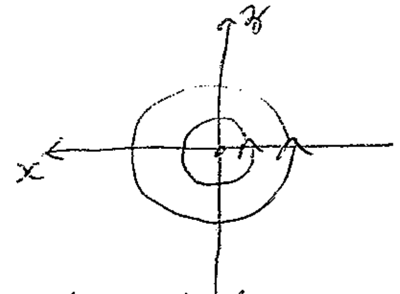
PHYS 1231

MARKING SCHEME

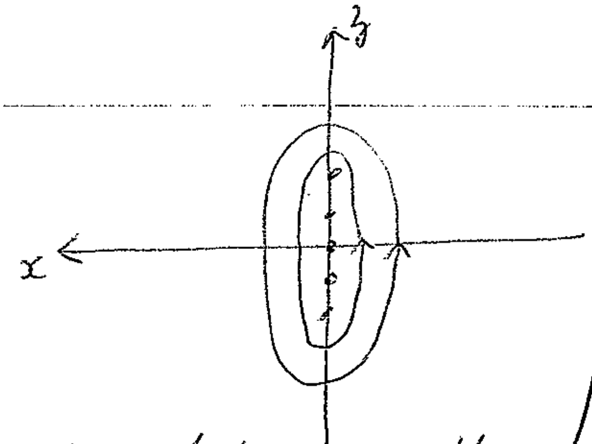
m. ashley

Q1

(a) /8 The field from a line of charge looks like this



Adding more lines of charge gives, e.g.



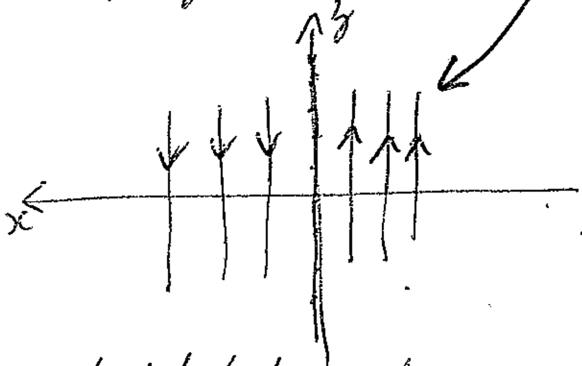
6 marks if get the right answer, without reasoning

+2 marks for good reasoning

or

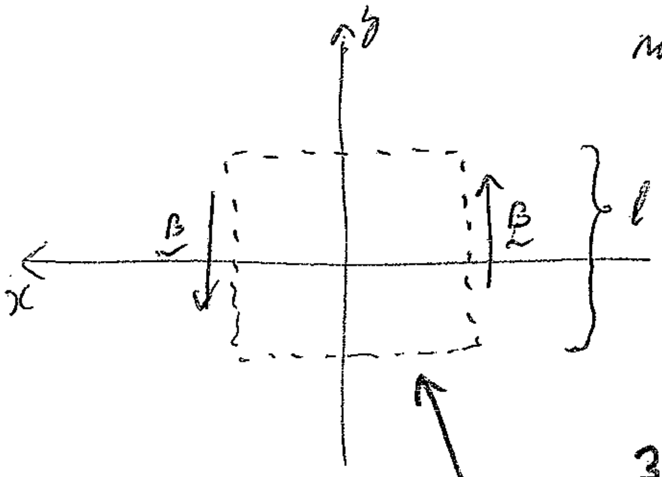
4 marks for good reasoning with the wrong answer

