VCAA Physics Exam 2 Solutions 2005

SECTION A – Core

Area of study 1 – Electric power

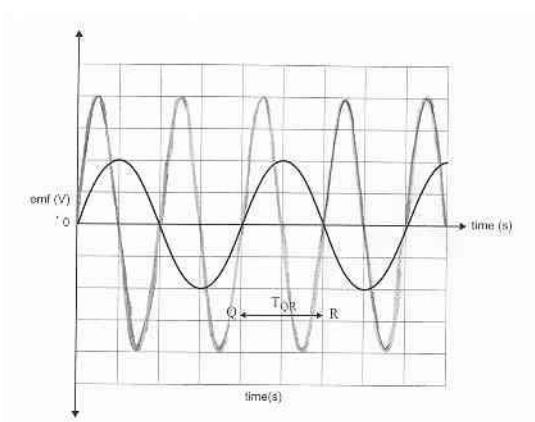
Q1 The magnetic field of the bar magnet at P is in the direction B. Use right-hand slap rule, the magnetic force on the wire is in the direction D.

Q2 $\phi = BA,\ \therefore A = \frac{\phi}{B} = \frac{8\times10^{-6}}{2.0\times10^{-2}} = 4.0\times10^{-4}$ m^2.

Q3 $f = 10,\ T = \frac{1}{f} = 0.10,\ T_{QR} = \frac{T}{2} = 0.050$ s.

Q4 $\xi_{av} = -n\frac{\Delta\phi}{\Delta t} = -n\times\frac{\phi_f - \phi_i}{\Delta t} = -100\times\frac{^{-}8\times10^{-6} - {}^{+}8\times10^{-6}}{0.050}$
$= 0.032$ v.

Q5



Q6 Kris

Q7 Slip rings give rise to a sinusoidal emf, AC (see diagram above). Every second half of a cycle of the rotation, the induced emf is in the opposite direction to that of the first half. A split-ring commutator can reverse the direction every second half to make it the same as the first half and the emf becomes DC.

Q8 C

Q9 $P = VI,\ \therefore I = \frac{P}{V} = \frac{1200}{240} = 5.0$ A$_{RMS}$

Q10 $P_{loss} = I^2R = 30^2\times2.0 = 1.8\times10^3$ w.

Q11 $V_{drop} = IR = 30\times2.0 = 60$ v. Voltage $= 240 - 60 = 180$ v.

Q12 For the same amount of power delivered at a higher voltage, the current in the supply line will be lower because $VI = const$. Since $P_{loss} \propto I^2$, a reduction in current results in a much bigger reduction in P_{loss}. 11000v is about 50 times 240v, $\therefore$ the current is about 0.02 times of the original current, hence the power loss is $0.02^2 = 0.0004$ i.e. 0.04% of the original loss.

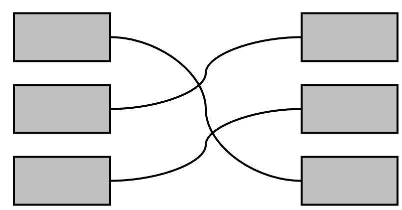
Q13 $V_{peak} = 11000\sqrt{2},\ V_{peak-peak} = 2\times11000\sqrt{2} = 3.1\times10^4$ v.

Q14 For an ideal transformer, $P_{in} = P_{out}$, $\therefore V_P I_P = V_S I_S$,
or $I_P = \frac{V_S I_S}{V_P} = \frac{11.3\times2.2}{240} = 0.10$ A$_{RMS}$.

Q15 **Faraday's Law**: $|\xi_{av}| = n\frac{\Delta\phi}{\Delta t}$ where n is the number of loops in the coil through which the flux passes. $\xi_{av} \propto n$, $\xi_{av} \propto \Delta\phi$, $\xi_{av} \propto \frac{1}{\Delta t}$. **Lenz's Law**: an induced current in a conducting loop flows in a direction such that the magnetic field of the induced current *opposes* the change in magnetic flux that produces it. The terminal that the induced current flows to is +, the other –.

