THE UNIVERSITY OF SYDNEY

FACULTIES OF ARTS, EDUCATION, ENGINEERING AND SCIENCE

SAMPLE EXAM SOLUTIONS

PHYSICS 1 (ADVANCED)

November 2000

Answer to Question 1

(a) True — Because the column on the left is open to the air, P_A is the pressure of the atmosphere.

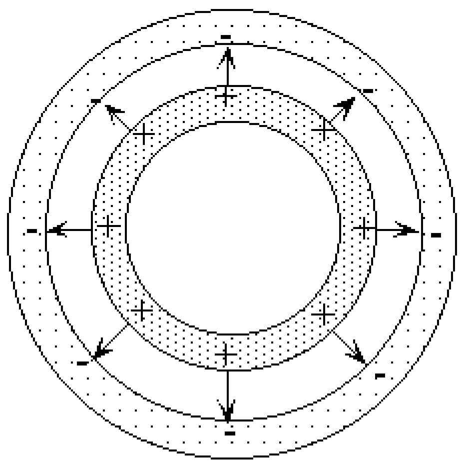
(b) False — The pressure at B must be the same as the pressure at a depth d below the surface A, or $P_B = P_A + \rho g d$. This is also the pressure of the air chamber above B.

(c) True — Because we can neglect the weight of the air, the pressure of the air in the "CD" chamber is constant; $P_C = P_D$.

(d) Undecidable — The pressure at E is given by $P_E = P_A - 4\rho g d$.
[Note that if $d = P_A / 4\rho g d$ = 2.5 m, then $P_E = 0$.]

(e) True — The pressure at D is $P_D = P_A - \rho g d$.

Answer to Question 2



1 mark for no field inside inner cylinder and no charge on its inner surface

1 mark for positive charge on outer surface of inner cylinder

1 mark for field between outer surface of inner cylinder and inner surface of outer surface

1 mark for negative charge on inner surface of outer cylinder

1 mark for no charge on outer surface of outer cylinder and no field beyond inner surface of outer cylinder.

Answer to Question 3

(i) Volume flow rate $= Av$

$= p(10)^2 mm^2 \times 3\ mm\ s^{-1}$

$= p\ 300\ mm^3\ s^{-1} = 0.94 \times 10^{-6} m\ s^{-1}$

(ii) Pressure difference is given by Bernoulli equation, assuming non-viscous incompressible fluid, A_1 = cross section of narrow pipe, and both pipes at the same height

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2$$

but $A_1 v_1 = A_2 v_2$ equation of continuity

$$v_2 = \frac{A_1}{A_2} v_1 = \left(10/15\right)^2 \cdot 3.0\ mm^{-2}$$

$$= 1.3\ mm.s^{-1} = 1.3 \times 10^{-3} m\ s^{-1}$$

To find pressure difference

$$P_1 - P_2 = \tfrac{1}{2}\rho \times (1.3^2 - 3^2) \times 10^{-3}\ m\ s^{-1}$$

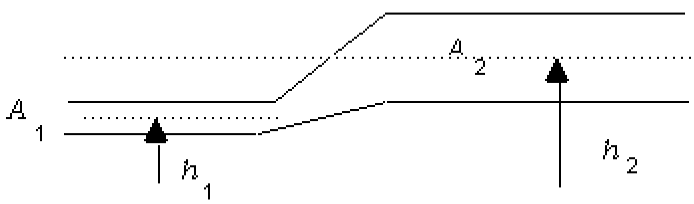
$$= -\tfrac{1}{2}\rho \times 6.31 \times 10^{-3}\ m\ s^{-1}$$

The negative sign indicates that

$P_2 > P_1$

ie the pressure in the narrow pipe is less.

(c)



If the relative heights of the pipes are changed then Bernoulli's equation gives us

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

If volume flow rate remains the same then v_1 and v_2 are unchanged.

But $h_2 - h_1 = h$ so h is positive

and

$$P_1 - P_2 = \tfrac{1}{2}\rho v_2^2 - \tfrac{1}{2}\rho v_1^2 + \rho g h\ .$$

The pressure difference will depend on the size of h. As h becomes larger the pressure difference becomes less.

Answer to Question 4

(a) Force on m =0 for $r < b$ *(1 mark)*

Spherical symmetry (Shell Theorem), proved by Gauss' Law gives $F = 0$ always inside uniform shell.