Until we get for an ∞ plane:



i.e. uniform, equal & opposite fields on each side

(b) /7 Use the dashed loop as shown:



now $\oint \underset{\sim}{B} \cdot \underset{\sim}{ds} = 2Bl$

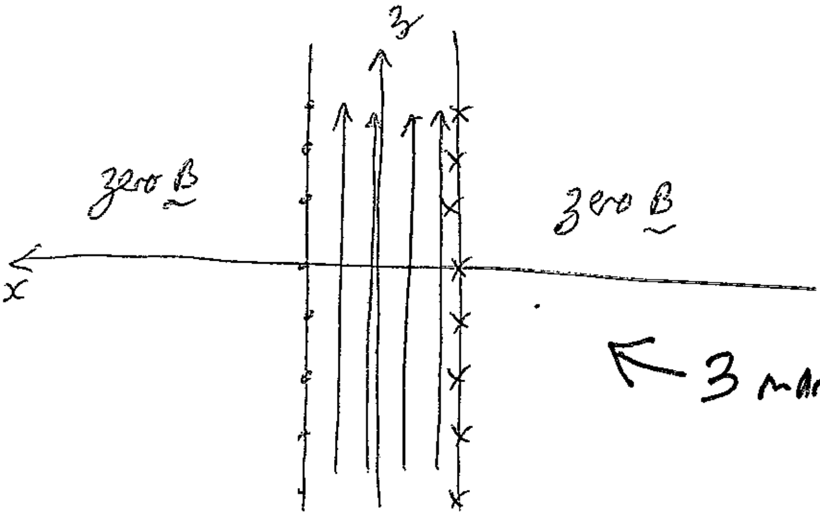
& from Ampere's Law this equals $\mu_0 J_s l$

$\therefore \boxed{B = \dfrac{\mu_0 J_s}{2}}$

3 marks for right answer

4 marks for the correct loop

(c) /5

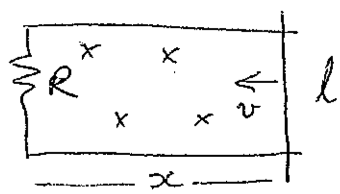


← 3 marks for sketch

region of uniform $\underset{\sim}{B}$, with twice the strength of that from one plate, i.e. $\boxed{B = \mu_0 J_s}$

2 marks for right answer

(Q2) (a) /6



The field in the loop is $\underset{\sim}{B}$

The flux is $\phi_B = Bxl$

The induced emf is $-\frac{d\phi_B}{dt} = -Blv$

$\therefore$ the current $I = \frac{|\varepsilon|}{R} = \frac{Blv}{R} = \frac{5.0\times10^{-4}\times 1.50\times 5.0}{0.200}$

3 marks for correct reasoning $= 0.01875\ A$

3 marks for correct answer $\approx 0.0188\ A$

(b) /3 The direction is such as to maintain $\underset{\sim}{B}$. By the right hand rule this is from b to a.

(c) /4 Force $F = \frac{\text{power}}{\text{velocity}} = \frac{I^2R}{v} = \frac{0.0188^2\times 0.200}{5.00}$

$= 1.41\times10^{-5}\ N$

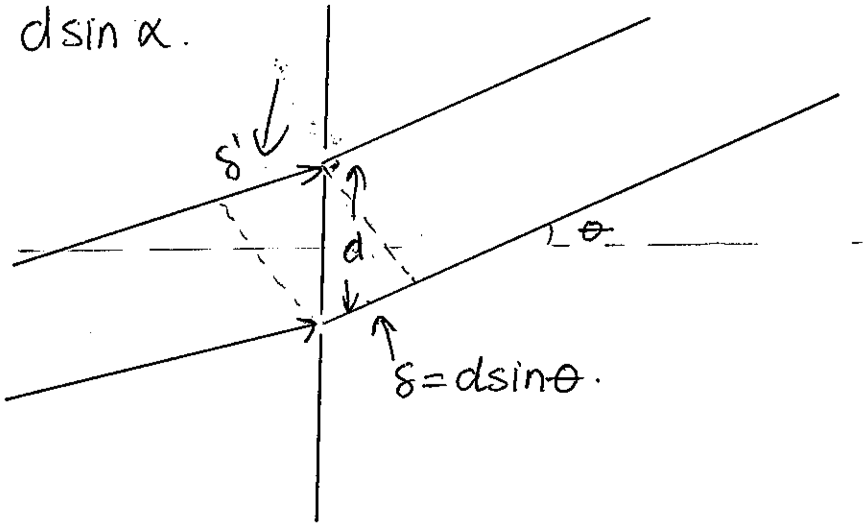
(d) /3 The work done by the force appears as heat in the resistor

(e) /4 No, the direction around the loop changes, but not through the resistor.

