# UNIT 4 PHYSICS 2005
# WRITTEN EXAMINATION 2 - SOLUTIONS

## SECTION A – CORE STUDIES
## AREA OF STUDY 1 – ELECTRIC POWER

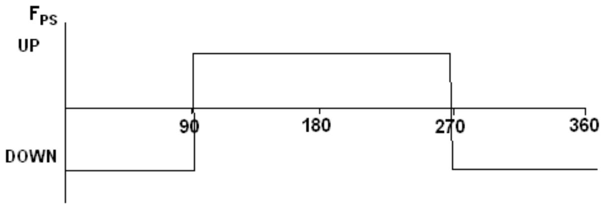
**QUESTION 1** Answer is D

**QUESTION 2** Answer is A

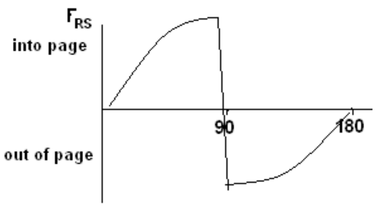
**QUESTION 3**

(a) 0.12 N Down

(b)




(c)




(d) The split ring commutator allows the direction of the current in the coil to reverse whenever PQ reaches the bottom and RS the top of the rotation, then PQ has an upward force acting (and RS down), thus keeping the coil rotating in an anti-clockwise direction.

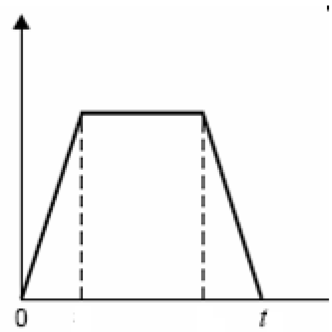
**QUESTION 4**

(a) $F = Blv = 5\times 10^{-4} \times 40 \times 120 = 2.4V$

(b) The left wing tip is positive.

**QUESTION 5**

(a)




(b) Answer is D.

**QUESTION 6** Answer is A

**QUESTION 7**

(a) A

(b) $\phi = BA = 0.1 \times 4.0 \times 10^{-3} = 4.0 \times 10^{-4}\, Wb$

(c) $\Delta\phi = BA = 0.1 \times 4.0 \times 10^{-3} = 4.0 \times 10^{-4}\, Wb$

$\Delta t = \frac{0.2}{4} = 0.05s$

$\xi = -40 \times \frac{4.0 \times 10^{-4}}{0.05} = 0.32V$

(d) C is correct. Doubling the rate of rotation halves the period. Induced emf is inversely proportion to period. Therefore, halving the period will double the induced emf.

**QUESTION 8**

(a) $P = VI$ Power loss in lines $= I^2 R$

$2000 = 200I$ $= (10)^2 \times 2$

$I = 10A$ $= 200W$

(b) $I_p = 10A$ $V_p = 200$ $V_s = 1000$

$\frac{V_S}{V_p} = \frac{I_p}{I_s}$

$\frac{1000}{200} = \frac{10}{I_s}$ $I_s = 2.0A$

Power loss $= I^2 R = (2.0)^2 \times 2.0 = 8.0W$

# AREA OF STUDY 2 – INTERACTIONS OF LIGHT AND MATTER

**QUESTION 1**

(a) The alternating pattern represents an interference pattern which is a wave phenomenon. The bright bands represent regions of constructive interference where the difference in path length from each source is a multiple of wavelengths. Waves therefore arrive from both sources in phase. The dark regions represent bands of destructive interference with the waves being half a wavelength out of phase due to path differences.

(b) The indicated position is on the sixth antinode from the centre. The path difference is $6\lambda = 6 \times 600\,nm = 3.6 \times 10^{-6}\ m$

**QUESTION 2**

(a) The curve should show a greater $V_o$ because blue is more energetic.
A greater photocurrent should be indicated.