(b) b £ r £ a

$$F = \frac{GmM'}{r^2}$$ where M' =mass enclosed at radius r. Mass outside radius r exerts no force.

Assume density of mass in shell is constant.

Therefore,

Density $\rho = \frac{M}{V} = \frac{M'}{V'}$, M' is mass enclosed at r and V' is volume enclosed at r .

$$V = \tfrac{4}{3}\pi a^3 - \tfrac{4}{3}\pi b^3$$

$$V' = \tfrac{4}{3}\pi r^3 - \tfrac{4}{3}\pi b^3$$

$$M' = M\frac{V'}{V} = M\frac{(r^3 - b^3)}{(a^3 - b^3)}$$

$$F = \frac{GmM(r^3 - b^3)}{r^2(a^3 - b^3)}$$

Again mass in uniform spherical shell exerts no force on objects inside the shell. Gravitational force on objects due only to mass enclosed at a particular radius.

(c) $r > a$

$$F = \frac{GmM}{r^2}$$

Spherical symmetry (shell theorem), proved by Gauss' Law says gravitational force is same as if mass were concentrated at a point at the centre of the shell.

(d) Second mass M_2 added.

Yes,force on m changes

Superposition holds. M experiences a force due to to second mass M_2. No equivalent concept of a conductor in gravitational fields,ie no shielding effect by being inside shell of mass M.

$$F = 0 + \frac{GM_2 m}{r^2}$$, where r = distance from m to M_2.

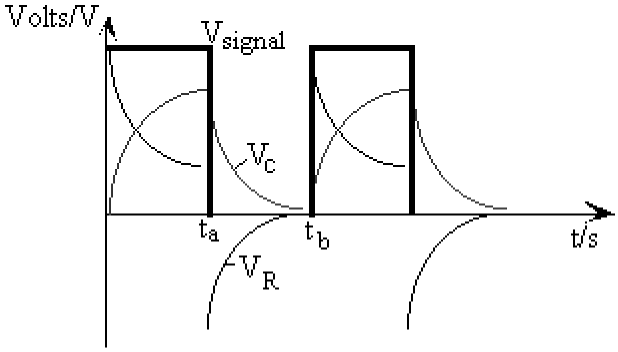
SECTION B

Answer to Question 5

(i)The shape shows the capacitor being charged up while the signal voltage is switched on and discharging when the signal voltage is switched off.

(ii)Since RC is the time taken for the voltage V to fall to 1/e (=0.37) of its value we can see that the pulse width is of the order of a few times RC.

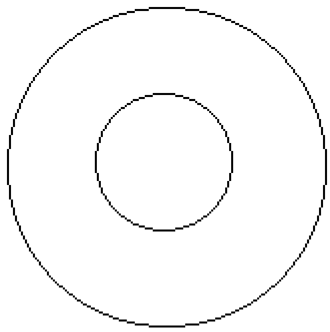
(iii)At all times, $V_R + V_c = V_{\text{signal}}$



From $t_a \rightarrow t_b$, $V_R + V_C = 0$.

V_R is negative since the current reverses as the capacitor is discharging.

Answer to Question 6



The magnetic field due to the outer loop is into the paper, using right hand rule.
(1 mark)

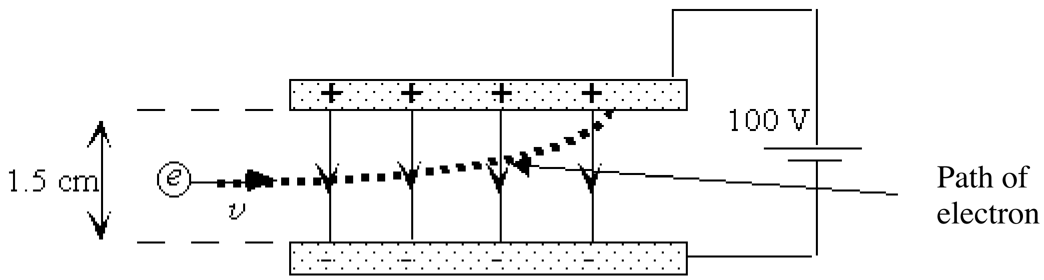
(i) The force on an element of the inner loop has direction given by $d\mathbf{s} \times \mathbf{B}$ where d**s** is element length in direction of current. Thus the force is radially outward.

