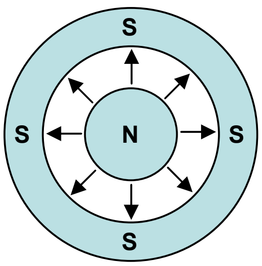
Physics
Written examination 2

2006 Trial Examination

SOLUTIONS

AREA 1- Electric Power

Question 1



Question 2

F (use RH-slap rule or otherwise)

Question 3

F = nBIL
0.6 = 10 x 0.25 x 2 x L $\rightarrow$ L = 0.12m

Question 4

Coil would tend to vibrate into and out of the page as the force acting on it changed direction 20 times per second (every half period)

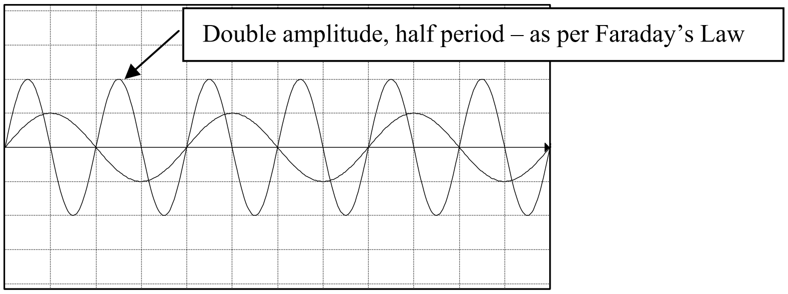
Question 5

D $\rightarrow$ C $\rightarrow$ B $\rightarrow$ A (using Lenz's Law or otherwise)

Question 6

(For a quarter turn): emf = $\dfrac{N\Delta(BA)}{\Delta t} = \dfrac{30\times 0.4\times 0.1\times 0.15}{0.05} = 3.6V$

Question 7 & 8



Question 9

$V_{p\text{-}p} = 2\sqrt{2}$ x V_{rms} = 1697V

Question 10

$P_{loss} = I^2R = \left(\frac{100 \times 10^3}{600}\right)^2$ x 0.4 = 11.1kW

Question 11

$I = \frac{P}{V} = 100 \times \frac{10^3}{3500}$ = 28.6A

Question 12

V_{prim} = 3500 – V_{cable} = 3500 – I_{cable} x R_{cable} = 3500 – 28.6 x 0.4 = 3489V

Question 13

Turns Ratio = V_{prim}:V_{sec} = 3489:240

Question 14

B (Using Lenz's Law)

Question 15

Current in upper loop creates a magnetic field directed downwards, which is opposed by an induced field in the lower loop (directed upwards). The induced field has an accompanying ACW current, which will flow in the closed lower loop.

Question 16

A commutator reverses the direction of the current flowing in the moving coil of the motor, so that the force also changes direction (according to RH slap rule). Thus, the coil rotates continuously.

Question 17

Both alternator and generator use electromagnetic induction to produce electricity.
However, an alternator uses a stationary coil and rotating solenoid (i.e. mag field) to avoid the use of slip rings where large currents are involved. In contrast, a generator uses a stationary solenoid and a rotating coil.

AREA 2- Interactions of light and matter

Question 1

A

Question 2

C

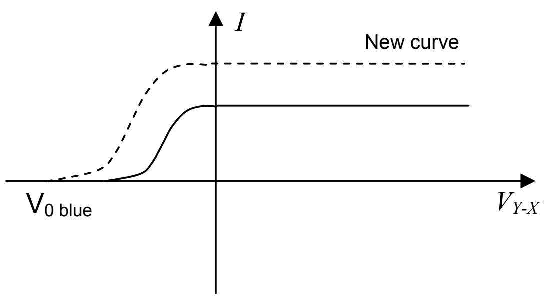
Question 3

The bands and the regular pattern is due to constructive and destructive interference between the two sources (each slit is a source). Increased wavelength or decreased slit separation will lead to wider spacing between antinodes (bright) and nodes (dark) regions. This interference effect supports the model of light acting as a wave.

