Tan Zhi Yong 03S6H

2003 VJC Prelim P2

See

1 (a) (i) What is meant by **random error** ?

A scatter of values about a mean value.

[1]

(ii) Name two ways whereby random errors can be reduced.

Take the average of a few values.

Ensure that experimental conditions are as constant as possible.

[2]

(b) Young's Modulus E of a material is given by

$$E = \frac{FL}{Ae}$$

where F = force exerted on the material,
L = original length of the material,
A = cross-sectional area of the material over which the force acts,
e = extension of the material.

A student performs an experiment to find Young's Modulus of an unknown material. The material is cylindrical in shape. The student records the readings as follows:

Force exerted, $F = (10.0 \pm 0.1)$ N
Original length, $L = (40.0 \pm 0.1) \times 10^{-2}$ m
Extension, $e = (0.50 \pm 0.01)$ mm
Diameter of the material, $d = (0.38 \pm 0.01)$ mm

(i) Determine the SI base units of Young's Modulus.

Units of $F = N$
$= kg\,ms^{-2}$
Units of $L = m$
Units of $A = m^2$
Units of $e = m$

Units of $E = \frac{kg\,ms^{-2}\,m}{m^2\,m}$
$= kg\,m^{-1}s^{-2}$

Units of Young's Modulus: $kg\,m^{-1}s^{-2}$ [2]

$\frac{\Delta A}{A} = 2\frac{\Delta d}{d}$

(ii) Find the value of Young's Modulus and its associated uncertainty.

$A = \pi r^2 = \frac{\pi d^2}{4}$

$\frac{\Delta E}{E} = \frac{\Delta F}{F} + \frac{\Delta L}{L} + \frac{\Delta A}{A} + \frac{\Delta e}{e}$

$= \frac{0.1}{10.0} + \frac{0.1 \times 10^{-2}}{40.0 \times 10^{-2}} + \frac{0.01}{0.50} + 2\frac{\Delta d}{d}$

$= 0.08266$

$E = \frac{10.0(40.0)10^{-2}}{\frac{\pi\left(\frac{0.38}{1000}\right)^2}{4}\left(\frac{0.50}{1000}\right)}$

$\Delta E = 5.83 \times 10^9$ (3s.f)

$= 7.054 \times 10^{10}\ kg\,m^{-1}s^{-2}$ (3s.f)

Young's Modulus = $(7.054 \pm 0.583)10^{9}\ kg\,m^{-1}s^{-2}$ [5]

ΔE to 1 s.f.

2 A satellite of mass m orbits the Earth in a circular path of radius r. The period of the orbital motion is T and the mass of the Earth is M. Assume that the Earth is spherical and uniformly dense.

(a) Find the acceleration of the satellite in terms of r and T.

$g = \frac{GM}{r^2}$

$a_c = r\omega^2$
$= r\left(\frac{2\pi}{T}\right)^2$
$= \frac{4\pi^2 r}{T^2}$

[2]

(b) (i) Show that $T^2 = \frac{4\pi^2}{GM}r^3$.

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

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

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

[2]

[Turn over

(ii) If the orbital radius of the satellite increases by 10 %, find the corresponding change in period.

$T^2 \propto r^3$

$r \propto T^{\frac{2}{3}}$

$r = kT^{\frac{2}{3}}$

$\frac{\Delta r}{r} = \frac{2}{3}\frac{\Delta T}{T}$

$\frac{\Delta r}{r}(100) = \frac{200}{3}\frac{\Delta T}{T}$

if $\frac{\Delta r}{r} \times 100\% = 10\%$, $10 = \frac{200}{3}\frac{\Delta T}{T}$

$\Delta T = \frac{3}{20}T$

?

[4]

(c) Find, in terms of G, M, m and r,

(i) an expression for the kinetic energy of the satellite,

$\frac{mv^2}{r} = \frac{GMm}{r^2}$

$v^2 = \frac{GM}{r}$

$K.E = \frac{1}{2}mv^2$

$= \frac{1}{2}m\left(\frac{GM}{r}\right)$

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

[2]

(ii) an expression for the total mechanical energy of the satellite.

$\phi = -\frac{GM}{r}$

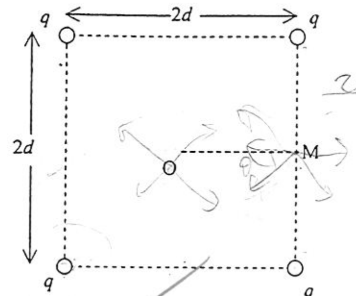
$U = -\frac{GMm}{r}$

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

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

[2]

3 Four identical charges q are positioned at the corners of a square of side $2d$ as shown below.



2d

$\sqrt{\left(\frac{d}{2}\right)^2 + \left(\frac{d}{2}\right)^2}$

$\sqrt{\frac{d^2}{2}}$

(a) State the magnitude of the strength of the electric field at point O, the centre of the square.

0 [1]

(b) Derive an expression for the electric potential at point O in terms of π, q, d and ε_o (permittivity of free space).

$V = \frac{q}{4\pi\varepsilon_o r}$

$= \frac{q}{4\pi\varepsilon_o \sqrt{d^2}}$

$= \frac{q}{4\pi\varepsilon_o d}$

electric potential at point O = $\frac{q}{4\pi\varepsilon_o d}$ [2]

(c) Show that the electric potential at point M is given by $\frac{q}{2\pi\varepsilon_o d}\left(1 + \frac{1}{\sqrt{5}}\right)$.

$V_m = \left(\frac{q}{4\pi\varepsilon_o\sqrt{(2d)^2+d^2}}\right)\left(\frac{2d}{\sqrt{(2d)^2+d^2}}\right)$

$= \frac{q}{2\pi\varepsilon_o\sqrt{5d^2}}\left(\frac{d}{\sqrt{5d^2}}\right)$

$= \frac{q}{2\pi\varepsilon_o}\left(\frac{d}{5d^2}\right)$

$= \frac{q}{2\pi\varepsilon_o}\left(\frac{1}{5d}\right)$

$= \frac{q}{2\pi\varepsilon_o d}\left(\frac{1}{5}\right)$

[4]

(d) Show that the **minimum** initial speed v a proton (of mass m and charge e) must have for it to escape from the square, if it starts off from point O and travels along line OM, is given by

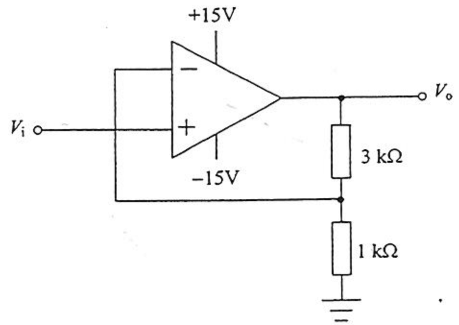
$$v = k\sqrt{\frac{eq}{\varepsilon_o dm}}$$

What is the value of k ?

?

[3]

4 (a) An ideal operational amplifier has power supplies of +15 V and −15 V.



(i) Assuming that the output voltage V_o remains unsaturated, determine the relationship between V_o and V_i.

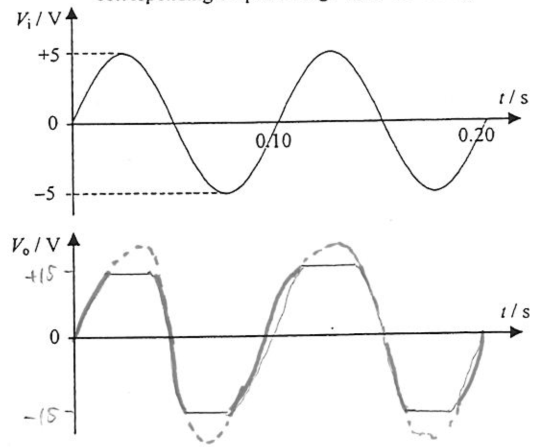
$A = 1 + \frac{3000}{1000}$

$= 4$

$V_o = 4V_i$

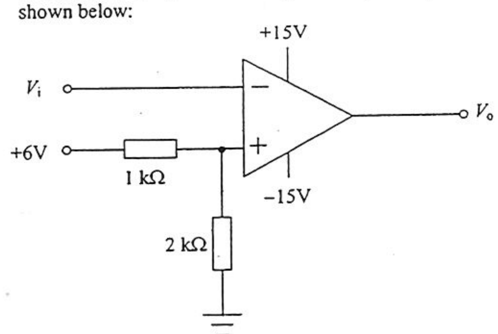
Relationship between V_o and V_i : $V_o = 4V_i$ [2]

(ii) A sinusoidal voltage of frequency 10 Hz and amplitude 5 V is now applied to the non-inverting input terminal. This input voltage is shown in the graph below as V_i. Sketch the corresponding output voltage V_o in the axes given below.