(2 marks)

(ii) Since the force is symmetric, ie radially outwards everywhere, and the loops are concentric, there is no net force on the inner loop. However there is a radial stress tending to expand the inner loop. ***(2 marks)***

Answer to Question 7

(a)



(c) For the electron to pass through **undeflected**, the force due to the electric field must be equal and opposite to the force due to the magnetic field. The force due to the magnetic field depends on the speed of the electron (**F** = q **v** X **B**) and so the first step is to calculate the speed υ of the electron as it enters the plates.

The electron is accelerated by the 1.0 kV potential difference through electric field E ' before it reaches the plates shown in the above diagram..

The force F on the electron as it is being accelerated is eE 'and

the work done = Fs cos q = eE' d where d is the distance it is accelerated through.

But $E'd = V$ where V is the potential difference of 1.0 kV, assuming the accelerating field is uniform

Work done (W) = Kinetic Energy gained = $\frac{1}{2}m\upsilon^2$ assuming the electron starts from rest

Thus work $W = eV = \frac{1}{2}m\upsilon^2$,

so

$$\upsilon = \sqrt{2eV/m}$$

Now in the region of the plates the electric force = magnetic force

$$eE = e\upsilon B \sin q$$

$$E = \upsilon B$$

(Note we are told B is perpendicular to υ and so the sin$q$ = sin 90 =1,

and the electric field $E = V/d$ = 100V/1.5 x 10^{-2} m = 66.7 x10^2 V/m

This gives $B = E/\upsilon = E/\sqrt{2eV/m}$

= 66.7 x10^2 V/m/[2 x 1.6x10^{-19} C x 1000V/9.11x10^{-31} kg]$^{1/2}$

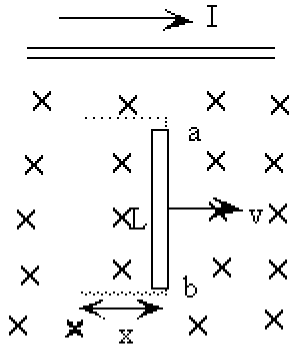
= 3.6 x10^{-4} T

Since Force due to E is towards the positive upper plate, the force due to B must be down towards the negative plate, if the electron is to follow a straight path.

An electron moving to the right is equivalent to a conventional current moving towards the left, from the relationship (F = q v X B) B must be directed into the page to give a downwards force on the electron.

B = 3.6 x10^{-4} T in a direction into the page.

Answer to Question 8



a)

The magnetic field is into the paper. *(1 mark)*

Consider the flux inside the dashed line after the time t ,so $x = vt$ *(1 mark)*

$\Phi_B = \int B dA = \int B x . dr$ *(1 mark)*

$= \int \frac{\mu_0 I}{2\pi r} x dr = \frac{\mu_0 I x}{2\pi} \int_d^{d+L} \frac{1}{r} dr$

$= \frac{\mu_0 I x}{2\pi} \ell n\left(\frac{d+L}{d}\right)$ ***(2 marks)***

$\therefore$ The emf is $\frac{d\Phi_B}{dt} = \frac{\mu_0 I v}{2\pi} \ell n\left(1 + \frac{L}{d}\right)$ ***(1 mark)***

b) Charges in the bar flow in the $q\mathbf{v}x\mathbf{B}$ direction, so +ve charges accumulate at a, -ve at b , and potential at a is higher than at b *(2 marks)*

OR, a current would flow in the bar around a wire placed on the dashed line to decrease the magnetic field into the page, ie anti-clockwise, so the bar would be equivalent to a battery with a potential higher at a than at b .

c) Current is induced upwards in both the left and the right arms, so the net current is zero. ***(2 marks)***

SECTION C

Answer to Question 9

(d) While precision associated with experimental measurement and uncertainty as discussed in quantum theory are not identical the precision gives an upper limit to the uncertainty . The uncertainty principle states that

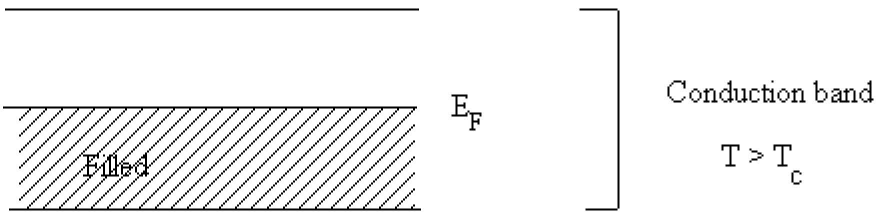
$\Delta p_x \Delta x \geq \hbar$. We will take the direction of motion in the x-direction.