Question 4

When $V_{Y\text{-}X}$ is positive, **all** electrons that are ejected from the surface will reach the collector. Increased potential between X and Y will increase the kinetic energy of each electron, but will not increase the amount of electrons, so current remains constant.

Question 5



Question 6

$E_{k\,max} = Vq = 1.9 \times 1.6 \times 10^{-19} = 3.04 \times 10^{-19}$ J

Question 7

$E_{k\,max} = Vq = hf - hf_0$

$$1.9 = 4.14 \times 10^{-15} \times \left(\frac{3\times10^{8}}{490\times10^{-9}}\right) - 4.14 \times 10^{-15} \times f_0$$

$f_0 = 1.5 \times 10^{14}$ Hz

Question 8

375nm = 8×10^{14} Hz. Read of graph: $E_{K\,max} \sim 0.9$eV. $V_o = 0.9$V
Note: Check by using: $E_{k\,max} = Vq = hf - hf_0 = 4.14 \times 10^{-15} (8 \times 10^{14} - 5.8 \times 10^{14}) = 0.91$eV

Question 9

$$\lambda = \frac{h}{mv} = 6.63\times\frac{10^{-34}}{\left(9.1\times10^{-31}\times6.7\times10^{5}\right)} = 1.08 \times 10^{-9} = 1.1\text{nm}$$

Question 10

$\lambda_{\text{X-ray}} = 1.1\text{nm} = \dfrac{c}{f} \rightarrow f_{\text{X-ray}} = 2.8 \times 10^{17}$ Hz

Question 11

Diffraction patterns are a wave phenomenon – so the wavelike nature of light and matter is supported here.

AREA 3- Detailed Studies

DETAILED STUDY 1- Synchrotron and its applications

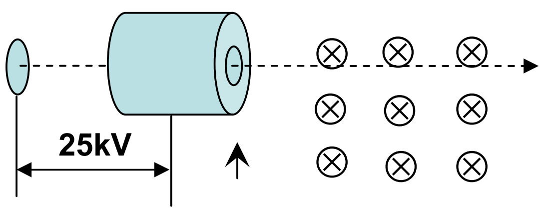
Question 1

E_k = 25 000eV

Question 2

$$v = \sqrt{\left(\frac{2E_k}{m}\right)} = \sqrt{\left(\frac{2 \times 25 \times 10^3 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}\right)} = 9.4 \times 10^7 \text{ ms}^{-1}$$

Question 3



Question 4

$F = qvB = 1.6 \times 10^{-19} \times 9.4 \times 10^7 \times 1.4 = 2.1 \times 10^{-11}$ N

Question 5

$p = rBq = 9 \times 10^{-5} \times 1.4 \times 1.6 \times 10^{-19} = 2 \times 10^{-13}$ kgms^{-1}

Question 6

Booster Ring: Takes fast electrons from the linac and increases their speed and energy before injecting them into the storage ring.

Beamline: The line along which the synchrotron radiation passes to reach the target.

Question 7

At various energy levels X-Rays are able to:

1. Diffract when aimed at a crystal (wave)
2. Collide with electrons, sometimes losing energy (Compton scattering) sometimes elastically (Thomson scattering) (particle)
3. Be annihilated altogether in the photoelectric effect (particle)

Question 8

$n\lambda = 2d\sin\theta$

$n \times \dfrac{hc}{E} = 2d\sin\theta$

$\theta = \sin^{-1}\left(\dfrac{n \times hc}{(E \times 2d)}\right) = \sin^{-1}\left(\dfrac{3 \times 4.14 \times 10^{-15} \times 3 \times 10^{8}}{(8.3 \times 10^{3} \times 2 \times 0.28 \times 10^{-9})}\right) = 53.3^{o}$

Question 9

If n = 4, $\theta = \sin^{-1}(1.07)$ – for which there is no solution. So there are only 3 angles of reflection

Question 10

D

Question 11

$\lambda = \dfrac{hc}{E} = \dfrac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{0.04 \times 10^{6}} = 3.1 \text{ x } 10^{-11}\text{m}$

DETAILED STUDY 2- Photonics

Question 1

Light Bulb: Light emitted due to collisions between outer shell electrons in violently vibrating atoms within the tungsten filament.

