i) A laboratory has facilities suitable for the storage of waste radioactive material for periods not exceeding 3 months (7.8×10^{6} s). For which of the nuclides would storage for 3 months before disposal be worthwhile? Give your reasons. [3]

....

....

....

....

(ii) Why must radioactive waste normally be stored for a period of time before disposal? [1]

....

....

....

(e) Give an explanation for the figures in the percentage column for the nuclides ^{60}Co and ^{241}Am. [3]

....

....

....

....

....

(f) A power source with an output of 2.00 kW is required for use in a space probe. This power is to be derived from the energy of the emitted radiations from the nuclide ^{60}Co. It is known that 2.68×10^{-9} cm^3 of this nuclide has a total activity of 3.00×10^{6} Bq. What volume of cobalt is required? [4]