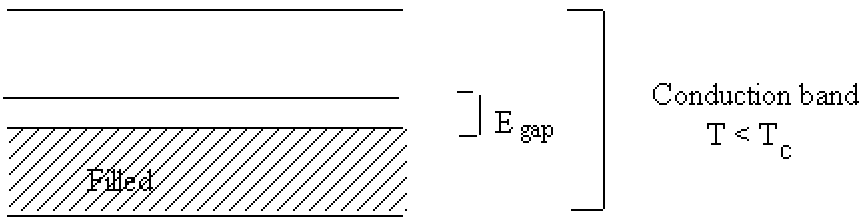
So $\Delta p_x = m\Delta v_x = 0.045\text{kg} \times \frac{1.5}{100} \times 35\text{ms}^{-1} = 0.024$ kg.m.s^{-1}.

And $\Delta x = \hbar / \Delta p_x = \frac{6.626\times10^{-34}\text{J.s}}{2\times\pi\times0.024\text{kg.m.s}^{-1}} = 4.3\times10^{-33}\text{m}$

(b) The correspondence principle states that the predictions of quantum theory must correspond with the predictions of classical physics in the region of sizes where the classical theory is known to hold. These classical sizes for length, mass and time are of the order of millimeters, grams and seconds. Since we cannot measure to 4.3×10^{-33} m in an experimental laboratory this uncertainty would never be noticed.

Answer to Question 10





In type I superconductivity, all flux is suddenly excluded at T_c

In type II the fluid is trapped, forming vortices

Answer to Question 11

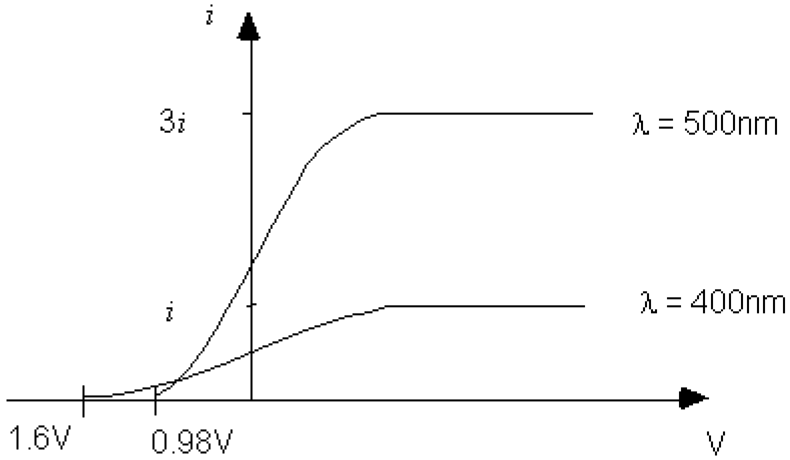
(a) From conservation of energy, $eV_o = hf - \phi$
where V_0 is the stopping potential(ie the potential necessary to slow the ejected electrons down to zero velocity).

But $$eV_0 = \frac{hc}{\lambda} - \phi$$

therefore $$eV_o = \frac{4.14\times10^{-15}\text{eVs}\times3\times10^{8}\text{ms}^{-1}}{\lambda\,\text{m}} - 1.5\,\text{eV}$$

For $\lambda = 400\,\text{nm}$ $\quad eV_o = (3.105 - 1.5)\ \text{eV} = 1.6\ \text{eV} \ \therefore V_o = 1.60\text{V}$
For $\lambda = 500\,\text{nm}$ $\quad eV_o = (2.484 - 1.5)\ \text{eV} = 0.98\text{eV} \ \therefore V_o = 0.98\text{V}$

(b)Graphing current versus stopping potential gives the following.