Q3. 2008.

a)

$d\sin\alpha$.



path difference $= \delta - \delta' = d\sin\theta - d\sin\alpha = n\lambda$.

for constructive interference. n is an integer.

b) for interference mins path difference $= (n + \frac{1}{2})\lambda$

$\Rightarrow d\sin\theta - d\sin\alpha = (n+\frac{1}{2})\lambda$.

c). $\sin\theta = \frac{n\lambda}{d} + \sin\alpha = n \times 0{\cdot}3 + 0{\cdot}342$

$\theta_0 = 20^\circ$.
$\theta_1 = 40^\circ$
$\theta_2 = 70^\circ$.
$\theta_{-1} = 2{\cdot}4^\circ$.
$\theta_{-2} = -15^\circ$.
$\theta_{-3} = -34^\circ$.
$\theta_{-4} = -59^\circ$.

d). 1231 <u>only</u>. $I = I_{max}\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$ for ⊥ light.

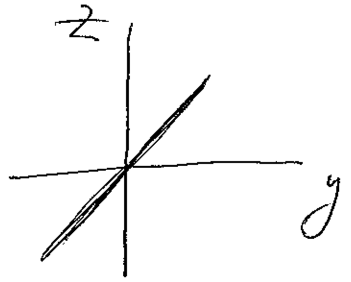
in this case. $d\sin\theta \rightarrow d\sin\theta - d\sin\alpha$ as p.d.

$\Rightarrow I = I_{max}\cos\left(\frac{\pi}{\lambda}(d\sin\theta - d\sin\alpha)\right)$

(2

Q 4

a)



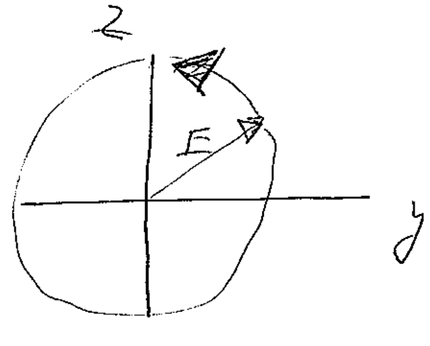
5

b) $$\frac{2\pi d}{\lambda}(n_o - n_e) = \frac{\pi}{2}$$

5

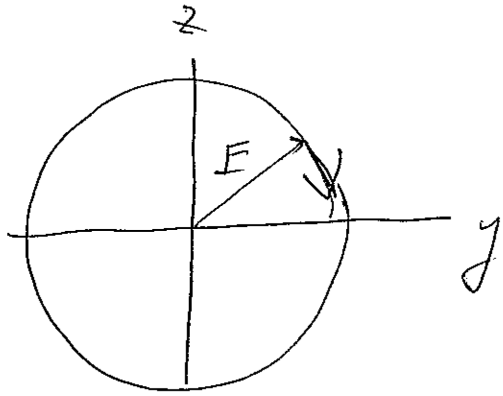
$$d = \frac{\lambda}{4(n_o - n_e)} = \frac{600}{4\ 0.172} = 872\,nm$$

c)



circular 5
anticlockwise

d)