Q16 B

Q17



Area of study 2 – Interactions of light and matter

Q1 Thermal oscillations of electrons in atoms give off electromagnetic radiation (visible light). In an incandescent light bulb, the atoms in the filament are excited by heating, and they give off their excess energy as wave trains (with wide spectrum of wavelengths) of light, each lasts about 10^{-8}s.The emitted light is the sum of such wave trains.

Q2 B. The wave trains bear a random phase relation to each other.

Q3 Extrapolate the line of best fit to intersect the vertical axis at about −2.7 v. This indicates that the work function is about 2.7 eV. The metal is sodium.

Q4 From the graph, Planck's constant = $q\times$ gradient
$= 1e\times\frac{3.3 - {}^{-}2.7}{13\times10^{14} - 0} = 4.6\times10^{-15}$ eVs.

Q5 B.

Q6 Without considering the relativistic effects of high speed, momentum of an electron
$p = mv = (9.10\times10^{-31})(2.0\times10^{7}) = 1.82\times10^{-23}$ kgms^{-1}.

de Broglie wavelength $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{1.82\times10^{-23}} = 3.6\times10^{-11}$ m.

Q7 The students would not observe an electron diffraction pattern because the ratio $\frac{\lambda}{\Delta w} = \frac{3.6\times10^{-11}}{0.50\times10^{-3}}$ is very much less than 1.

Q8 B, D.

Q9 The lowest energy photon is from the electron transition from $n = 3$ to $n = 2$. $E = 5.2 - 3.4 = 1.8$ eV.

Q10 $E = 3.4 - 0 = 3.4$ eV, photon energy $E = \frac{hc}{\lambda}$,
$\therefore \lambda = \frac{hc}{E} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{3.4} = 3.7\times10^{-7}$ m.

Q11 de Broglie used the idea of standing matter waves to explain the quantised energy levels of the atom. The only matter waves that persist are those for which the circumference of the orbit is an integral multiple of λ.

SECTION B

Detailed study 1 – Synchrotron and its applications

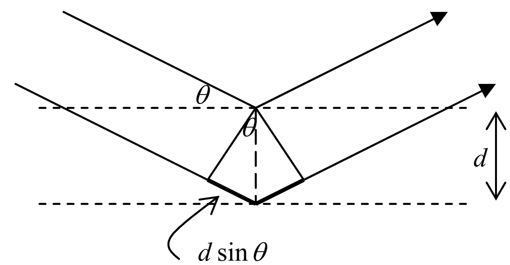
Q1 electron gun, 99.99%, linac

Q2 $r = \frac{p}{eB}$, $B = \frac{p}{er} = \frac{1.2\times10^{-18}}{1.6\times10^{-19}\times7.7} = 0.97$ T

Q3 $E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3.0\times10^{8}}{0.115\times10^{-9}} = 10800$ eV
$= 10.8$ keV

Q4 $n\lambda = 2d\sin\theta$, $d = \frac{n\lambda}{2\sin\theta} = \frac{1\times0.115\times10^{-9}}{2\sin 9.6^{o}}$
$= 0.345$ nm

Q5 The second maximum appears because the path difference between reflected rays from any two consecutive layers of particles equals 2λ. This gives rise to constructive interference of the rays. Path difference $= 2\lambda$, $\therefore 2d\sin\theta = 2\lambda$.



Q6 When they are in circular motion, they accelerate because of a continuous change in direction. They emit x-rays when they accelerate. B

Q7 $qV = \Delta E_k$, $V = \frac{\Delta E_k}{q} = \frac{8.0\times10^{-16}}{1.6*10^{-19}} = 5000$ V

Q8 An electron moving forwards is equivalent to a positive charge moving backwards. Use right hand slap rule. C

Q9 Synchrotron x-rays have a much higher intensity (around 10^8 times) than conventional x-rays. They are also coherent and collimated.

