# Suggested Solution for 2005 A'Level Physics Paper 2

Q1

(a)(i) Using $s = ut + ½ at^2$

$1.00 = 0 + ½ (9.79)t^2$

$t = 0.45198 = 0.452$ s (shown)

(ii) Let the length of the plate be L

To cover L, time taken, t = 0.052 s

Total time of fligh = 0.0452 + 0.052 = 0.504 s

Total distance covered = 1.00 + L

Using $s = ut + ½ at^2$

$1.00 + L = 0 + ½(9.79)(0.504)^2$

L = 0.24 m (2 s.f)

(b)

1. Air resistance will act against the fall of the metal plate. Therefore the plate's acceleration will be reduced and the time of flight will be increased.

2. The falling plate may not be vertical when falling thereby affecting the time measured during its fall

Q2

(a) (i) $E = hc/\lambda$

$1.17 \times 10^6 \times 1.6 \times 10^{-19} = (6.63 \times 10^{-34} \times 3 \times 10^8)/\lambda$

$\lambda = 1.06 \times 10^{-12}$ m

(ii) Using de Broglie's equation

$p = h/\lambda$

$= 6.63 \times 10^{-34} / 1.06 \times 10^{-12}$

$= 6.255 \times 10^{-22}$

$= 6.26 \times 10^{-22}$ $kgms^{-1}$

(b)

(i)


(ii) By Principle of conservation of momentum, the total momentum of the nickel before the emission must be equal to the total momentum of the nickel and the photon after emission.

$0 = P_{photon} + (-P_{nickel})$

$0 = 6.255 \times 10^{-22} - 9.95 \times 10^{-26} V_{nickel}$

Speed of nickel after the emission, $V_{nickel} = 6286 = 6300\ ms^{-1}$

(c) By Principle of conservation of momentum, the momentum of the nickel before the emission must be equal to the total momentum of the nickel and the photon after emission.

~~The moving nickel has momentum in one direction initially. In order for the total momentum of the system to be conserved in one direction, the sum of final momentum of the photon and final momentum of the nickel must be in the same direction as before. Hence the angle between the emitted photon and the final nickel direction is zero.~~ The angle need not be zero.


3a A gravitational field is a region of space in which a mass experiences a force due to the presence of another mass.

b

$g \alpha \frac{1}{r^2}$

$gR^2 = g_1(1.3R)^2$

$g_1 = 0.59g(shown)$

c i) In orbit, gravitational force acting on the astronaut/satellite is used to provide the centripetal acceleration necessary for the astronaut/satellite to orbit the Earth.

Both astronaut & satellite are in free fall

⇒ Both have same centripetal acceleration

∴ No force exist b/w them

It is the rxn force b/w an object & its support that determine the object apparent weight

ii)

$\frac{GMM}{r^2} = Mr\omega^2$

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

$0.59g = 1.3R\omega^2$

$\omega = 8.3 \times 10^{-4} rads^{-1}(shown)$

iii)

$T = \frac{2\pi}{\omega}$

$T = 2.09hrs$

4a) (i) Forced oscillations are the vibrations of a body that is made to vibrate by an external periodic force.

(ii) Resonance

b) (i) 1. $\omega = 2\pi f$

$= 2(3.14)(12)$

$= 75.4\ rads^{-1}$

For max speed,

$v = \omega x_0$

$= (75.4)(0.016)$

$= 1.21\ ms^{-1}$

2. For max acceleration,

$a = -\omega^2 x_0$
$= -(75.4)^2(0.016)$
$= -91.0\ ms^{-2}$

(ii) $T = 1/f$
$= 1/12$
$= 0.083$ s
Time interval = T/4
$= 0.083/4$
$= 0.021$ s

c) The increase in mass will result in a lower natural frequency. Hence, the peak of the graph will be displaced to the left. In addition, the graph will have a lower peak value due to the damping effects of an increased mass. As the graph has a lower peak, the range of frequencies in which there is adequate response has increased.