(b) $W = h\,f_o$
$W = 4.14 \times 10^{-15} \times 5.2 \times 10^{14}$
$W = 2.15\,eV$

(c) $E_{PHOTON} = h\,f$
$E = 4.14 \times 10^{-15} \times 6.0 \times 10^{14}$
$E = 2.48\,eV$

(d) $V_o = E_{PHOTON} - W$
$V_o = 2.48 - 2.15 = 0.33 eV$

(e) $\lambda = \dfrac{c}{f} = \dfrac{3.0 \times 10^{8}}{6.0 \times 10^{14}} = 500 nm$

(f) Increasing the wavelength provides a frequency less than the threshold.
Therefore no photocurrent.

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}}{600 \times 10^{-9}} = 5.0 \times 10^{14}\ Hz$$

**QUESTION 3**

(a) The circular pattern is a diffraction pattern. With X-rays, the bright lines represent regions of constructive interference alternating with regions of destructive interference. The corresponding electron pattern shows similar diffraction properties which suggests electrons have wave properties, as diffraction is a wave phenomenon.

(b) The electrons have a similar wavelength to the X-rays.

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^{8}}{1.5 \times 10^{19}} = 2.0 \times 10^{-11}\ m$$

(c) $$P = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{2.0 \times 10^{-11}} = 3.3 \times 10^{-23}\ kgms^{-1}$$

**QUESTION 4**

(a) A,B,C & D
(b) B, E
(c) F

**QUESTION 5**

Second excitation state (n = 3).

# SECTION B – DETAILED STUDIES

## DETAILED STUDY 1 - SYNCHROTRON

**QUESTION 1**

(a) $E = \dfrac{V}{d}$

$E = \dfrac{2000}{5 \times 10^{-2}}$

$E = 4.0 \times 10^{4}\ V\,m^{-1}$

(b) Work done = V q = 2000 x 1.6 x $10^{-19}$ = 3.2 x $10^{-16}$J

(c) $E_K = \dfrac{1}{2} m v^2$

3.2 x $10^{-16}$ J = 0.5 x 9.1 x $10^{-31}$ x velocity$^2$

Velocity = 2.65 x $10^{7}$ ms$^{-1}$

(d) 'C' is correct. Since the amount of work done is equal to Vq, and both V and q are unchanged, then a similar amount of work is done and there is the same gain of kinetic energy.

**QUESTION 2**
As the electrons accelerate, they cover greater distances in the same time period. So that the electrons don't reach the next tube too soon, the length of the tubes increases as the speed of the electrons increases.

**QUESTION 3**

$r = \dfrac{mv}{Bq}$

$r = \dfrac{9.1 \times 10^{-31} \times 2.99 \times 10^{8}}{0.2 \times 1.6 \times 10^{-19}}$

r = 8.5 x $10^{-3}$ m

**QUESTION 4**

(a) The peaks result from constructive interference of the scattered rays when the extra distance travelled by $X_2$ equals one wavelength i.e. BC + CD = $\lambda$

(b) $n\lambda = 2d\sin\theta$

n = 1 when $\theta = 15^o$

$\lambda =$ 9.3 x$10^{-11}$m

(c) For n = 3, $\sin\theta = \frac{3\times 0.093}{2\times 0.18} = 0.775$ , $\theta = 51^o$

(d) B

A higher energy X-ray will have a shorter wavelength since $n\lambda = 2d\sin\theta$.
Therefore, $\lambda \propto \sin\theta$, so reducing wavelength will also reduce the angle that gives constructive interference.

**QUESTION 5**

$$\Delta E = E_{X-ray\,initial} - E_{X-ray\,final}$$

$$\Delta E = \frac{hc}{\lambda_{initial}} - \frac{hc}{\lambda_{final}}$$

$$\Delta E = \frac{6.63\times10^{-34}\ \times 3\times10^{8}}{1.45\times10^{-10}} - \frac{6.63\times10^{-34}\ \times 3\times10^{8}}{2.25\times10^{-10}}$$

$$\Delta E = 4.88\times10^{-16}\ J$$

**QUESTION 6**

Thomson scattering, or elastic scattering, is, as the name suggests, when the X-ray is scattered from an atom or an electron without any loss of energy. In Compton scattering the energy of the scattered photon is less than the incident photon. Some of the photon energy is transferred to an electron.