[2]

(b) An operational amplifier is set up in the open-loop configuration as shown below:



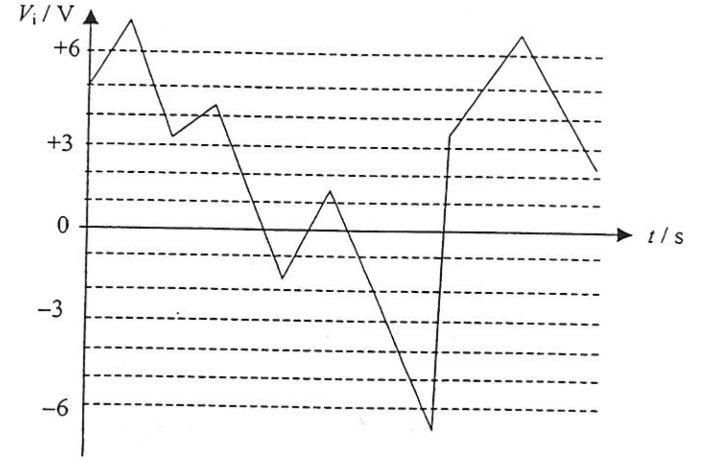
(i) What is the potential at the non-inverting terminal ?

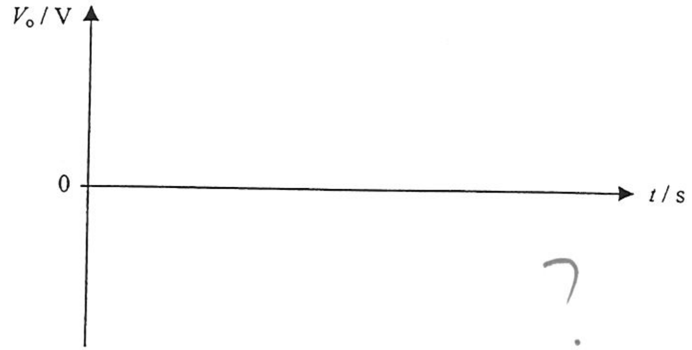
?

Potential at non-inverting terminal = ____________ V [1]

[Turn over

(ii) The random voltage signal shown below is applied to the inverting terminal of the operational amplifier. In the axes below, sketch the corresponding output voltage V_o.

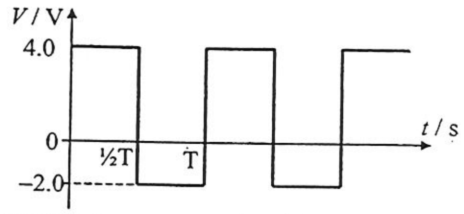




?

[2]

5



(a) Find the root-mean-square value of the voltage waveform above.

$T = T$

$V_0 = 4.0$ in +ve dir

$= -2.0$ in −ve dir

$V_{ave} = \frac{4.0 - 2.0}{T}$

Area under V^2 $= (16.0 \times \frac{T}{2}) + (4.0 \times \frac{T}{2})$

$= 10\,T$

$\langle V^2 \rangle = 10$

$V_{rms} = \sqrt{10}$

$= 2\sqrt{2}$

Root-mean-square voltage = $2\sqrt{2}$ V [3]

(b) Find the mean power dissipated if this voltage is applied across a resistor of fixed resistance 5.0 Ω.

Power $= I^2 R$

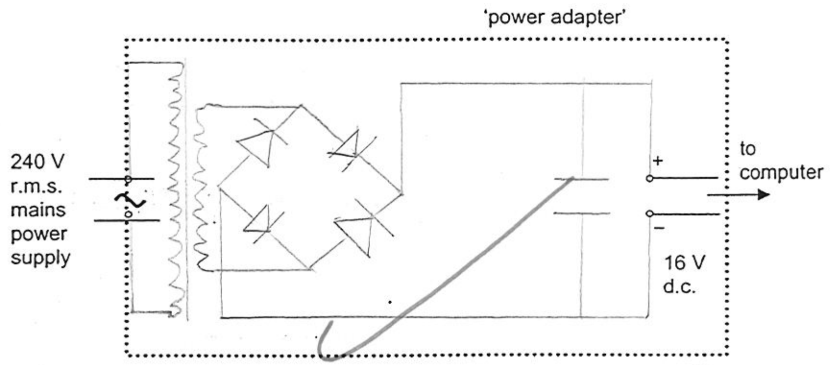
$= \frac{V^2}{R} = \frac{(2\sqrt{2})^2}{5.0} = 2.0$

Power dissipated in resistor = 2.0 W [2]

[Turn over

(c) The 'power adapter' of a portable computer serves to convert the 240 V r.m.s. a.c. mains voltage into a constant 16 V d.c. voltage that the computer can use. To do so, it contains a transformer, a full-wave rectifier circuit and a capacitor with a large capacitance.

(i) In the diagram below, complete the circuit of this 'power adapter'.



[3]

(ii) Calculate the turns ratio (primary : secondary) of the transformer used.

$\frac{V_s}{V_p} = \frac{N_s}{N_p}$

$\frac{16}{240} = \frac{N_s}{N_p}$

$\frac{N_p}{N_s} = 15$

Turns ratio of transformer = 15 [2]

refer to tutorial.

91608684

6 (a) An electron of mass m and charge e is projected at a velocity v_x at right angles to a uniform electric field E mid-way between two plane, parallel, charged plates.

(i) Show that the path is parabolic and given by

$$y = \frac{eE}{2mv_x^2}x^2$$

where y = vertical displacement, and x = horizontal displacement.

Electron will travel vertically due to E and horizontally due to V of charged plates

$E = \frac{q}{4\pi\varepsilon_0 r}$ $V = \frac{E}{x}$

?

[3]

(ii) Find the vertical displacement of the electron after it has travelled a horizontal displacement of 1.5 cm. The electric field strength is 1.2×10^4 N C^{-1} and the electron enters the field with a kinetic energy of 2.0 keV.

$y = \frac{1.60\times10^{-19} \times 1.2\times10^4}{4(2000)}\left(\frac{1.5}{100}\right)$?

$= 3.60\times10^{-21}$ m (3s.f)

Vertical displacement = 3.60×10^{-21} m [3]

(b) A proton of charge e and mass m moves in a circular path of radius r in a plane perpendicular to a uniform magnetic field of magnitude B.

(i) Show that the kinetic energy of the proton is given by

$$K = \frac{e^2r^2B^2}{2m}$$

?

[2]

[Turn over

(ii) If the proton has a kinetic energy of 10 eV, what is the kinetic energy of an alpha particle moving in the same circular path in the same magnetic field ?

?

Kinetic energy of alpha particle = __________ eV [2]

(iii) What path would a proton travel if it were injected into the magnetic field at an acute angle to the magnetic field lines ?

__________ [1]

7 (a) A hydrogen atom undergoes a transition from the –3.4 eV level to the –13.6 eV level. Calculate the wavelength of light emitted.

$E = \frac{hc}{\lambda}$

$\lambda = \frac{hc}{E}$

$= \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{[-3.4-(-13.6)] \times 1.60 \times 10^{-19}}$

$= 1.22 \times 10^{-7}$ m (3s-f)

Wavelength of light = 1.22×10^{-7} m [2]

(b) The light emitted in (a) is made to fall on cesium whose work function energy is 1.8 eV.

(i) Calculate the threshold frequency for cesium.

$1.8 \times 1.60 \times 10^{-19} = hf$

threshold $f = \frac{1.8 \times 1.60 \times 10^{-19}}{6.63 \times 10^{-34}}$

$= 4.34 \times 10^{14}$ Hz (3s-f) careless

Threshold frequency = 4.34×10^{14} Hz [2]

(ii) What is the maximum kinetic energy of emitted electrons ?

Max KE $= 8.4 \times 1.60 \times 10^{-19}$

$= 1.34 \times 10^{-18}$ J (3s-f)

Maximum k.e. of electrons = 1.34×10^{-18} J [2]

(iii) If the incident power is 1.0×10^{-6} W, how many photons are incident on the cesium surface per second ?