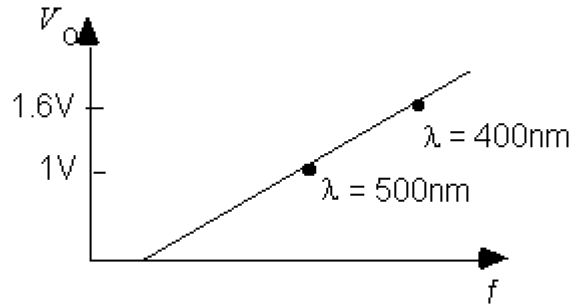


Note that the stopping potential is greater (1.6V) for the higher energy (shorter wavelength) photons, but that the current at high positive values of potential is greater for the light of greater intensity given that the photons of both the given wavelengths are capable of ejecting electrons.

(c) In wave theory, photoelectric effect should occur for any frequency (wavelength) of light.

In photon model, for electron to be ejected it must obtain certain minimum amount of energy from photon (= work function of surface) to be ejected. Energy of photon, $E = hf$. If f is not large enough, then photon does not have enough energy to overcome work function of material This implies that a cut off frequency exists below which the photoelectric effect will not occur.

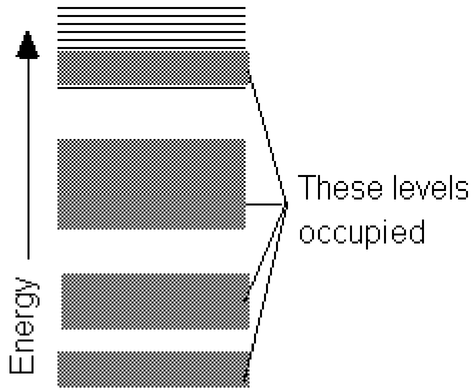
(d) If we plot stopping potential V_o vs $f\ (=1/\lambda)$, we get a straight line



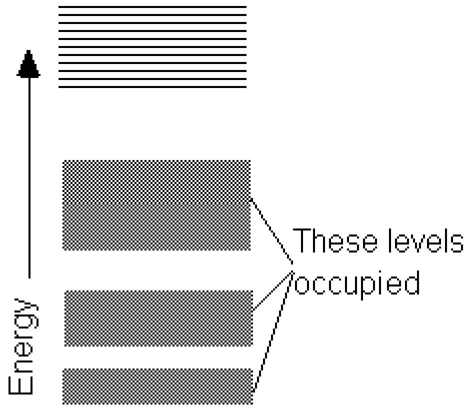
ie $V_o = \frac{h}{e} f - \frac{\phi}{e}$, so slope = $\frac{h}{e}$,(comparing with $y = mx + c$).
Since e, the charge on the electron, is known, we can calculate h .

Answer to Question 12

(a) Conductor

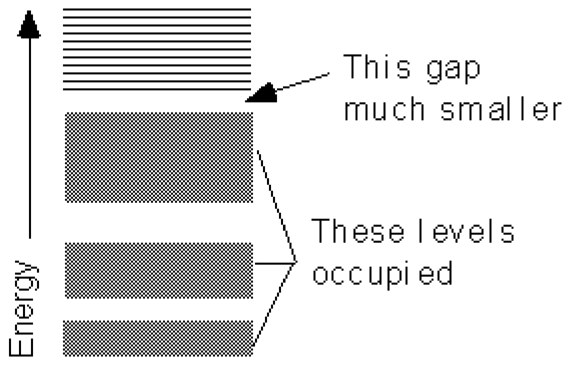


(b)Insulator



(c) If a current is to flow then the electric field has to start accelerating the electrons which make up the current. it must therefore give them the kinetic energy and raise them to a higher energy level. In a conductor the uppermost electrons have energy levels very close to them which are unoccupied.Hence the necessary increase in energy can occur and the electrons are free to move.
In an insulator the next available level is separated by a large energy gap. The electric field is not strong enogh to give the electron the required energy. Therefore the electron cannot gain any energy and therefore does not accelerate and so there is no current.

(d) Semi conductor



(e) The effect of increasing the temperatue is to give the electrons in the valence band more energy. Some can jump into the conduction band(which is not far away) and take part in conduction. As the temperature increases more electrons can make the jump and so the conductivity will increase.(i.e. the resistivity will decrease.)