# DETAILED STUDY 2 - PHOTONICS

**QUESTION 1**

$$E = \frac{hc}{\lambda}$$
$$\lambda = \frac{4.14\times10^{-15} \times 3.0\times10^{8}}{2.1}$$
$$\lambda = 591 nm$$

**QUESTION 2**

(a) $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{6.0\times10^{-7}} = 5.0\times10^{14}\ Hz$

(b) $E = h\,f = 3.3\times10^{-19}\ J$

(c) $number\ of\ photons = \frac{total\ energy}{photon\ energy} = \frac{3.0\times10^{-3}}{3.3\times10^{-19}} = 9.1\times10^{15}\ photons$

(d) $dist = velocity \times time = 3\times10^{6}\ m$

(e) 33 nm

**QUESTION 3**

$$\sin\theta_c = \frac{n_2}{n_1} = \frac{1.33}{1.52} = 61^o$$

**QUESTION 4**

(a) $\sin\theta_C = \frac{1.46}{1.5}$, hence $\theta_C = 76.7^o$ . Therefore $\theta_1 = 90 - \theta_C = 13.3^o$

(b) The maximum extra distance is given by $\frac{1}{\cos\theta_1} = 1.028$. Therefore the longest path that can be taken is 2.8% longer.

(c) $NA = \sqrt{n_{CORE}^2 - n_{CLADDING}^2}$

$NA = \sqrt{1.5^2 - 1.46^2}$

$NA = 0.344$

(d) $NA = n_{EXT} \sin\theta_1 = 0.344$

$\sin\theta_a = 0.344$

$\theta_a = 20.1^o$

(e) The multimode characteristics of this fibre limits the data transfer rate because of the range of possible paths. This has the effect of spreading the pulse out over time. The spread of the signal increases with fibre length. This is known as modal dispersion.

**QUESTION 5**

(a) Signal attenuation = $-10\log_{10}\frac{P_{OUT}}{P_{IN}}$

= $-10\log_{10}\frac{50\mu W}{3.0\,mW}$

= 17.8 dB

(b) Attenuation rate (dB/km) = $\frac{attenuation\,(dB)}{dis\tan ce\,(km)}$

Hence, $dis\tan ce = \frac{attenuation}{attenuation\ rate} = \frac{17.8}{1.2} = 14.8\,km$

# DETAILED STUDY 3 - SOUND

**QUESTION 1**

(a) $I \propto \frac{1}{r^2}$, therefore, decreasing distance to one quarter increases intensity by a factor of 16.

$16 \times 1.25 \times 10^{-4} = 2.0 \times 10^{-3}\ Wm^{-2}$

(b) 93 dB

**QUESTION 2**

Being connected to a common source, the speakers will be 'in phase', ensuring the midpoint is an antinode or a region of loudness. The distance between successive antinodes is $\frac{\lambda}{2}$, and $\frac{\lambda}{4}$ between an antinode and an adjacent node. Accordingly, Mary has moved $\frac{3\lambda}{4}$ from the central antinode to the second node.

Also, $\lambda = \frac{v}{f} = \frac{340}{340} = 1.0m$

Therefore, Mary has moved 0.75 m from the centre, which puts her 4.25 m from speaker B.

**QUESTION 3**

(a) The ear is at its most sensitive at 3000 Hz.
(b) 80 dB at 50 Hz would seem as loud as 70 dB at 1000 Hz.

**QUESTION 4**

40 dB; consisting of the 5 dB threshold plus the 35 dB that the earmuffs reduce the sound level.

**QUESTION 5**

(a) $f = \frac{v}{2l} = \frac{340}{1.60} = 213\,Hz$

(b) Answer is A.

$f = \frac{v}{2l} = \frac{352}{1.60} = 220\,Hz$

(c) Answer is C.

$\lambda = 2l = 1.60m$

**QUESTION 6**

(a) Condenser.

(b) The sound wave vibrates the diaphragm which is permanently charged (polarised). The diaphragm is effectively one side of a capacitor. As the capacitance changes, a tiny current is induced and hence a signal voltage appears across the resistor.

**QUESTION 7**

(a) The speaker performs well in the frequency range 50 Hz – 1 kHz.
(b) This speaker is a low frequency speaker (or woofer or bass speaker).