5

a) i) the p.d across the resistor = $(0.93 \times 10^{-3})$ (5700) = 5.3 V

ii) the p.d. across the capacitor = 7.5 – 5.3 = 2.2 V

iii) rate at which the p.d. across the capacitor is increasing
$= V_c / t = (Q/C) / t = I / C = (0.93 \times 10^{-3}) / (2200 \times 10^{-6}) = 0.423\ V\ s^{-1}$

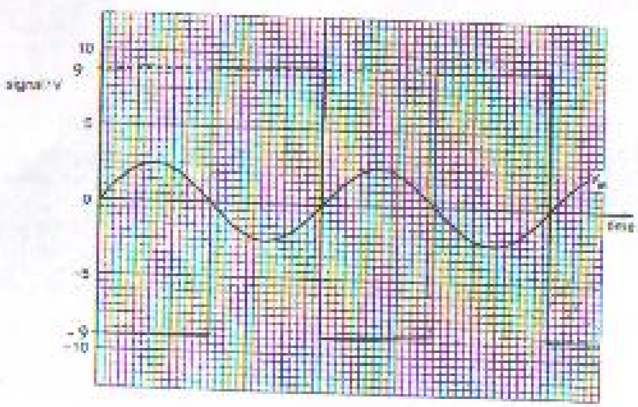
b) i) The final energy stored in the capacitor = ½ $(2200 \times 10^{-6})(7.5)^2$
= 0.0619 J

ii) The energy supplied by the battery is more than 0.0619 J of energy stored in the fully charged capacitor. This is because during the charging process, current flows in the circuit will cause heating of the resistor and the connecting wire.

6 (a) Properties of an ideal operational amplifier:
- an infinite input impedance
- infinite open loop gain
- zero output impedance
- infinite bandwidth
- infinite slew rate

Any of the three properties mentioned.

(b)




(c) (i) Since the output voltage saturates at +6 V and -6 V, the supply voltage to op-amp must be changed from ±9 V to ±6 V.
From fig 6.1, since $V_{out} = A_0(V^+ - V^-)$, $V^-$ must be set at +2 V and $V^+$ must at $S_e$ for $S_{out}$ = +6 V when $S_{in}$ > +2 V

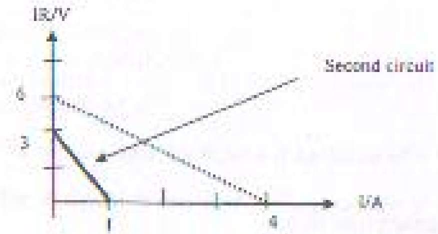
(ii) From fig 6.1, $S_{out}$ = +6 V when $S_{in}$ > +2 V. To vary the length of time for $S_{out}$ to be positive, we can vary the voltage at $V^-$.
By varying 2 V < $V^-$ < +4 V, the length of time for $S_{out}$ to be positive will decrease. When $V^-$ > +4 V, $S_{out}$ will always be negative.
By varying -4 V < $V^-$ < +2 V, the length of time for $S_{out}$ to be positive will increase. When $V^-$ < -4 V, $S_{out}$ will always be positive.

Q7

a) i) $\Sigma E = \Sigma IR$
$E = IR + Ir$
$IR = E - Ir$

b) i)
1. When I = 0, IR = E = y-intercept = 6.0 V
2. p.d. across R = IR = 4.2 V when I = 1.2 A.
power dissipation = 4.2 x 1.2 = 5.04 W
3. internal resistance r = gradient of the graph = 6.0 / 4.0 = 1.5 Ω

(ii)




8 (a)(i) Visible range is from 400 nm to 700 nm.

(ii) The wavelength corresponding to red light (700 nm) would have greatest intensity within the spectrum of visible light at 1100 K, thus only the red colour is observed.

