Mr. Ong Jensen

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Registration Number

0382624

NATIONAL JUNIOR COLLEGE
JC 2 SPECIAL PAPER TEST

PHYSICS | **9248/0**
Friday | 2 JULY 2003 | 1 hour 45 min

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Write your **name** and **registration number** in the spaces at the top of this **cover sheet**.

Answer ALL questions in Section A [30 marks] and Section B [40 marks].

You are given **1 hour 45 minutes.**

Write your answers on the **writing paper** provided.

INFORMATION FOR CANDIDATES

For numerical answers, all working should be shown.

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

FOR EXAMINER'S USE	
Section A	
Qn	**Marks**
1	1
2	4
3	3
4	1
5	0
Section B	
1	13
2	8

Total : 30/70

This section consists of 7 printed pages including this cover page.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ ms^{-1}
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ Js
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,	$R = 8.31$ JK^{-1}mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ JK^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall,	$g = 9.81$ ms^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
refractive index,	$n = \frac{1}{\sin C}$
displacement of particle in s.h.m.,	$x = x_0 \sin\omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos\omega t$ $v = \omega\sqrt{x_0^2 - x^2}$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
alternating current/voltage,	$x = x_0 \sin\omega t$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$
equation of continuity,	$Av = \text{constant}$
Bernoulli equation (simplified),	$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$
Stokes' law,	$F = Ar\eta v$
drag force in turbulent flow,	$F = Br^2\rho v^2$

Section A (30 marks)

$mv_A - mu_B = mv_B - mv_A$

1 A ball which is moving with a speed *v* hits and makes an elastic collision with a table tennis paddle that is moving with a speed *u* toward the ball.

(a) What is the velocity of the ball after it bounces back from the paddle? [2]

(b) What is the change in the kinetic energy of the ball if its mass is *m*? [2]

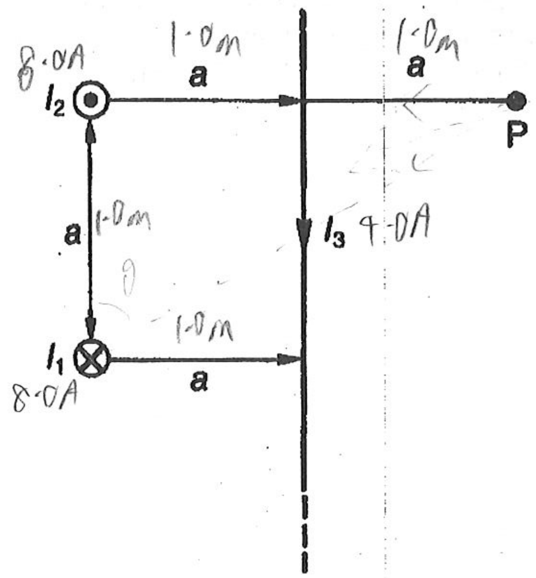
(c) Try to show that your answer to part (b) is equal to the work done by the paddle on the ball. [4]

2 You have a ball of mass *m* attached to a massless string. The maximum tension the string can handle before breaking is *T*.

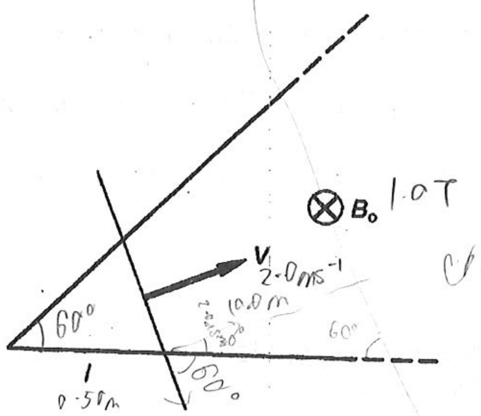
If you hold one end of the string at a height *h* above the ground, what is the maximum length the string can have so that you can still swing the ball in a horizontal circle around you without the ball touching the ground or the string breaking?

[4]

3 Three long wires carrying current I_1 = 8.0 A, $I_2 = I_1$ and $I_3 = I_1 / 2$. Find the magnitude of the resultant magnetic flux density at point P indicated, with a = 1.0 m. The field of a long straight wire carrying current I is $B = \dfrac{\mu_0 I}{2\pi r}$ at a point r away from the wire. [7]



4 A long conducting wire is bent at an angle of 60° and lies in a plane perpendicular to a **uniform** magnetic field B_o = 1.0 T. A second very long conducting wire is pulled with velocity v = 2.0 ms^{-1} while lying on top of the bent wire so that the points of contact and the 60° vertex make an equilateral triangle.