$1.0 \times 10^{-6} = 1.34 \times 10^{-18} n$

$n = 7.44 \times 10^{-11}$ s^{-1} (3s-f)

No. of photons per second = 7.44×10^{-11} s^{-1} [2]

(iv) The intensity of incident light is now doubled, while the frequency remains unchanged. What effect, if any, does this have on

1. the maximum kinetic energy of photoelectrons ?

No effect. [1]

2. the photoelectric current ?

Doubles. [1]

8 The acceleration due to gravity g of the Earth is known to depend on several factors, one of which is the altitude h above the Earth's surface. It can be shown that for altitudes much smaller than the Earth's radius, the variation of g with h is given as follows:

$$g = g_0 - \frac{2GM}{R^3}h$$

where g_0 is the field strength at the Earth's surface,
G is the universal constant of gravitation,
M is the mass of the Earth, and
R is the Earth's radius.
It is known that $M \approx 6.0 \times 10^{24}$ kg.

Measurements of g were made at and above a certain location on Earth and given in Table 1 below :

h / m	g / m s^{-2}
0	9.806
1,000	9.803
4,000	9.794
8,000	9.782
16,000	9.757
32,000	9.710

Table 1

(a) (i) Write down the value of g_0 by referring to Table 1.

$g_0 = 9.806\ ms^{-2}$ (4s.f) [1]

(ii) Plot a graph of g versus h.

g/ms^{-1}

?

[3]

h/m

(iii) What is meant by the inverse square law as applied to gravitation? Why is the graph plotted in (a)(ii) not consistent with the inverse square law ? What quantities should be plotted to illustrate this law for the case of the Earth ?

Inverse square law: Gravitational potential inversely proportionate to square of radius. Quantities plotted should be g versus (-h)^2.

what radius?

[3]

(iv) Using the graph plotted in (a)(ii), compute a value for the radius of the Earth.

?

Radius of Earth = ____________ m [3]

(v) A jet aircraft is cruising at an altitude of 10.0 km above the surface of the Earth. Calculate a value of g at this altitude to 4 significant figures.

?

g at altitude of 10.0 km = ____________ m s^{-2} [2]

[Turn over

(vi) The acceleration of the Moon due to the Earth is known to be 2.71×10^{-3} m s^{-2}. Determine a value for the distance from the Earth to the Moon.

Distance from Earth to moon = ? m [2]

(b) Table 2 below shows how g varies with latitude at sea level.

latitude	g / m s^{-2}
0°	9.78039
30°	9.79329
60°	9.81818
90°	9.83217

Table 2

(i) What is the difference in values of g at the pole and at the equator ?

$\Delta g = 9.83217 - 9.78039 = 0.05178$ (5d.p)

Difference in values of g = 0.05178 m s^{-2} [1]

$T^2 = kr^3$

r

$g = \frac{GM}{r^2}$

$r = \sqrt{\frac{GM}{g}}$

(ii) Calculate the centripetal acceleration a_c at the equator.

$a_c = r\omega$

$= \sqrt{\frac{GM}{g}} \cdot \frac{2\pi}{24 \times 3600}$

$= 464\ ms^{-2}$ (3s.f)

Centripetal acceleration at the equator = 464 m s^{-2} [3]

(iii) It is thought that the value of g at the equator (g_e) is related to the value of g at the pole (g_p)by the equation

$$g_e = g_p - a_c$$

Is this equation consistent with the data in Table 2 ? ~~Comment on your answer.~~

No. $g_e \neq g_p - a_c$

why?

[2]

VICTORIA JUNIOR COLLEGE
PRELIMINARY EXAMINATION

PHYSICS 9248/3
PAPER 3

Thursday 18 September 2003 8:00 am to 10:30 am

Additional Materials:
Foolscap Writing Paper
Electronic Calculator

Time 2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES

Write your name and CT group in the spaces provided on the top of the foolscap writing paper.

Answer **four** questions from **Section A** and **all** questions from **Section B**.

Write your answers on the separate foolscap writing paper provided.

Start your answer to each question on a fresh page of paper.

If you use more than one sheet of paper, fasten the sheets together.

All working for numerical answers must be shown.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

You are advised to spend about 40 minutes on Section B.

You are reminded of the need for good English and clear presentation in your answers.

This question paper consists of 13 printed pages including this cover sheet.

[Turn Over

Data

Speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
Permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
Permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}
Elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
Unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
Molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	L	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
Gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^{2}kg^{-2}
Acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

Uniformly accelerated motion,	s	$= ut + ½at^2$
	v^2	$= u^2 + 2as$
Work done on/by a gas,	W	$= p\Delta V$
Gravitational potential,	Φ	$= -Gm/r$
Refractive index,	n	$= 1/\sin C$
Resistors in series,	R	$= R_1 + R_2 + ...$
Resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + ...$
Electric potential	V	$= Q/4\pi\varepsilon_o r$
Capacitors in series,	$1/C$	$= 1/C_1 + 1/C_2 + ...$
Capacitors in parallel,	C	$= C_1 + C_2 + ...$
Energy of a charged capacitor,	W	$= ½QV$
Alternating current/voltage,	x	$= x_o \sin \omega t$
Hydrostatic pressure,	p	$= \rho gh$
Pressure of an ideal gas,	p	$= \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
Radioactive decay,	x	$= x_o \exp(-\lambda t)$
Decay constant,	λ	$= 0.693/t_{½}$
Critical density of matter in the Universe,	ρ	$= 3H_o^2/8\pi G$
Equation of continuity,	Av	$= constant$
Bernoulli equation (simplified),	$p_1 + ½\rho v_1^2$	$= p_2 + ½\rho v_2^2$
Stokes' law,	F	$= Ar\eta v$
Reynolds' number,	R_e	$= \rho vr/\eta$
drag force in turbulent flow,	F	$= Br^2\rho v^2$

Section A

Answer any **4** questions from this section.
(You can obtain a maximum of **80 marks** from this section)

1. Figure 1.1 shows two masses connected to a light, *very long* and inextensible string which passes over a fixed, smooth and light pulley.

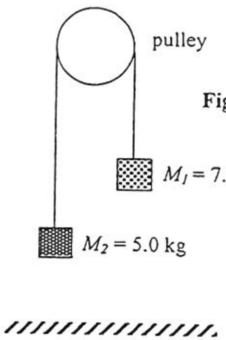


Figure 1.1

(a) (i) Draw a free-body force diagram for each of the two masses. [2]

The system is released from rest and the 7.0 kg mass reaches the ground after 3.0 s.

Calculate

(ii) the magnitude of the acceleration of the masses while the string remains taut. [3]

(iii) the tension in the string before the 7.0 kg mass strikes the ground. [1]

(iv) the vertical distance the 7.0 kg mass falls through before it strikes the ground. [2]

As the 7.0 kg mass moves downwards, the 5.0 kg mass moves vertically upwards.

(v) How far has M_2 displaced vertically from rest before the string loses its tension? What is its velocity at this point? What will be its acceleration as it continues to move upwards *beyond this point*? [3]

(vi) From the point where the tension in the string disappears, find the further vertical distance moved by the 5.0 kg mass before it comes instantaneously to rest, assuming that it does not hit the pulley. [2]

(vii) Draw labelled graphs of acceleration against time and velocity against time for the motion of the 5.0 kg mass from the instant of release to the instant when it reaches its maximum height. [3]

(b)

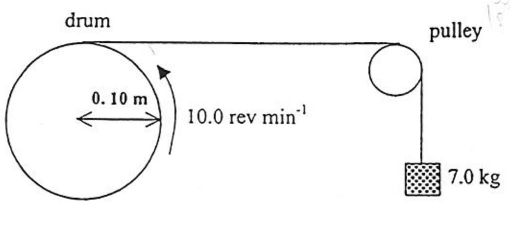


Figure 1.2

The 5.0 kg mass is now disconnected from the pulley, while the 7.0 kg mass is connected via the long string to a drum of radius 0.10 m (see Figure 1.2). The drum is rotated by an electric motor at a steady rate of 10.0 revolutions per minute.

(i) Calculate the time taken to raise the 7.0 kg mass by 2.0 m. [2]

(ii) Assuming that 20 % of the work done by the motor is lost, calculate the power developed by the motor. [2]

2. (a) (i) What is simple harmonic motion ? [1]

A particle oscillates according to the equation $x = x_0 \sin \omega t$ where x is the particle's displacement at time t, x_0 is the amplitude and ω is the angular frequency.

(ii) Sketch labelled graphs of velocity versus time and velocity versus displacement for this particle. [2]

Such a particle has a mass 5.0 g and oscillates with an amplitude of 10.0 cm and a period of 5.0 s.