(b)(i)

| T / K | $\lambda_{max}$ / nm | $T\lambda_{max}$ / $10^{-9}$ Km |
|---|---|---|
| 600 | 4830 | 2898 000 |
| 700 | 4140 | 2898 000 |
| 800 | 3610 | 2888 000 |
| 900 | 3210 | 2889 000 |
| 1000 | 2900 | 2900 000 |
| 1100 | 2630 | 2893 000 |

From the calculation of all the values of $T\lambda_{max}$, it was found that the values ranged from $2.898 \times 10^{-3}$ Km to $2.900 \times 10^{-3}$ Km. This may be due to experimental errors experienced during the process. Thus, by taking the average of the values, the value of the constant is found to be 2894 333 x $10^{-9}$ Km.

(ii) $T\lambda_{max} = 2884\ 333 \times 10^{-9}$
$\lambda_{max} = 2.41 \times 10^{-6}$ m

(c)(i) $I_{tot} = c\,T^{n}$
$\lg(I_{tot}) = \lg(c) + n\lg(T)$

$n$ = gradient = 4

(ii) $\dfrac{\lg I - \lg 71}{\lg 1200 - \lg 900} = 4$

$I = 227.4\ \mathrm{Wm^{-2}}$

(e)(i) Wavelength at maximum intensity or the total intensity of the radiation can be used with the help c the graph in this question to determine the temperature of the body.

(ii) Advantage: No physical contact at high temperature, or this method can be used for measuring high temperature, or any sensible answer.
Disadvantage: Difficulty in measuring the wavelength accurately at max intensity, or this method cannot be used to measure low temperature, or any sensible answer.

2c(v). At take off, $F_{net}$ = ma
a = $F_{net}$/m
a = $F_{net}$/(Weight/g)
a = (4000)/(177 000/9.81)
a = 0.213 $ms^{-2}$

2d(i). Since PV = 1/3 Nm<c2> and PV = NkT (remember that m is the mass per molecule)
By substitution,
1/3 Nm<c2> = NkT and rearranging gives
½ m<c2> = 3/2 kT
Therefore, the kinetic energy of the Helium molecule or ANY gas molecule that is approximated as an ideal gas is = 3/2kT

2d(ii) Note: the kinetic energy of any ideal gas is solely based (or determined) by it's temperature. At 32.0 km, T = 228 K
Thus, ½ m<c2> = 3/2 kT
= 3/2 (1.381 x $10^{-23}$)(228)
= 4.72 x $10^{-21}$ J

2d(iii) PV = nRT
Hence, n = (P1V1)/RT1 = (101 x 103)(15000)/(8.314)(288)
= 632717
= 6.32 x $10^5$ moles

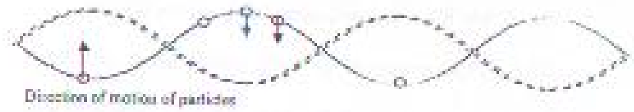
(note: PnVn and Tn can be used as long as these quantities are based on the same state)

2d(iv) Now, since 4.72 x $10^{-21}$ J is the average kinetic energy per molecule of He
Total amount of energy = number of molecules x average Ek per molecule
= n x NA x average Ek per molecule
= (6.32 x $10^5$)(6.02 x $10^{23}$)( 4.72 x $10^{-21}$)
= 1.80 X $10^9$ J

2e. The internal energy of a system of gas is based on it's the potential energy between molecules and the net kinetic energy of it's molecules. This potential energy is based on the forces of attraction between molecules within the system – in this case, in the balloon. The gravitational potential energy is the stored energy between the mass of the earth and the gas molecules, not the intermolecular forces of attraction.
Also, for an ideal gas (any gas under low pressure can be approximated as an ideal gas), there is negligible potential energy between gas molecules.



3(a) Stationary waves are set up as a result of superposition of two waves of equal frequency and amplitude travelling at the same speed but in opposite directions.




The wave is not progressing and there is no transfer of energy in a stationary wave. When the waves interfere constructively, antinodes are formed. When the waves interfere destructively, nodes are formed. Antinodes are region where the amplitude of vibration is the maximum and nodes are regions where the amplitude of vibration is zero.