30 45 60

cos $\frac{\sqrt{3}}{2}$ 2 $\frac{1}{2}$

At time t = 0, the triangle has side l_o = 0.50 m. Both wires have uniform resistance per unit length r = 0.1 Ω m^{-1}.

(i) Determine the induced emf in the triangle at time t = 5.0 s. [3]

(ii) Find the current in the triangle at this instant. State one assumption you have made. [3]

root mean square $pV = nRT$ $p = \frac{nRT}{V} =$

5a Estimate the rms speed of water molecules at room temperature (T = 27 °C). State any assumption used. [3]

moles = $\frac{mass}{Mr}$

b A bottle of perfume is opened in one corner of a large room. Show that typical molecular rms speeds do not give a good estimate of how soon you would expect to notice the scent in a distinct part of the room? Why not? [2]

$E = hf$ $\quad \frac{E}{V} = \frac{hf}{\frac{m}{\rho}}$ $\quad v = f\lambda$ $\quad v = f\lambda$ $\quad I \propto f^2 A^2$ $\quad \lambda = \frac{h}{mv}$ $\quad \rho = \frac{mass}{vol}$ $\quad vol = \frac{mass}{\rho}$

Section B (40 marks)

1a Distinguish between the amplitude and the intensity of a wave. [2]

$E = hf$ $\quad KE = \frac{1}{2}mv^2$

Sound waves of frequency f and amplitude S are transmitted through a gas of density ρ.

$\lambda = 2\pi S$

(i) By considering each molecule of the gas to be undergoing simple harmonic motion, find D, the energy per unit volume due to the sound wave, in terms of f, S and ρ.

(ii) Hence show that the intensity I at a point in the path of the sound wave is given by

$$I = 2\pi^2 f^2 S^2 \rho v$$

$\lambda^2 = \frac{h^2}{m v^2}$

where v is the speed of the wave.

(iii) A point source of frequency of 3.0 kHz radiates sound energy uniformly in air at a rate of 1.0 mW. At this frequency an observer can hear the sound clearly when standing 150 m from the source. Assuming no absorption or reflection of the sound energy and using approximate values of any quantities, estimate the amplitude of the wave at the observer.

[8]

b A short-wave radio receiver receives simultaneously two signals from a transmitter 500 km away, one by a path along the surface of the earth, and one by reflection from a portion of the ionospheric layer situated at a height of 200 km. The layer acts as a perfect horizontal reflector. When the frequency of the transmitted wave is 10 MHz, it is observed that the combined signal strength varies from maximum to minimum and back to maximum 8 times per minute.

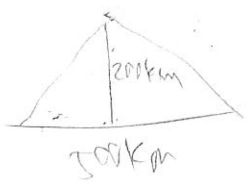
$f = 10 \times 10^6$ Hz

(i) Explain qualitatively the fluctuation in the signal strength of the signal arriving at the receiver.

(ii) With what slow vertical speed is the ionospheric layer moving?

(iii) State one assumption you have made about the surface of the earth.

[10]



2a The energy levels of the Bohr model of the hydrogen atom are

$$E_n = -E_o/n^2$$

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

where E_o = 13.6 eV and n is the principal quantum number.

A hydrogen atom in the n = 4 state makes a transition to the ground state, emitting one photon. Calculate

m

(i) the wavelength of the emitted photons.
(ii) recoil velocity of the atom.

[5]

b An atom of singly ionized helium has a single electron, whose energy levels are given by an expression similar to that of a hydrogen atom, i.e.

$$E_n = -4E_o/n^2$$

A beam of electromagnetic radiation has a continuous spectrum extending between λ_{low} = 2.40 x 10^{-8} m and λ_{high} = 5.00 x 10^{-8} m. It is incident on an ensemble of singly ionized helium atoms, which are all in the ground state.

(i) What is the minimum energy required to ionize a helium atom completely?

(ii) How many absorption lines involving transitions from the ground state will be seen if the experiment is viewed along the beam axis? Show your working clearly.

(iii) How many different emission lines will be seen if the experiment is viewed from the side? How many different emission lines will be seen if the experiment is viewed along the beam axis? Explain.

$N = N_0 e^{-\frac{t}{t_1}}$

[9]

c The natural uranium ore now consists of η_1 = 99.28% ^{238}U and η_2 = 0.72% ^{235}U. Half-life periods of ^{238}U and ^{235}U nuclei are correspondingly equal to T_1 =4.47 x 10^9 years and T_2 =0.70 x 10^9 years. Estimate the Earth's age assuming the amounts of two isotopes were equal at the moment of birth of our planet.