(iii) Find the interval of time when the displacement of the particle is greater than 4.0 cm in half an oscillation cycle. [3]

(iv) What is the ratio of its kinetic energy to potential energy at displacement 4.0 cm? [3]

(b) All the particles except at the ***nodes*** in a stationary wave, vibrate simple harmonically. The formation of stationary waves can be explained using the ***Principle of Superposition***.

(i) Explain the words in italics. [2]

(ii) A string is vibrating in its fundamental mode. It is suspected that the frequency of vibration f is dependent on the length L of the string, the tension T applied to the string, and the mass per unit length μ of the string. Using the Principle of Homogeneity, determine how f might depend on L, T and μ. [3]

(iii) Like vibrating strings, stationary waves can also be set up in pipes. Compare the length of an open-end pipe with that of a closed-end pipe when both pipes emit the same fundamental note. [3]

(iv) Thomas Young made use of superposition of light waves to produce interference fringes.

A beam of light consisting of two wavelengths 650 nm and 520 nm is used to obtain interference fringes in a Young's double slit experiment. The slit separation is 2.0 mm and the distance between the plane of the double slits and the screen is 1.2 m. What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide? [3]

3. (a) The circuit in Figure 3.1 shows a cell of negligible internal resistance connected to a network of resistors.

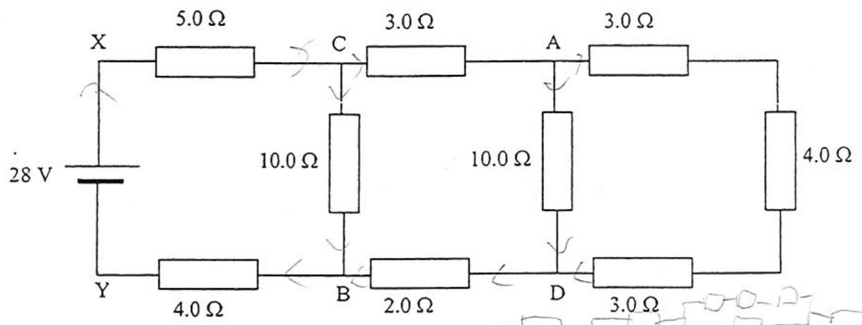


Figure 3.1

(i) Find the equivalent resistance between the points X and Y. [3]

(ii) Calculate the current in the 5.0 Ω resistor. [1]

(iii) What power is dissipated in the entire circuit? [2]

(iv) What fraction of the total power is dissipated in the 10 Ω resistor between points C and B? [3]

(v) Determine the potential difference between points A and B. Which point is at the higher potential? [4]

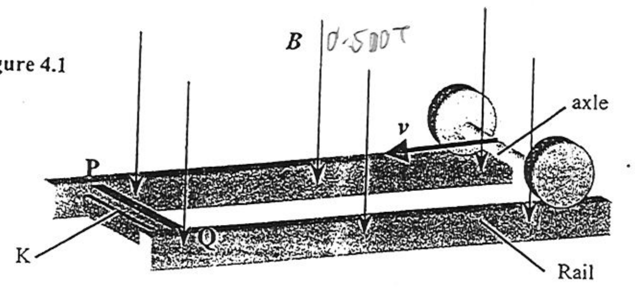
(vi) The 2.0 Ω and 5.0 Ω resistors are made of wires of different materials such that they are of the same cross-sectional area but their respective lengths are in the ratio 0.90. Calculate the ratio of their resistivities. [2]

(b) A metre potentiometer wire is used to determine the internal resistance of a voltaic cell. The e.m.f. of the cell is balanced by a potential difference along 45.0 cm of the wire. When a standard resistor of 5.0 Ω is connected across the cell, the balance length is found to be 30.0 cm. Draw suitable labelled circuit diagrams and calculate the internal resistance of the cell. [5]

4. (a) State the laws of electromagnetic induction. [2]

(b) In Figure 4.1, a rolling axle which is 2.00 m long is pushed along an infinitely long pair of horizontal rails at a constant speed $v = 2.50\ \text{m s}^{-1}$. A resistor K of resistance (R) 0.500 Ω is connected to the rails at points P and Q. A uniform magnetic field (B) of 0.500 T is acting vertically downward as shown. It can be assumed that the wheels always make good electrical contact with the rails during its motion. In addition, it can be assumed that K carries the only significant resistance in a closed-loop circuit formed by the axle, rails and K.

Figure 4.1



(i) Calculate the induced current I in the resistor. [2]

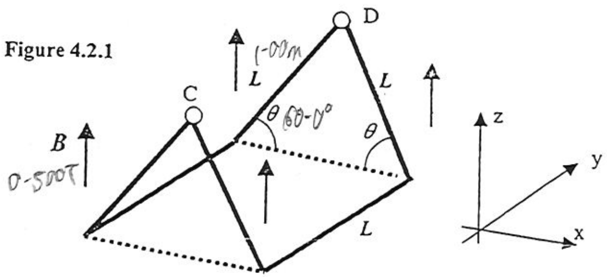
(ii) Calculate the horizontal force F required to keep the axle rolling at constant speed. [2]

(iii) State which end of the resistor, P or Q, is at a higher electric potential. [1]

(iv) After the axle rolls past the resistor, does the current in K reverse its direction of flow? Explain your answer. You may assume that the rod continues to move in the uniform magnetic field. [2]

(c) The wire of resistance 3.00 Ω shown in Figure 4.2.1 is bent in the shape of a tent, with $\theta = 60.0°$ and $L = 1.00$ m. It is placed in a uniform magnetic field of magnitude 0.500 T perpendicular to the horizontal floor which lies in the x-y plane. The wire is rigid but hinged at points C and D. The triangular sides of the tent structure are initially in the x-z plane.

Figure 4.2.1



(i) If the "tent" is flattened out on the floor in 0.200 s (see Figure 4.2.2), what is the average induced current in the wire during this time? [4]

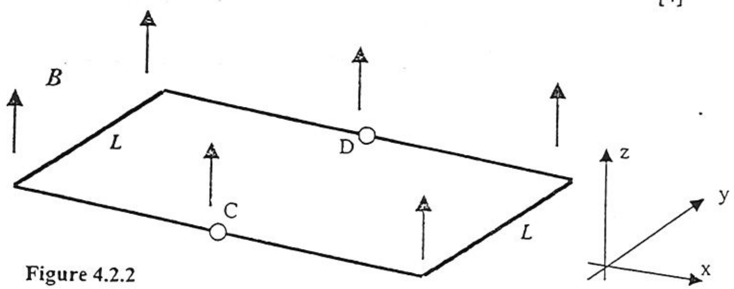
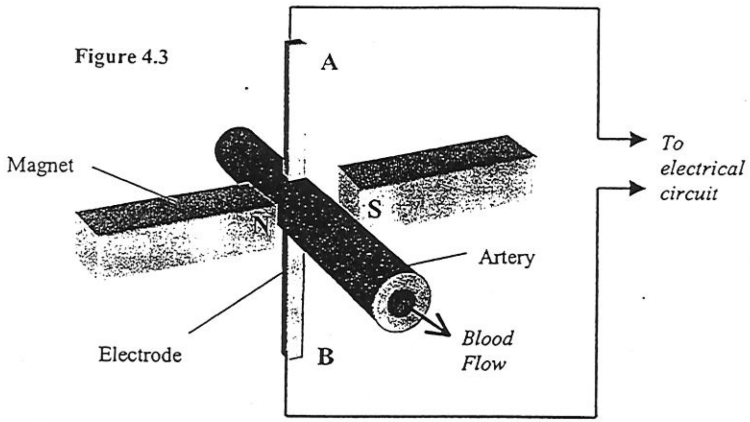


Figure 4.2.2

(ii) After the "tent" is flattened, it is rotated about the z-axis at a frequency of 20 Hz. State the value of the induced e.m.f in the wire. Explain your answer. [2]

Figure 4.3



(d) A heart surgeon monitors the flow rate of blood through an artery using an electromagnetic flowmeter (see Figure 4.3). The blood is known to contain mobile ions. Electrodes A and B make contact with the outer surface of the blood vessel, which has interior diameter 2.80 mm.

(i) For a magnetic field of 0.050 T, a potential difference of 180 μV appears between the electrodes. Calculate the speed of the blood. [3]

(ii) State the electrode that is at a higher electric potential. Explain your answer. [2]

5. (a) In 1991, a German tourist discovered the well-preserved remains of a man trapped in a glacier in the Italian Alps. Radioactive dating with ^{14}C revealed that this person was alive about 5300 years ago. Why did scientists date the sample using ^{14}C which has a half-life of 5730 years rather than ^{11}C which has a half-life of 20.4 minutes? [2]

(b) It is known that in a live sample of wood, the ratio of ^{14}C to ^{12}C is 1.3×10^{-12}. A piece of charcoal was discovered in some underground ancient city. Upon discovery, the activity of ^{14}C was measured to be 250 decays per minute.