(b)(i),(ii)

| | | |
|---|---|---|
| 270 Hz: | 1348-102 = 1246 mm | 336 m/s |
| 405 Hz: | (1332-82)2/3 = 833.3 mm | 337.5 m/s |
| 540 Hz: | (1310-62)/2 = 624 mm | 337.0 m/s |
| 675 Hz: | (1300-52)/2.5 = 499.2 mm | 332.1 m/s |
| 810 Hz: | (1298-47)/3 = 416.3 mm | 337.2 m/s |

(iii) Average speed of sound = 335.96 = 336 m/s
(iv) Using the values measured for 810 Hz,
$v = f\lambda_i = f\,(l_2 - l_1)/n$
$\Delta v/v = \Delta f/f + (\Delta l_2 + \Delta l_1)/(l_2 - l_1)$
Assuming that f has no uncertainty,
$\Delta v$ = [(1mm+1mm)/(1249-47)] (337.2) = 0.5 m/s

(c) The direction of vibration of the air particles is along the tube as indicated in the diagram. At the node, the particle is stationary. However, adjacent particles to the nodes are moving toward the stationary particle, resulting in a largest pressure variation at the node. At the anti node, although the particle is vibrating at its largest amplitude, the separation of the particles remain unchanged, thus the pressure variation is the minimum.

(c) Reflect microwave using a smooth metal plate. A stationary wave would be formed in between the source and the metal plate. A simple diagram of the set up should be included. (refer to lecture notes/superposition demonstration for more details)

4(a) Electric field strength – electrostatic force acting per unit positive charge
SI unit – $NC^{-1}$

(b) Since $E = \frac{F_E}{q}$

and W (work done by the field) $= F_E \times x$

therefore $E = \frac{W/x}{q} = \frac{q\Delta V/x}{q}$ where $\Delta V$ is negative (work done by the field)

hence $E = \frac{\Delta V}{x} = \frac{V}{d}$ between the plates

(c) (i) $E = \frac{\Delta V}{x} = \frac{V}{d} = 600\,kVm^{-1}$

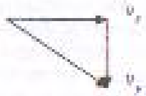
(ii) $v = \frac{d}{t}$, $t = \frac{d}{v} = \frac{40\times10^{-3}}{3.9\times10^{6}} = 1.0256\times10^{-8} = 1.03\times10^{-8}\,s$

(d) (i) 1. $F_E = qE = ma_y$, hence $a_y = E\frac{q}{m} = 600\times10^{3}\frac{q}{m}$

2. $v_x = 3.9\times10^{6}\,ms^{-1}$ remains the same,

$v_y = a_y t = 600\times10^{3}\frac{q}{m}\times1.0256\times10^{-8} = 6.1536\times10^{-3}\frac{q}{m} = 6.15\times10^{-3}\frac{q}{m}$

(ii) $\tan 4.3^\circ = \frac{v_y}{v_x}$,




$6.15\times10^{-3}\frac{q}{m} = 3.9\times10^{6}\tan 4.3$

$\frac{q}{m} = 4.765\times10^{7}\;Ckg^{-1}$

$\frac{n_p e}{n_n m_{p}} = 4.765\times10^{7}$

$\frac{n_p}{n_n}\left(\frac{e}{m_{p}}\right) = 4.765\times10^{7}$

$\frac{n_p}{n_n}\left(\frac{1.6\times10^{-19}}{1.67\times10^{-27}}\right) = 4.765\times10^{7}$

$\frac{n_n}{n_p} \approx 2$



(e) (i) Refer to screen at a distance away from the end of the plate and measuring the distance x and y from the initial entry from the parallel plate. Use simple trigo like tan to solve for angle.

(ii) Velocity selector setup using cross B and E-field

(iii) Alpha particle $\left({}^{4}_{2}He\right)$ or deuterium particle $\left({}^{2}_{1}H\right)$.

5(a)(i) Isotopes are elements with the same proton number but different nucleon number. They are chemically indistinguishable since they have the same electronic configuration.