[6]

National Junior College

Name: Tan Zhi Yong Subject: Physics is Sick

Reg. No. 03S2624 6H Date: 2/7/04

1a) $M_B V + m_p U = m_p V_p - m_B V_B$

$m_B V_B = m_B V + m_p U - m_p V_p$

$V_B = V + \frac{m_p}{m_B} U - \frac{m_p}{m_B} V_p$

0

1b) $\Delta K.E = \frac{1}{2} m V_B^2 - \frac{1}{2} m V^2$

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

$= \frac{1}{2} m \left(\left(V + \frac{m_p}{m} U - \frac{m_p}{m} V_p\right)^2 - V^2 \right)$

$= \frac{1}{2} m \left(V^2 + \frac{m_p}{m} UV + \frac{m_p}{m} V_p V + \frac{m_p}{m} UV + \frac{m_p^2}{m^2} U^2 - \frac{m_p^2}{m^2} UV_p - \frac{m_p}{m} V V_p - \frac{m_p^2}{m^2} U V_p + \frac{m_p^2}{m^2} V_p^2 - V^2 \right)$

$= \frac{1}{2} m \left(2 \frac{m_p}{m} UV + \frac{m_p^2}{m} U^2 - 2 \frac{m_p^2}{m^2} U V_p + \frac{m_p^2}{m^2} V_p^2 \right)$

$= \frac{1}{2} \left(2 m_p UV + m_p^2 U^2 - 2 \frac{m_p^2}{m} U V_p + \frac{m_p^2}{m} V_p^2 \right)$

1

1c) WD by paddle on ball = Change in p_{ball}

$= p_{ball(final)} - p_{ball(initial)}$

$= m \left(V + \frac{m_p}{m} U - \frac{m_p}{m} V_p - V \right)$

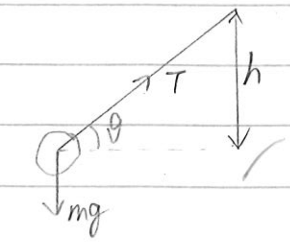
$= m \left(\frac{m_p}{m} U - \frac{m_p}{m} V_p \right)$

$=$

0

1

2)



$$T \sin\theta = \cancel{k}\, mg \text{ —— } (1)$$

$$\cancel{\theta = \sin^{-1}\left(\frac{mg}{T}\right)}$$

Let the length of the string be l units 1

$$\cancel{\tan\theta}\ \sin\theta = \frac{h}{l} \text{ —— } (2)$$ 2

subst (2) into (1):

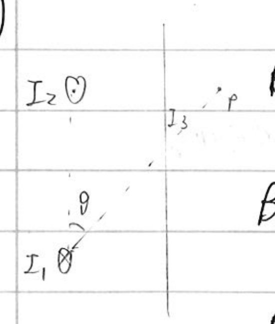
$$T\frac{h}{l} = mg$$ 1

$$l = \frac{Th}{mg}$$

4

3)

$$\cancel{\phi = BA\cos\theta}$$



$$B_p \text{ due to } I_3 = \frac{\mu_0\, 4.0}{2\pi(1.0)}$$

$$= \cancel{2.0\mu_0}\ \cancel{2.0A}\ \frac{2.0}{\pi}\mu_0\ T$$

$$B_p \text{ due to } I_2 = \frac{\mu_0\, 8.0}{2\pi(2.0)}$$

$$= \frac{2.0}{\pi}\mu_0\ T$$ 2

$$B_p \text{ due to } I_1 = \frac{\mu_0\, 8.0}{2\pi(\sqrt{1+2^2})}$$

$$= \frac{4.0}{\sqrt{5}\pi}\mu_0$$

$$\cancel{|B_p \text{ total}| = B_p \text{ due to } I_3 + B_p \text{ due to } I_2}$$

$$B_{px} = B_p \text{ due to } I_2 + B_p \text{ due to } I_3 + (B_p \text{ due to } I_1)\sin\theta$$

$$= \frac{2.0}{\pi}\mu_0 + \frac{2.0}{\pi}\mu_0 + \cancel{\frac{4.0}{\sqrt{5}}}\left(\frac{4.0}{\sqrt{5}\pi}\mu_0\right)\cancel{\sin}\left(\frac{2.0}{\sqrt{2.0^2+1.0^2}}\right)$$