(i) What is the physical interpretation of the decay constant λ? [1]

(ii) Using the half-life of ^{14}C given in (a), calculate the value of λ (in min^{-1}) for ^{14}C. [2]

(iii) Given that the number of ^{12}C nuclei in the live sample of wood is 1.00×10^{24}, calculate the number of ^{14}C nuclei in the live sample. [1]

(iv) Hence, estimate the age of the charcoal in years. [3]

(c) A radioactive isotope ^{198}Au has a half-life of 64.8 h. A sample containing this isotope has an initial activity ($t = 0$) of 50.0 μCi.
(1 curie or 1 Ci = 3.70×10^{10} Bq)

(i) What are isotopes? [1]

(ii) Calculate the number of nuclei that decay in the time interval between $t = 0$ and $t = 3.0$ h. [4]

(d) Consider the nuclear reaction

$$^{28}_{14}Si + \gamma \rightarrow ^{24}_{12}Mg + X$$

where X is a nuclide. $^{0}_{-1}e$

(i) Write down the chemical symbol for the nuclide X. [1]

(ii) Ignoring the effects of recoil, what minimum energy must the photon have for this reaction to occur?

(mass of $^{28}_{14}Si$ nucleus = 27.976927u
mass of $^{24}_{12}Mg$ nucleus = 23.985042u
mass of X nucleus = 4.002603u) [3]

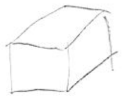
(iii) Can the above reaction be considered a fission process? Explain. [2]

6. (a) (i) State the equivalent temperature of 25.00°C in kelvin. [1]

(ii) In establishing the Absolute Thermodynamic Scale, the concept of the triple point of water is introduced. What is meant by the triple point of water? Also, state the triple point temperature of water. [2]

(b) A copper cup with a mass of 150 g contains 500 g of water in thermal equilibrium at 70.0°C. The combination of cup and water is cooled uniformly so that the temperature decreases at a rate of 2.00°C per minute. At what rate is energy being removed as heat?
(Specific heat capacity for copper, c_m = 387 J kg^{-1} K^{-1}; Specific heat capacity for water, c_w = 4186 J kg^{-1} K^{-1}) [3]

(c) A sealed cubical container with length l of 30.0 cm per side contains 5 times of the Avogadro's number of neon atoms at a temperature of 25.0°C.



(i) Find the force exerted by the gas inside the container on one of the walls of the container. Assume the neon atoms behave ideally. [3]

(ii) Calculate the root-mean-square speed of the atoms if the molar mass of neon is 20.2 g mol^{-1}. [2]

(iii) What is meant by internal energy of an ideal gas? If the gas is in a container located in a car which suddenly picks up speed, does its internal energy increase? Explain. [3]

(iv) If 5 moles of argon gas (molar mass = 40.0 g mol^{-1}) is used to replace the neon gas, keeping all other physical quantities constant, what will be the change in the total internal energy of the gas in the container? Explain your answer. [2]

(v) Suppose the container of neon gas is heated over a flame so that the temperature of the gas rises to 30.0°C. Expansion of the container can be considered negligible.

1. Write down the thermodynamic process which has taken place during the heating procedure. [1]

2. Show that the change in internal energy of the gas is $25C_{v,m}$ where $C_{v,m}$ is the molar heat capacity of the gas at constant volume. [3]

Section B

Answer **all** questions from this section.
(You can obtain a maximum of **30 marks** from this section)

7. A 50.0 kg lady stands on a cubical slab of ice (density of ice, ρ_i = 920 kg m^{-3}) which floats on a freshwater lake (density of lake water, ρ_w = 1000 kg m^{-3}).

(a) What is the Archimedes' Principle? [2]

(b) Calculate the minimum volume (V) of ice slab for the lady to be able to stand on it without getting her feet wet, i.e. when the entire ice slab is **just** submerged in water. [3]

(c) The lady begins to shift her position on the slab such that the stability of the lady-slab system becomes altered.

(i) Explain the term *stability*. [2]

(ii) Suppose the cubical slab turns over as the lady shifts closer to the edge. Illustrate with a diagram and explain how the relative positions of the metacentre (M) and the effective center of gravity (G) cause the slab to turn over. [3]

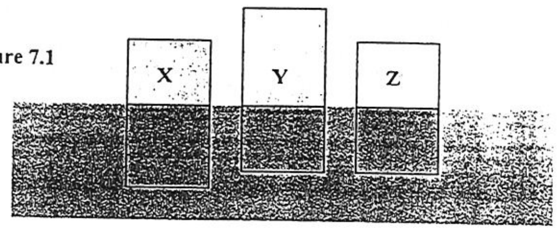
(d) When the lady falls into the lake, the slab returns to stable equilibrium.

(i) Determine the percentage of slab submerged under the lake surface. [3]

(ii) Write down an expression for the fraction of slab above the lake surface in terms of ρ_i and ρ_w. [1]

(iii) If 3 uniform solid objects of regular cross-sectional areas float in seawater as shown in Figure 7.1, list the ranking of the objects according to their density, starting from the greatest. [1]

Figure 7.1



8. (a) Figure 8.1 shows how the cross-sectional area of a stream of oil, flowing from a tap, reduces as it falls. According to the figure, $A_0 = 1.50\ \text{cm}^2$ and $A = 0.400\ \text{cm}^2$. The speed of the oil at Y is $1.03\ \text{m s}^{-1}$.

(i) Determine the speed of the oil at position X. [3]

(ii) Calculate the flow rate in $\text{m}^3\ \text{s}^{-1}$ from the tap. [2]

(iii) Using energy considerations or otherwise, determine the distance h between the points X and Y. [3]

(iv) Differentiate between streamline flow and turbulent flow. [2]

Figure 8.1

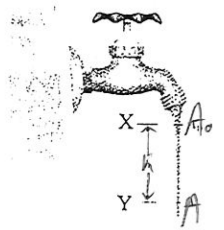
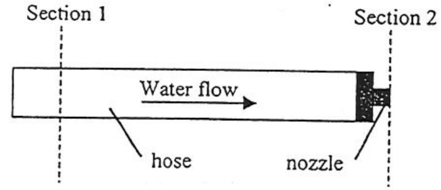


Figure 8.2



(b) A water hose is laid flat on a horizontal ground. Its end section with an attached nozzle is shown in Figure 8.2. The cross sectional areas of the hose and the nozzle are A_1 and A_2 respectively while the water speeds at sections 1 and 2 are v_1 and v_2 respectively.

(i) Assuming that the hose is totally filled with water of density ρ at all times, show that the pressure difference exerted on the water between sections 1 and 2 is given by:

$$p_1 - p_2 = \tfrac{1}{2}\rho v_1^2[(A_1^2/A_2^2) - 1)]$$

[3]

(ii) The nozzle end of the hose is raised 1.5 m from the ground while making sure that the hose is still totally filled with water and that the flow rate is constant. Suggest the main reason why the pressure difference expressed in (b)(i) will be significantly different. [2]

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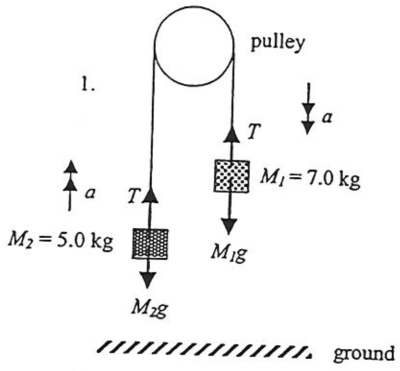
VICTORIA JUNIOR COLLEGE
2003

SUGGESTED SOLUTIONS TO
PHYSICS PAPER 3

1.