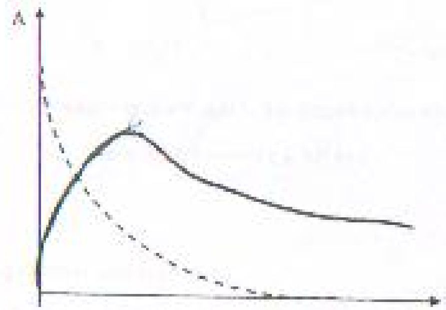
(ii) ${}^{214}_{82}Pb$ has 82 protons and 132 neutrons

(b) ${}^{214}_{83}Bi \rightarrow {}^{210}_{81}Tl + {}^{4}_{2}\alpha$

${}^{214}_{83}Bi \rightarrow {}^{214}_{84}Po + {}^{0}_{-1}\beta$

(c) Photons emitted are energy released from the nucleus during the radioactive decay. When Bi undergone the 2 decays, the mass difference and thus the change in binding energy is different for both decays. As a result, photons of different energy are released.

(d)




(e) (i) Number of atoms = mass/Mr (Av) = 2.6μ/214 (6.02 x $10^{23}$) = 7.31 x $10^{15}$ atoms
(ii) $\lambda = \ln 2/t_{1/2} = 4.278\times10^{-4}\,s^{-1}$
(iii) $A = N\lambda = 3.127\times10^{12}$ Bq
(iv) $A = A_0 e^{-\lambda t}$
$8.3\times10^{6} = 3.127\times10^{12}\,e^{-\lambda t}$
t = 231 min

6(a) Magnetic flux through a region is the product of the area of the region and the magnetic flux density perpendicular to the region. Its SI units is Weber.

(b)(i) $\theta = \omega t$

$$t = \frac{\theta}{\omega} = \frac{\theta}{2\pi f} = \frac{\pi/180}{2\pi(50)} = 5.5x10^{-5}s$$

(ii) $\Delta\phi = \phi_f - \phi_i = (BA\cos\theta) - (0) = BA\sin\alpha = 0.0121Wb$

(Note: $\theta$ refers to the angle between the normal and the field, while $\alpha$ refers to the angle between the plane of the coil and the field. In this question, $\alpha = 1°$. Also, initial flux thru the coil is zero.)

(iii) $$|E_i| = \frac{\Delta\phi}{\Delta t} = 218V$$

(iv) $$|E_{38}| = 38|E_i| = 8310V$$

(c)(i) $$Vrms = \frac{1}{\sqrt{2}}Vo = 5880V$$

(ii) By Flemming's Right Hand Rule, current flows from A to D.

(d) (Adapted from lecture notes) Alternating currents (instead of d.c.) are widely used for the transmission of electrical energy because:

(i) a.c. voltages are easier to step up/down with little loss using transformers. Electric power is transmitted most efficiently at high voltage and low current. These conditions result in a minimum loss of energy as heat. On the other hand, low voltages are desirable in factories and at homes for reasons of safety and insulation. For alternating currents, the job of changing voltage from one value to another can be done easily and cheaply by a transformer.

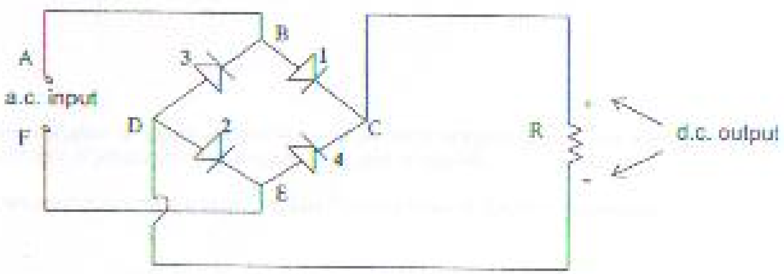
(ii) a.c. are easier to generate than d.c

(iii) a.c. are just as suitable for heating as for d.c. (refer to definition of rms values)

(iv) where d.c. are required, it is easy to convert or rectify a.c. into d.c. (refer to rectification of a.c.)

(v) a.c. voltage is easier to switch on and off as it passes through zero many times per second.