Metal Vapour Lamp: Light emitted due to electrons emitting photons as they fall from excited to lower energy states

Question 2

Lasers generate a beam of coherent EMR. Atoms are excited to a higher energy state by the input power of the laser, then stimulated to release their energy (in the form of photons) by interacting with a photon of the same energy. Random emission of a single photon causes emission of similar photons. The light emerges from a partially reflective mirror as a coherent, monochromatic parallel beam, as all other, non coherent photons are lost through the sides of the medium.

Question 3

An LED produces light through spontaneous emission – where electrons fall from a high to a low energy band. The energy gap between the conduction (high energy) and valence (low energy) band determines the wavelength of the photon that is emitted.

Question 4

$$\lambda = \frac{hc}{Eg} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2.1} = 591\text{nm}$$

Question 5

B

Question 6

$$NA = \sqrt{{n_1}^2 - {n_2}^2} = 0.35$$

Question 7

Material dispersion: Different wavelengths of EMR travel at different speeds. To minimize, reduce range of wavelengths into the same fibre.

Modal dispersion: spreading of pulses resulting from different transit lengths of different modes. To minimize, use smaller diameter fibre, graded-index fibres, single-mode fibres.

Question 8

Coherent fibre imaging occurs when all fibres are arranged in the same position relative to each other at each end. This is necessary when a clear image is needed.
Non-coherent bundles are not arranged as orderly, but can still be used to carry light to illuminate the region.

Question 9

Loss Type B is absorption and for $\lambda > 1.7\mu m$, the glass starts absorbing light energy due to the vibration and resonance of SiO_2 molecules, so losses increase markedly.

DETAILED STUDY 3- Sound

Question 1

T = 4ms

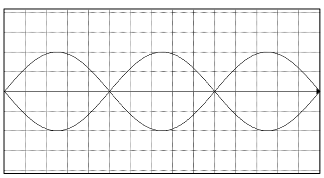
Question 2

$\lambda = \dfrac{v}{f}$ = v x T = 1.3m

Question 3

Dynamic loudspeaker uses electromagnetic induction to generate a variable force on a cone, which vibrates as the current varies. Vibrations in the cone cause compressions and rarefactions in the nearby medium, which travel outwards through the air. Our ears detect the compressions as they arrive due to vibrations in the ear drum membrane which are interpreted by the brain.

Question 4



Question 5

Using fundamental frequency: $f = \dfrac{v}{2L} \rightarrow L = \dfrac{v}{2f} = \dfrac{330}{(2 \times 120)}$ = 1.38m

Question 6

Gill

Question 7

Vibrations in the string are passed to the body by the bridge. The air in the body responds to the frequencies in the string by vibrating with the same frequency. The overall effect is an amplification of the original standing waves which were set up in the string.

Question 8

Phon is the unit of equivalent loudness, a measure of how loud a sound is relative to a reference sound. For example, point A (100Hz, 42dB) will be perceived as loud as point B (1000Hz, 20dB)

Question 9

6dB reduction = 1/4 intensity $\rightarrow$ 2 x distance by inverse square law. So d = 6m

Question 10

200Hz signal would tend to diffract more than the 4000Hz signal, because diffraction is dependent upon wavelength (λ_{200} = 2.8m, λ_{4000} = 0.085m), so Jim would detect an increase in intensity as the 200Hz sound diffracted around the wall more significantly.

Question 11

Fidelity is the degree to which the system accurately reproduces the essential parts of the input signal
Multiple speakers would be preferable as the designer could employ a range of **response curves** (e.g. Woofers, tweeters & midrange) to ensure all frequencies were reproduced effectively.

Question 12

A dynamic coil could act as a microphone (audio-electro) where sound waves cause vibrations in the cone and induce an electrical signal in the coil. The same device could also act as a loudspeaker (electro-audio) as per Question 3.