T = tension in string;
g = acceleration due to gravity

[1 m for correct labelling of forces for each of the two masses]

(ii) By Newton's 2nd Law,
for mass M_1, $M_1g - T = M_1a$ ... (1)
where a = acceleration of mass [1m]
for mass M_2, $T - M_2g = M_2a$ ... (2) [1m]

Solving,

$$a = \frac{M_1 - M_2}{M_1 + M_2}g = \frac{7.0-5.0}{7.0+5.0}(9.81)$$

$\therefore$ **$a \approx 1.64$ m s^{-2}** [1m]

(iii) In equation (1), $T = M_1(g-a)$
$T = 7.0(9.81 - 1.64) \approx$ **57.2 N** [1m]

(iv) Using "$s = ut + \frac{1}{2}at^2$" [1m]

$s = 0 + \frac{1}{2}(1.64)(3.0)^2$

$s \approx 7.4$ m [1m]

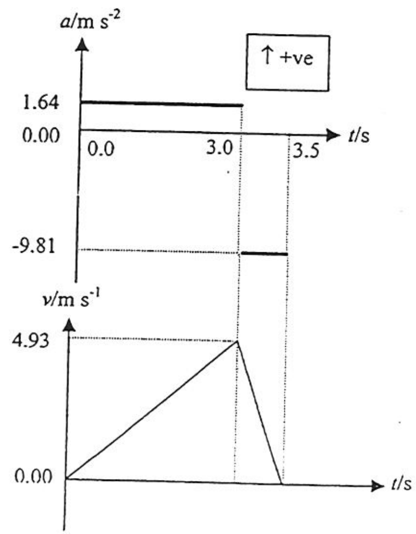
(v) When the tension of the string just disappears, the 5.0 kg mass would have moved up 7.4 m from its initial position of rest. [1m]

Let its velocity be v at this point.
Using "$v^2 = u^2 + 2as$", we have
$v = \sqrt{0 + 2(1.64)(7.4)}$
$v \approx 4.93$ m s^{-1} (upwards) [1m]

As the 5.0 kg mass continues to move beyond this point, it will decelerate under gravity, i.e. $a = -g = -9.81$ m s^{-2} [1m]

(vi) Using "$v^2 = u^2 + 2as$", we have
$0 = 4.93^2 + 2(-9.81)s$ [1m]
$s \approx 1.24$ m [1m]

(vii) Let the time for the 5.0 kg mass to reach its maximum height from the time when the string loses its tension be t.
Using "$v = u + at$", we have
$t = -4.93/-9.81 \approx 0.50$ s



[1m for correct shape for each of the two graphs; 1 m for labelling : total 3 m]

(b) Given: $r = 0.10$ m; $f = 10.0$ rev min^{-1} $= 10.0/60 = 16.67\text{x}10^{-2}$ rev s^{-1};
$h = 2.0$ m ; $M = 7.0$ kg

(i) The circumferential distance is
$s = 2\pi r = 2(3.142)(0.10) \approx 0.6284$ m
In 1 sec, distance covered by string along rim of drum is $16.67\text{x}10^{-2}$ rev
$= (0.6284)(16.67\text{x}10^{-2})$
≈ 0.1048 m [1m]

Time taken to raise the 7.0 kg mass by 2.0 m is therefore $t = \dfrac{2.0}{0.1048} \approx$ **19.1 s** [1m]

(ii) Given: efficiency $\eta = 1 - 0.20 = 0.80$
$P_{useful} = \eta P_{motor}$ [1m]

$$P_{motor} = \frac{Mgh}{t\eta} = \frac{(7.0)(9.81)(2.0)}{(19.1)(0.80)}$$

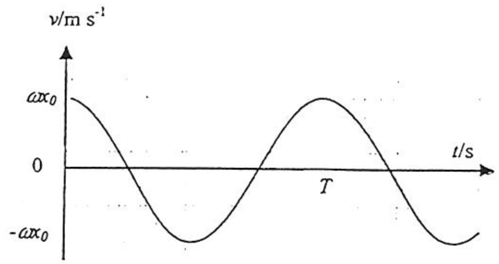
≈ 9.0 W [1m]

2(a)(i) Simple harmonic motion is the periodic motion of a particle whose acceleration is proportional to its displacement and always directed opposite to the displacement, i.e. acceleration $\propto$ - displacement
or $a \propto -x$ [1m]

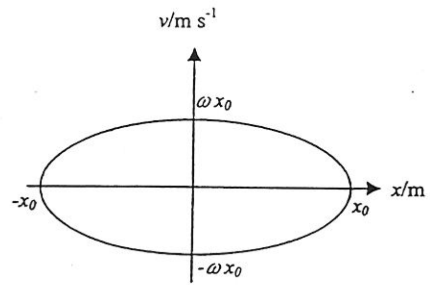
(ii)

$$x = x_0 \sin(\omega t) \Rightarrow v = \frac{dx}{dt} = x_0\omega\cos(\omega t)$$

Also, $v = \pm\omega\sqrt{x_0^{\ 2} - x^2}$



[1m]



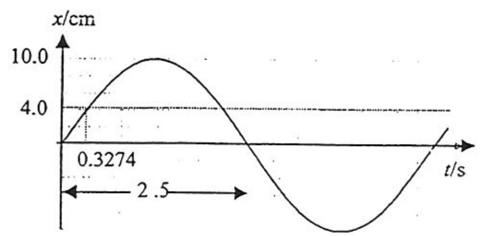
[1m]

Given:
$M = 5.0$ g; $x_0 = 10.0$ cm; $T = 5.0$ s

(iii) $x = 10.0\sin\left(\dfrac{2\pi}{5.0}t\right)$

For x = 4.0 cm, $4.0 = 10.0\sin\left(\dfrac{2\pi}{5.0}t\right)$

$t \approx 0.3274$ s [1m]



Hence interval of time over half a cycle when x ≥ 4.0 cm
= 2.5 – 2(0.3274) [1m]
≈ **1.85 s** [1m]

(iv) $\dfrac{K}{U} = \dfrac{\frac{1}{2}M\omega^2({x_0}^2 - x^2)}{\frac{1}{2}M\omega^2 x^2}$ [2m]

$= \dfrac{10.0^2 - 4.0^2}{4.0^2} = 5.25$ [1m]

(b)(i) **Nodes** are positions in a stationary wave where the particles in the medium do not participate in oscillations and hence there is no displacement of particles at the nodes. [1m]

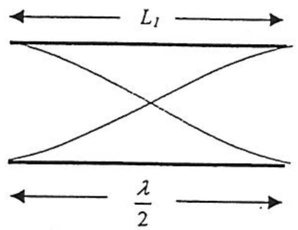
The **Principle of Superposition** states that when two or more waves of the same kind meet at a point, the resultant amplitude is the vectorial sum of the amplitudes of the individual waves at that point. [1m]

(ii) Let $f \propto L^x T^y \mu^z$ or
$f = kL^x T^y \mu^z$ [1m]
where k, x, y and z are unitless constants.
Let BU stand for base units.
LHS: BU = s^{-1}
RHS: BU = $m^x (kg\ m\ s^{-2})^y (kg\ m^{-1})^z$
= $m^{(x+y-z)}\ s^{-2y}\ kg^{(y+z)}$
Comparing indices of similar units on both sides of equation,
For s, -1 = -2y ⇒ y = ½ … (1)
For m: 0 = x + y – z … (2)
For kg, 0 = y + z … (3)
Substitute (1) into (3), z = -½
In (2), x = -1
[1m off for wrong value of x, y or z up to a maximum of 2 m]

Hence $f = kL^{-1}T^{1/2}\mu^{-1/2}$

Or $f = \dfrac{k}{L}\sqrt{\dfrac{T}{\mu}}$

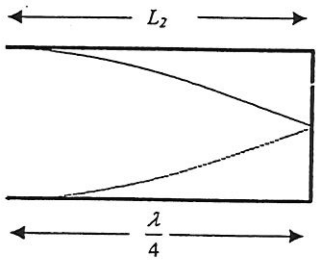
(iii) **Open-end pipe**



$\frac{\lambda}{2} = L_1 \Rightarrow \lambda = 2L_1$

$v = f\lambda \Rightarrow f = \dfrac{v}{2L_1}$ … (1) [1m]

Close-end pipe



$\frac{\lambda}{4} = L_2 \Rightarrow \lambda = 4L_2$

$v = f\lambda \Rightarrow f = \dfrac{v}{4L_2}$ …(2) [1m]

Comparing (1) and (2),
$2L_1 = 4L_2$
or $\dfrac{L_1}{L_2} = 2$ [1m]

(iv) Given: λ_1 = 650 nm; λ_2 = 520 nm; D = 1. 2 m ; d = 2.0 mm

Using $y = \dfrac{n\lambda D}{d}$ [1m]

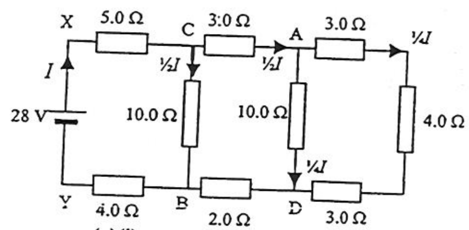
where y = distance from central maximum to n^{th} off-axis maximum,
λ = wavelength of light used,
D = distance from screen to double slits,
d = slit separation,
we have
$y_1 = \dfrac{n\lambda_1 D}{d}$ and $y_2 = \dfrac{m\lambda_2 D}{d}$
Where the two wavelengths coincide,
$y_1 = y_2$
Hence $\dfrac{n\lambda_1 D}{d} = \dfrac{m\lambda_2 D}{d}$ [1m]

$\dfrac{n}{m} = \dfrac{\lambda_2}{\lambda_1} = \dfrac{520}{650} = \dfrac{4}{5}$

Hence minimum distance from central maximum where the 4th maximum of the first wavelength coincides with the 5th maximum of the second wavelength is

$y = \dfrac{4(650x10^{-9})(1.2)}{2.0x10^{-3}} \approx \mathbf{1.56x10^{-3}\ m}$ [1m]

3.