(e)



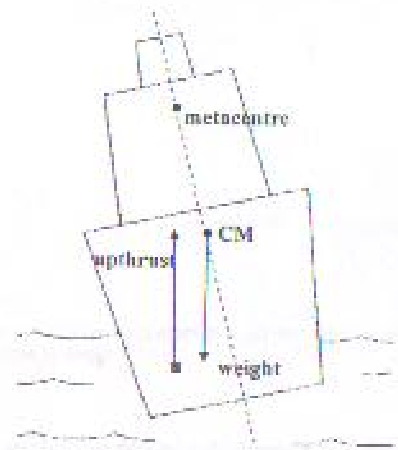



## Physics of Fluids

10(a) Centre of mass of a ship is the point through which its weight acts. Metacentre of a ship refers to the intersection between the centerline of the ship and the line of action of upthrust acting on it

10(b)

(i)




(ii) Torque on the ship = moment due to the couple comprising the weight and upthrust

= 1.3(5 x 10[7]) = 6.5 x 10[7] Nm

11(a)

(i) **Applying Conservation of Mass,**

**mass of fluid enter A1 per unit time = mass of fluid exiting A2 per unit time**

$A_1v_1\rho_1 = A_2v_2\rho_2$ , where $Av = A_1v_1 = A_2v_2$ = volume flow rate of fluid

Since fluid is ideal, i.e. incompressible, $\rho_1 = \rho_2 = \rho$

Hence $A_1v_1\rho = A_2v_2\rho$ and $A_1v_1 = A_2v_2$

(ii) Refer to 2006 NJC Prelim P3 Q8 (a) solutions.

11(b)

(i) Applying Conservation of Energy.

Rate of net work done on the fluid = rate of increase of Fluid KE + rate of increase of GPE

$$(p_1 - p_2)Av = \frac{\Delta m v_2^2 - \Delta m v_1^2}{2} + \Delta mgh$$

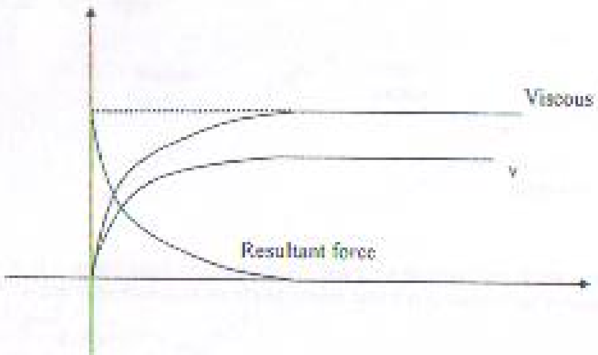
$$p_1 - p_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho gh$$

(ii) If v2 = 0, v1 also = 0 because of Equation of Continuity
*(It makes sense, if there is no outflow, how can there be inflow? )*

Equation derived in b(i) is reduced to

$p_1 - p_2 = \rho gh$ = pressure difference !!!

12(a)




The time variation of object velocity is similar to that of viscous force due to the fact the viscous force is proportional to velocity or square of velocity.

Initial resultant force on the object equals the drag force at the terminal velocity.



12(b)

(i) Please refer to lecture notes for the experimental setup

Theory

When traveling at terminal speed,

Weight = upthrust + Drag force

$$\frac{4}{3}\pi r^3\rho_s g = \frac{4}{3}\pi r^3\rho_f g + F_D$$

$$F_D = \frac{4}{3}\pi r^3 g(\rho_s - \rho_f)$$

For spherical object,

$$6\pi\eta r v_T = \frac{4}{3}\pi r^3 g(\rho_s - \rho_f)$$

$$\eta = \frac{2}{9}\frac{gr^2(\rho_s - \rho_f)}{v_T}$$

(ii) Ensure laminar conditions by choosing a sphere with small enough diameter so that the drag force is small.

OR

Choose a ball which has a density only slightly greater than the density of the fluid so that the initial resultant force on it is small. Hence the final drag force will be kept small.