circular 5
clockwise

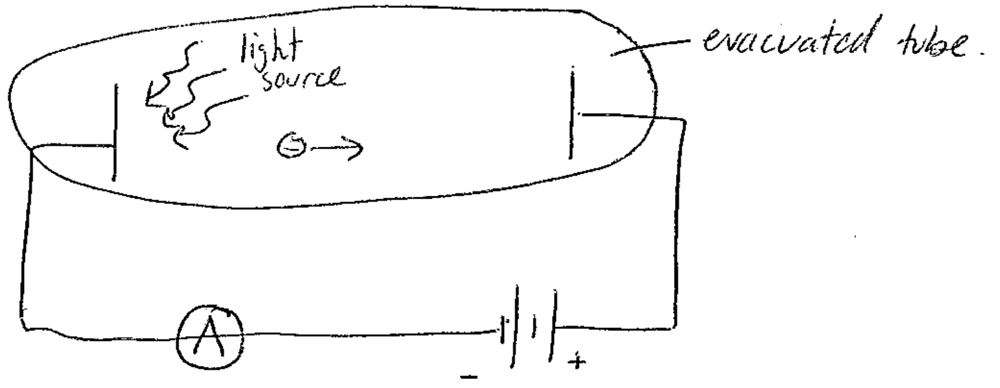
PHYS 1231 – Marking Scheme

1231 Q 5-8

S2, Final 200

Final Exam, S2, 2008.

Q5). a). When the external voltage is positive, the ejected electrons are attracted to the other anode. When the external voltage is negative, electrons are repelled (stopped)



External voltage.

b). Stopping voltage, measuring the energy of the electrons ejected from the surface, is independent of light intensity.

c) One of:

- stopping voltage is proportional to wave frequency.
- existance of a Threshold frequency → if light frequency is less than this value no electrons are emitted.
- no measurable time delay when low intensity light is used.

d). $V_{stop} = 5.5V \Rightarrow q V_{stop} = h f_{Threshold}$.

$$\therefore f_{th} = \frac{q V_{stop}}{h} = \frac{1.6 \times 10^{-19} \times 5.5}{6.626 \times 10^{-34}} = 1.33 \times 10^{15}\ Hz.$$

e). Firstly, find the number of photons striking the surface per second:

$$n_p = \frac{IA}{hc/\lambda} = \frac{5\times10^{-3}\ Wm^{-2} \times 10\times10^{-6}\ m^2 \times 320\times10^{-9}}{6.626\times10^{-34} \times 3.0\times10^{8}} = \underline{8.05\times10^{10}} \text{ photons/sec.}$$

80% of photons eject an electron:

no. of electrons ejected per second : $n_e = 0.8 n_p = \underline{6.4\times10^{10}}$ electrons/sec.

Saturation current (all ejected electrons contribute to the current)

$$I_{sat} = n_e \times q = 6.4\times10^{10} \text{ electrons/sec} \times 1.602\times10^{-19} \text{ C/electron}$$

$$\underline{I_{sat} = 1.0\times10^{-8}\ A.}$$

Suggested Marking Scheme : PHYS 1231 + PHYS1221

Q5. a) 1 - Correct external voltage sign
1 - key features in diagram (electrodes/tube/voltage) /2

b) 2 - identify feature in clear sentence /2

c) 2 - describe on other feature /2

d). 1 - correct formula, $eV_s = hf_{th}$
1 - numerical value + units /2

e) 2 - no. of photons per second
2 - saturation current
} part marks as appropriate. /4.

Q6).

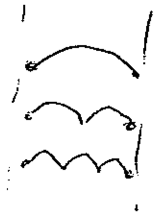
a) The electron could have any energy at all → continuous spectrum

b). $p = \frac{h}{\lambda}$ p = particle momentum, λ = particle wavelength

and $h = 6.626 \times 10^{-34}$ Js (Planck's constant).

c). Allowable stable states, → standing waves:

$$L = n\frac{\lambda_n}{2}$$



$$\Rightarrow \quad \lambda_n = \frac{2L}{n}$$

by de Broglie, $p_n = \frac{nh}{2L}$ and the associated energy is:

$$E_n = \frac{p_n^2}{2m_e} = \frac{n^2h^2}{8m_eL^2}$$

d). Energy of photon emitted $= \underset{(n=4)}{E_n} - \underset{(n=2)}{E_m}$.

$$\therefore \quad \frac{hc}{\lambda} = \frac{4^2 h^2}{8m_eL^2} - \frac{2^2 h^2}{8m_eL^2} = \frac{3h^2}{2m_eL^2}$$

$$\Rightarrow \quad \lambda = \frac{2m_e c L^2}{3h}.$$

Q7) a) Heisenberg Uncertainty Principle

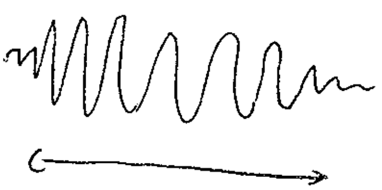
$\Delta x \cdot \Delta p \geq \hbar$

Δx = uncertainty in our knowledge of a particle's position.
Δp = uncertainty in our knowledge of a particle's momentum.