(a)(i)

$R_{AD} = \dfrac{(3.0+4.0+3.0)(10.0)}{(3.0+4.0+3.0)+(10.0)} = 5.0\,\Omega$ [1m]

$R_{CB} = \dfrac{(3.0+5.0+2.0)(10.0)}{(3.0+5.0+2.0)+10.0} = 5.0\,\Omega$ [1m]

$R_{XY} = 5.0 + 5.0 + 4.0 = \mathbf{14.0\,\Omega}$ [1m]

(ii) By Kirchoff's Law,
$I = \dfrac{E}{R_{eff}}$

$I = \dfrac{28}{14.0} = \mathbf{2.0\ A}$ [1m]

(iii) Power dissipated in the entire circuit is $P_{tot} = EI$ [1m]
=(28)(2.0) = **56 W** [1m]

(iv) By Kirchoff's Law, $E = V_{XC} + V_{CB} + V_{BY}$
28 = (2.0)(5.0) + V_{CB} + (2.0)(4.0)
V_{CB} = 10 V [1m]
$P = \dfrac{{V_{CB}}^2}{R} = \dfrac{10^2}{10} = 10$ W [1m]
$\therefore \dfrac{P}{P_{tot}} = \dfrac{10}{56} \approx \mathbf{0.18}$ [1m]

(v) $V_{CA} = V_C - V_A = (\frac{1}{2}I)3.0$
or $V_C - V_A$ = 3.0 … (1) [1m]
$V_{CB} = V_C - V_B = \left(\frac{1}{2}I\right)10.0$
or $V_C - V_B$ = 10.0 … (2) [1m]

take (2) – (1) :
$V_A - V_B$ = 10.0 – 3.0 = 7.0
Or V_{AB} = **7.0 V** [1m]
A is at the higher potential. [1m]

(vi) Given: R_A = 2.0 Ω ; R_B = 5.0 Ω
Area A = constant; $\dfrac{L_A}{L_B} = 0.90$; $\dfrac{\rho_A}{\rho_B} = ?$

$\dfrac{R_A}{R_B} = \dfrac{\rho_A \frac{L_A}{A}}{\rho_B \frac{L_B}{A}} = \dfrac{\rho_A L_A}{\rho_B L_B}$ [1m]

$\therefore \frac{\rho_A}{\rho_B} = \left(\frac{R_A}{R_B}\right)\left(\frac{L_B}{L_A}\right) = \left(\frac{2.0}{5.0}\right)\left(\frac{1}{0.90}\right)$
≈ 0.44 [1m]

(b)

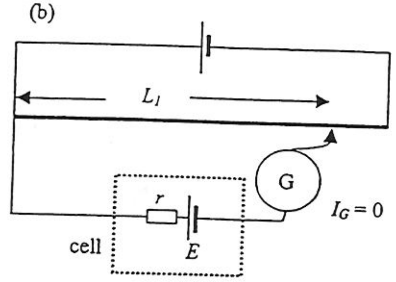


Fig (1)

[1m]

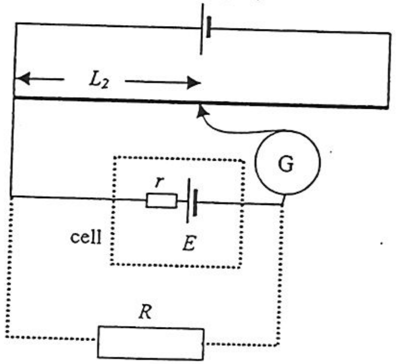


Fig (2)

[1m]

In fig (1), $E = kL_1$.:. (1) [1m]
where k is a constant

In fig (2), $\frac{R}{R+r}E = kL_2$ ... (2)

[1m]

(2)/(1) gives $\frac{R}{R+r} = \frac{L_2}{L_1}$

Hence $r = R\left(\frac{L_1}{L_2} - 1\right) = 5.0\left(\frac{45.0}{30.0} - 1\right)$

$r = 2.5\ \Omega$ [1m]

4(a)
The laws of electromagnetic induction comprise :

Faraday's Law which states that the induced e.m.f through a circuit or conductor is directly proportional to the rate of change of magnetic flux linkage.
[1 m]

Lenz's Law which states that the direction of the induced current is always such as to oppose the change producing it. [1 m]

(b)(i) Induced e.m.f. between the wheels of axle, $E = Blv$
$= (0.500)(2.00)(2.50) = 2.50$ V
[1 m]
$\therefore$ Induced current across K $= E/R$
$= 2.50/0.500 =$ **5.00 A** [1 m]

(ii) As the current-carrying axle moves across the magnetic field,
magnetic force acting on the axle = BIl
$= (0.500)(5.00)(2.00) = 5.00$ N
[1 m]
For axle to move at constant speed, net horizontal force acting on axle = 0. Thus, forward force $F =$ **5.00 N**
[1 m]

(iii) Q. [1 m]

(iv) No, the current in K does not flow in the reverse direction.
[1 m]

When the axle passes the resistor, Faraday's Right Hand Rule predicts that the induced current still flows through

the axle and hence the resistor in the same direction.
[1 m]

(c)(i) Change in area through which magnetic flux passes through,
$\Delta A = 2L^2 - L^2 = L^2 = 1.00\ m^2$
[1 m]
Average induced e.m.f. in wire,
$E = (\Delta\phi/\Delta t)$
$= B(\Delta A)/(\Delta t)$ [1 m]
$= (0.500)(1.00)/0.200$
$= 2.50$ V [1 m]
$\therefore$ Average induced current in wire
$= E/R = 2.50/3.00$
= 0.833 A [1 m]

(ii) **Induced e.m.f. = 0 V**
[1 m]
As the "tent" rotates about the z-axis, there is no change in the total magnetic flux associated with it. Hence,
$E = (\Delta\phi/\Delta t) = 0$. [1 m]

(d)(i) Emf E generated is
$E = Bdv$ (think of a rod of length d moving in a magnetic field) [1 m]
$\therefore v = \frac{E}{dB}$
$= (180 \times 10^{-6})/(2.80 \times 10^{-3})(0.050)$
[1 m]
= 1.29 m s^{-1} [1 m]

d(ii) A is at a higher electric potential.
[1 m]

Fleming's left-hand rule can verify that positive ions will gather at A while negative ions gather at B. Hence, electrode A is always relatively higher in electric potential with respect to B.
[1 m]

5(a) The fraction of ^{14}C nuclei remaining after one half-life is high enough to allow accurate measurements of changes in the sample's activity. [1 m]

Since ^{11}C has a very short half-life, its activity decreases to a negligibly small value over the age of the sample, making it very hard to be detected and hence is not useful for the dating process.
[1 m]

(b)(i) λ is a measure of the probability of decay of a particular atom within an interval of 1 second.
[1 m]

(ii) $\lambda = (\ln 2)/t_{½}$
$= \ln 2 /(5730\text{x}365\text{x}24\text{x}60)$
[1 m]
$\approx 2.30 \times 10^{-10}$ min^{-1} [1 m]

(iii) No. of ^{12}C nuclei in live sample of wood = 1.00×10^{24} $\therefore$
No. of ^{14}C nuclei in the sample is
$N_0 = (1.3 \times 10^{-12})(1.00 \times 10^{24})$
$= 1.3 \times 10^{12}$ [1 m]