$$= \frac{4.0}{\pi}\mu_0 + \left(\frac{4.0}{\pi}\mu_0\right)\cancel{\left(\frac{2.0}{\sqrt{5.0}}\right)}\left(\frac{2.0}{5\pi}\right)$$

$$= \frac{4.0}{\pi}\mu_0\left(1 + \cancel{\frac{2.0}{\sqrt{5.0}}}\ \frac{2.0}{5\pi}\right)$$

$$\cancel{= 3.45\times10^{-6}\ T\ (3\text{s.f.})\ (4\text{s.f.})\ 5.448\times10^{-6}\ T\ (4\text{s.f.})}$$

$$B_{py} = (B_p \text{ due to } I_1)\cos\theta$$ 1

$$= \left(\frac{4.0}{\sqrt{5}\pi}\mu_0\right)\left(\frac{1.0}{\sqrt{5.0}}\right)$$

$$= \frac{4}{5\pi}\mu_0\ T$$

$$|B_p| = \sqrt{\left(\frac{4.0}{\pi}\mu_0\left(1+\frac{2.0}{5\pi}\right)\right)^2 + \left(\frac{4}{5\pi}\mu_0\right)^2}$$

$$= \sqrt{\frac{16.0}{\pi^2}\mu_0^2\left(1+\frac{2.0}{5\pi}\right)^2 + \frac{16}{25\pi^2}\mu_0^2}$$

$$= \frac{16.0}{\pi^2}\mu_0^2\left[\left(1+\frac{2.0}{5\pi}\right)^2 + \frac{1}{25}\right]$$

$$= 3.31\times10^{-11}\ T\ (3\text{s.f.})$$

3

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Name: Tan Zhi Yong Subject: Physics S

Reg. No. 0352624 S6H Date: 2/7/04

4i)

$Emf = -\frac{d}{dt}(BA\cos\theta)$

$= \cancel{B\frac{d}{dt}}\ B\cos\theta\left(-\frac{d}{dt}A\right)$

$\cancel{= 10\cos\theta(}$

$\cancel{= \cos 60^\circ(}$

$h = l_0 \cos 30^\circ$

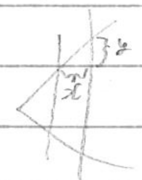
$= \frac{\sqrt{3}}{2}\cos 30^\circ$

$h_1 = 10 + \frac{\sqrt{3}}{2}\cos 30^\circ$

$\frac{h_1}{l} = \cos 30^\circ$

At $t = 5.0s$, distance moved by wire $= 2.0 \times 5$

$= 10.0m$



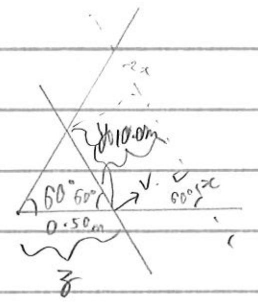
$\frac{y}{x} = \tan 30^\circ$

$y = x\tan 30^\circ$

$= vt\tan 30^\circ$

$\cancel{\cos 60^\circ = x}$ $\tan 60^\circ = \frac{10.0}{x}$

$x = 5.774m$ $l = l_0 + 2vt\tan 30^\circ$



Area covered by wire $= \frac{1}{2} \times 10.0 \times$

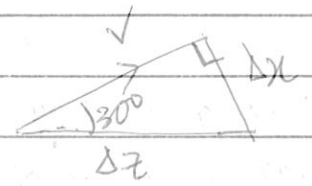
$(0.50 + (0.50 + (5.774)2))$

$= 62.74m^2$

$\frac{dA}{dt} = \frac{1}{2}vy(y+\Delta y)$

$\frac{dA}{dt}\ \cancel{A = \frac{1}{2}vy(y+dy)}$

$\cancel{\frac{dA}{dt}}\ \cancel{= \frac{1}{2}vy(}$



Rate of change of $z = V\cos 30^\circ$

$= 2.0\cos 30^\circ$ X

$E = -\frac{d\phi}{dt}$

$= -B_0\frac{dA}{dt}$

$\frac{dy}{dt} = z\cos 60^\circ$

$A = \frac{1}{2}l^2 \sin 60^\circ$

$= 2.0\cos 30^\circ \cos 60^\circ$

$\frac{dA}{dt} = \frac{1}{2}\left(\frac{1}{2}+\frac{4}{\sqrt{3}}t\right)^2\frac{\sqrt{3}}{2}$