$\Rightarrow$ our simultaneous knowledge of the position and momentum of a particle is fundamentally limited. If we increase the localisation of a particle, we lose knowledge of its momentum (and vice versa)

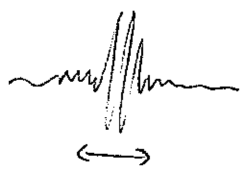
b). Localising wave packets.

$\Rightarrow$ need a <u>greater range of wavelengths</u> to superimpose to produce a <u>more localised wave packet</u>.



Δx large

($\Delta\lambda$ is small)



Δx small

($\Delta\lambda$ is large).

And from de Broglie, $\lambda = h/p$, relates to momentum.

c) Uncertainty in the energies of these states:

$$\Delta E \approx \frac{\hbar}{\Delta t} \simeq \frac{6.626\times10^{-34}}{2\pi \times 12\times10^{-9}} = 8.8\times10^{-27}\,\text{J}.$$

(and 4.6×10^{-27} J)

So spread of photon energies $\Rightarrow$ $\Delta E_{photon} \simeq 13.4\times10^{-27}$ J.

Relate this to the spread of photon wavelengths:

$$E = \frac{hc}{\lambda} \Rightarrow \frac{dE}{d\lambda} = -\frac{hc}{\lambda^2} \simeq \frac{\Delta E}{\Delta\lambda}.$$

$\Delta\lambda = 9.8\times10^{-16}$ m
$= \frac{\lambda^2}{hc}\Delta E$

$$\therefore \quad |\Delta\lambda| \approx \frac{\lambda^2}{hc} \Delta E$$

$$\simeq \frac{(122.3\times10^{-9})^2 \times 13\times10^{-27}}{6.626\times10^{-34}\times3.0\times10^{8}} \simeq$$

$$\Delta\lambda \simeq 9.8\times10^{-16}\,m. \ (\text{or} \approx 1\times10^{-6}\,nm). \quad 1$$

Q8). a) Assume each Cu atom contributes one electron to the conduction band

→ Find number of Cu atoms per m^3:

Each Cu atom has a mass, $M_{atom} = 63.54\,amu$

$= 63.54\times1.661\times10^{-27}\,kg$

$= 1.055\times10^{-25}\,kg$

Density of Cu is : $\rho = 8.96\,g/cm^3 = 8.96\times10^{-3}\times10^{6}\,kg/m^3$

$= 8.96\times10^{3}\,kg/m^3.$

$$\therefore \quad n = \frac{8.96\times10^{3}\,kg/m^3}{63.54\times1.661\times10^{-27}\,kg/atom} = \boxed{8.49\times10^{28}\ \text{electrons}/m^3}.$$

b). $I = nev_d a$

$$\Rightarrow \quad v_d = \frac{I}{nea} = \frac{1.3}{8.49\times10^{28}\times1.6\times10^{-19}\times\pi(2\times10^{-3})^2}$$

$$= \boxed{7.6\times10^{-6}\,ms^{-1}}.$$

c). Thermal velocity, $\frac{1}{2}m_e v_t^2 \cong kT.$

$$\therefore \quad v_t \cong \sqrt{\frac{2kT}{m_e}} \simeq \sqrt{\frac{2\times1.381\times10^{-23}\times300}{9.1\times10^{-31}}}$$

$$\simeq \boxed{9.5\times10^{4}\,ms^{-1}}.$$

Drift velocity is many orders of magnitude less than the typical thermal velocity.