Q10 $E = \frac{hc}{\lambda}$, $\lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3.0\times10^{8}}{10\times10^{3}} = 1.2\times10^{-10}$ m.
B

Q11 There is no loss of energy when x-rays undergo Thomson scattering. C

Detailed study 2 – Photonics

Q1 coherent, a population inversion, photons of the same

Q2

Spectrum A	Sodium vapour lamp
Spectrum B	LED
Spectrum C	Red hot slab of iron

Q3 In a semiconductor the valence and conduction bands are separated by a small energy gap called band gap, in the order of 1 eV. If the pn junction is forward biased, a large number of electrons (holes) are swept from the n-type (p-type) region into the p-type (n-type) region to fill the holes (to recombine with the electrons). The process is called recombination. Energy in the form of photons is released during the process.

Q4 $E = \frac{hc}{\lambda}$, $\therefore \lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3.0\times10^{8}}{2.1} = 5.9\times10^{-7}$ m.

Q5 B. $n_{air} < n_{cladding} < n_{core}$

Q6 $\theta_c = \sin^{-1}\left(\frac{1.00}{1.60}\right) = 38.7^o$, $\alpha = 90 - 38.7 = 51.3^o$.

Q7 B.

Q8 B.

Q9i Rayleigh scattering: Small irregularities in density inside an optical fibre scatter a small amount of light and thus cause degradation of the light signal.
Amount of scattering $\propto \frac{1}{\lambda^4}$, hence short wavelength light has a large amount of scattering.

Q9ii Absorption by impurities: Impurities e.g. water can be introduced into a glass fibre during the manufacturing process. These impurities give rise to O-H, Si-O, Ge-O bonds in the fibre. The O-H bonds absorb light with wavelengths around 0.9 and 1.2 μm, Si-O and Ge-O bonds absorb light of wavelength > 1.7 μm. These wavelengths are in the infrared region. See figure 4 in the exam.

Q10 D. single mode fibre with a laser diode as the light source

Detailed study 3 – Sound

Q1 longitudinal, parallel, energy

Q2

Microphone type	Principle of operation
Dynamic	Electromagnetic induction
Crystal	Piezoelectric effect
Electret-condenser	capacitance

Q3 The baffle board prevents the sound from the back of the speaker cones cancelling the sound from the front due to interference.

Q4 D.

Q5 A loudspeaker is omni-directional, (i.e. it radiates sound energy spherically in all directions) when $\frac{\lambda}{w} > 4$, w is the diameter of speaker cone. The higher the frequency the less omni-directional it becomes. Hence the fidelity will deteriorate as the listener moves off the centre line. It would be more satisfactory if the high frequency sound is from a loud-speaker with a smaller diameter (a tweeter).

Q6 For a closed pipe, fundamental frequency $f = \frac{v}{4L}$,

$\therefore L = \frac{v}{4f} = \frac{320}{4 \times 160} = 0.5$ m.

Q7 Third harmonic $= 3 \times 160 = 480$,
fifth harmonic $= 5 \times 160 = 800$ Hz.

Q8 For the pipes there are other harmonics (odd harmonics for closed pipes) besides the fundamental frequencies. Hence a microphone with a much higher frequency response is needed.

Q9 C.
$I = \frac{acoustic.power}{surface.area.of.sphere} = \frac{100}{4\pi(100)^2} = 8.0 \times 10^{-4}$ wm^{-2}.

Q10 When the distance is doubled, the intensity becomes $\frac{1}{4}$ of the original because $I \propto \frac{1}{r^2}$. $\frac{1}{4} = \frac{1}{2}\left(\frac{1}{2}\right)$. Sound level drops by 3 dB every time I is halved. Hence the sound level L at C is 6 dB lower than that at B.

Q11 B and C are the same distance from A, $\therefore I$ (and L) are the same at B and C.
$L = 10 \times \log_{10} \frac{1.0 \times 10^{-2}}{10^{-12}} = 10 \times \log_{10} 10^{10} = 100$ dB.

Please inform physicsline@itute.com re conceptual, mathematical and/or typing errors