$= 2\left(\frac{1}{2}+\frac{4}{\sqrt{3}}t\right)$

$\frac{dA}{dt} = \frac{1}{2}\cancel{(2.0)}\left(\frac{1}{2}vy(y + 2.0\cos 30^\circ\cos 60^\circ)\right)$

$= \frac{1}{2}(2.0)(0.50)(0.50 + 2.0\cos 30^\circ\cos 60^\circ)$

$t = 5s$

$= 0.50\left(0.50 + \frac{\sqrt{3}}{2}\right)$

$\frac{dA}{dt} = 24.1$

$Emf = \cos 60^\circ\left(0.50\left(0.50 + \frac{\sqrt{3}}{2}\right)\right)$

$= 0.342\ V\ (3s.f)$ X

$I = \frac{V}{R}$

$= \frac{0.342}{0.1 \times (0.50 + (5.774)2)}$ ← R is wrong

$= 0.284\ A\ (3s.f)$ X

Assumptions: The wire has a uniform cross-sectional area. X

1

5a)

$$\cancel{p = \frac{1}{3}\rho\langle c^2\rangle}$$

$$\cancel{1.01\times10^5 = \frac{1}{3}(1000)\langle c^2\rangle}$$

$$\cancel{\langle c^2\rangle = 3.03\times10^2\ ms^{-1}\ (3s.f)}$$

~~Assumption:~~ $pV = nRT$

$$p = \frac{nRT}{V}$$

$$= \frac{\frac{mass}{mr}RT}{V}$$

$$= \frac{\rho RT}{mr}$$

$$= \frac{1000\,(8.31)(300)}{18.0}$$

$$= 138500\ Pa$$

$$p = \frac{1}{3}\rho\langle c^2\rangle$$

$$138500 = \frac{1}{3}(1000)\langle c^2\rangle$$

$$\langle c^2\rangle = 416\ ms^{-1}\ (3s.f)$$

$\rho = \frac{N}{V}$

0

Assumption: No evaporation is taking place.

5b)

$$\langle c^2\rangle = \sqrt{c_{mean}^2}$$

$$= \sqrt{\left(\frac{c_1+c_2+c_3+\ldots c_n}{n}\right)^2}$$

There a a very large no. of molecules in a gas, with a wide variation of speeds and kinetic energies. Thus rms speeds do not give a good estimate of when the first gas molecules arrive in the distinct region of the room.

0

0

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Name: Tan Zhi Yong Subject: Physics S

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1a) Amplitude refers to the maximum displacement of the particles in a wave from equilibrium. Intensity is proportional to square of amplitude and measures the rate of energy transmission. 2

1ai)
$E = hf$ — (1)
$\lambda = \frac{h}{mv}$ — (2)
$\rho = \frac{m}{Vol}$ — (3)
$v = f\lambda$ — (4)

$KE_{max} = \frac{1}{2} m v_{max}^2$
$= \frac{1}{2} m (S w)^2$
$= 2m\pi^2 f^2 S^2$

From (3): $Vol = \frac{m}{\rho}$ — (5)

$\frac{(1)}{(5)}$: $\frac{E}{Vol} = \frac{hf\rho}{m}$ — (6)

~~subst~~ From (2): $h = mv\lambda$ — (7)

subst (7) into (6): $\frac{E}{Vol} = \frac{mv\lambda f \rho}{m}$
$= v\lambda f \rho$
$D = v\lambda f \rho = v^2 \rho$
$= f^2 \lambda^2 \rho$
$= 2\pi^2 f^2 S^2 \rho$

3.

1aii)
$I = \frac{E}{A}$
$= DV$
$= 2\pi^2 f^2 S^2 \rho V$

$P = \frac{E}{T} = \frac{DV}{T}$
$I = \frac{P}{A} = \frac{DV}{TA}$
$= \frac{DAL}{TA}$
$= DV$

2

extended source

(aiii) $I = 2\pi$

$\delta^2 = \frac{}{2}$

$\delta = \sqrt{\frac{}{2\pi}}$

$= \sqrt{\frac{1}{2\pi}}$

$= 4.$

1bi) The path difference
and destructive
wave to alter from

1bii) $V = f$

$\lambda =$

$= 3$

$=$

~~DA~~ Node

$T = 4$

$= 0$

Speed $= \frac{3}{}$

$= 5$

1biii) It is perfectly f

Name: ....

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2ai)

~~13·6~~

13·6 × 1·6

~~KE~~

~~2aii)~~ ~~KE of e~~

2aii) KE of

$\frac{1}{2}m_e$

1·36

2bi) E

Min E_n

2bii)

Uki

Ua

2biii)

2c)