(iv) Before decay, activity of ^{14}C
$A_0 = \lambda N_0$
$= (2.30 \times 10^{-10})(1.3 \times 10^{12})$
= 299 decays per min
[1 m]
Let the time period for which the tree has been dead be t. (Part of the tree could have been turned into the charcoal).
$\therefore A = A_0 e^{-\lambda t}$ [1 m]
=> $\ln(250/299) = (-2.30 \times 10^{-10})t$
Hence, $t = 7.78 \times 10^8$ min
$= 1.48 \times 10^3$ yrs [1 m]

(c)(i). Isotopes are atoms with the same atomic number but different mass numbers. [1 m]

(ii) $A_0 = \lambda N_0 = [(\ln 2)/t_{½}]\, N_0$ [1 m]

$(50.0 \times 10^{-6})(3.70 \times 10^{10})$
$= [(\ln 2)/(64.8 \times 60 \times 60)]\, N_0$
$\therefore N_0 = 6.226 \times 10^{11}$ [1 m]

Hence, number of nuclei that decay between $t = 0$ and $t = 3.0$ h = (no. of nuclei at $t = 0$) – (no. of nuclei which remains undecayed at $t = 3.0$ h) [1 m]

$N = N_0 - N_0 e^{-\lambda t}$

$= 6.226\times10^{11}(1 - e^{-\left(\frac{\ln 2}{64.8}\right)(3.0)})$

$= \mathbf{1.97\times10^{10}}$ [1 m]

d(i) $X = {}^4_2He$ [1 m]

(ii) Assume that Si atom is stationary initially.

By conservation of mass-energy:
$M_{Si}c^2 + E_\gamma = M_{Mg}c^2 + K_{Mg} + M_X c^2 + K_X$ [1 m]
$\therefore E_\gamma = c^2(M_{Mg} + M_X - M_{Si}) + (K_{Mg} + K_X)$
E_γ is minimum if $(K_{Mg} + K_X) \approx 0$
Hence $E_\gamma = (3.0 \times 10^8)^2(23.985042 + 4.002603 - 27.976927)(1.66\times10^{-27})$ [1 m]
$= \mathbf{1.60 \times 10^{-12}}$ **J** [1 m]

(iii) The above process is **not** a fission process. [1 m]
A fission process requires a bullet, typically a neutron, striking a heavy nucleus resulting in the production of two approximately equal-sized daughter nuclei and the emission of more neutrons. [1 m]

6(a)(i) $T = \theta + 273.15$
= **298.15 K** [1 m]

6(a)(ii) The triple point of water is the temperature at which water vapour, pure water and ice all coexist in equilibrium. [1 m]
Triple point temperature, T_{tr} = **273.16 K** [1 m]

(b)Rate of heat removal,
$dQ/dt = m_c c_c(d\theta/dt) + m_w c_w(d\theta/dt)$ [1 m]
$= (d\theta/dt)(m_c c_c + m_w c_w)$
$= (2.00/60)(0.150 \times 387 + 0.500 \times 4186)$ [1 m]
$=$ **71.7 W** [1 m]

(c)(i) Using $pV = NkT$ [1 m]
∴Force exerted on one side of container by the gas inside the container is
$F = pA = \frac{NkT}{V}A = \frac{NkT}{l}$
$= (5)(6.02 \times 10^{23})(1.38 \times 10^{-23})(25.0 + 273) \div (0.300)$ [1 m]
= **41. 3 kN** [1 m]

(c)(ii) Root-mean-square speed is
$c_{rms} = \sqrt{3RT/M_m}$ [1 m]
∴
$c_{rms} = \sqrt{3(8.31)(25.0+273)/(20.2\times10^{-3})}$
= **606 m s^{-1}** [1 m]

(iii) The internal energy of an ideal gas refers to the total kinetic energy of the molecules of the gas. [1 m]
When the car picks up speed, the bulk kinetic energy of the gas increases but its internal energy does not. [1 m]
This is because the internal energy of the gas depends on temperature which does not change perceptibly during the sudden pickup in speed of the car. [1 m]

(iv) The internal energy of a monatomic ideal gas is given by
$U = \frac{3}{2}\mu RT$ [1 m]
Since the number of moles and the temperature do not change, the internal energy of the argon gas should remain unchanged vis-à-vis neon. [1 m]

(v) 1. **Isochoric** or **isovolumetric** process [1 m]

(v)2.. Applying First Law of Thermodynamics:
$\Delta U = \Delta Q + \Delta W$
Since $\Delta V = 0$, $\Delta W = 0$ $\therefore \Delta U = \Delta Q$ [1 m]
Hence, $\Delta U = \mu C_{v,m}\Delta T$ [1 m]
$= (5)C_{v,m}(30.0 - 25.0)$
=> $\Delta U = \mathbf{25C_{v,m}}$ (Shown) [1 m]

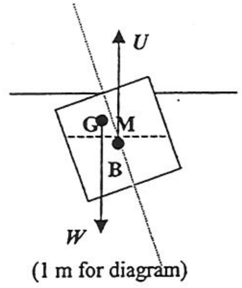
SECTION B

7(a) Archimedes' Principle states that any object fully or partially immersed in a fluid will experience an upthrust [1 m]
which is numerically equal to the weight of the fluid displaced. [1 m]

(b) By Principle of Flotation,
Upthrust = Weight of slab + Weight of lady [1 m]
$\rho_w Vg = \rho_i Vg + mg$ [1 m]
$(1000)V = (920)V + 50.0$
$\therefore V =$ **0.625 m^3**. [1 m]

(c)(i) Stability refers to the ability of an object to return to its equilibrium position after the object has been displaced from its equilibrium state. [1 m]

(ii) As the lady moves closer to the edge of the slab, the slab tilts and the effective center of gravity (G) will reposition so that it is above the metacentre (M). [1 m]
A toppling couple is hence generated by the upthrust (U) and the effective weight (W) to cause the ice slab to turn over. [1 m]



(1 m for diagram)

B : centre of buoyancy
G: centre of gravity
M: metacentre (intersection of central line and line of action of upthrust)
U; upthrust
W: weight

(d)(i) Let volume of slab submerged under water be V_s.
At equilibrium,
weight of slab = upthrust on ice
$\therefore \rho_i Vg = \rho_w V_s g$ [1 m]
Hence, percentage of slab under lake surface= $V_s/V \times 100\%$
$= \rho_i/\rho_w \times 100\%$ [1 m]
= 920/1000 x 100% = **92.0 %** [1 m]

(ii) Fraction of slab below lake surface = ρ_i/ρ_w
∴Fraction of slab above lake surface
= **1 - ρ_i/ρ_w** [1 m]

(iii). The larger the density of the object, the higher the fraction of the object is below the sea surface.
Hence, ranking is **X, Z, Y.** [1 m]

8(a)(i) Let water speeds at the higher and lower water levels be v_0 and v respectively.

Using equation of continuity, $A_0v_0 = Av$

$\Rightarrow v_0 = Av/A_0$ [1 m]

$$v_o = \frac{(0.400)(1.03)}{1.50} \approx \mathbf{0.275\ m\ s^{-1}}$$

[2 m]

(ii) Flow rate $= Av$ [1 m]

$= (0.400 \times 10^{-4})(1.03)$

$= \mathbf{4.12 \times 10^{-5}\ m^3\ s^{-1}}$ [1 m]

(iii) From X to Y, loss in GPE = gain in KE of oil [1 m]

$$mgh = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2 \quad [1\text{ m}]$$

$$h = \frac{v^2 - v_o^2}{2g} = \frac{(1.03)^2 - (0.275)^2}{2(9.81)}$$

$\therefore \mathbf{h \approx 0.052\ m}$

[1 m]

(a)(iv) Streamline flow refers to the condition where the flow lines are smooth and steady such that the neighbouring layers of the fluid slide by each other smoothly. [1 m]

Turbulent flow refers to the condition where the flow lines become erratic and eddy currents are generated. [1 m]

(b)(i) Consider Bernoulli's Equation,

$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

[1 m]

Thus, pressure difference

$p_1 - p_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$

$= \frac{1}{2}\rho(v_2^2 - v_1^2)$

$= \frac{1}{2}\rho[(A_1v_1/A_2)^2 - v_1^2]$ [1m]

$= \frac{1}{2}\rho v_1^2[(A_1^2/A_2^2) - 1)]$ [1 m]

(ii) In the derivation of the earlier expression in (b)(i), the form of Bernoulli's equation is only applicable when horizontal flow of water is considered. [1 m]

As the nozzle end of the hose is raised, gravitational potential energy of the water will have to be considered and the equation used will need to be modified. Thus the expression in (b)(i) will be different. [1 m]

********** END **********