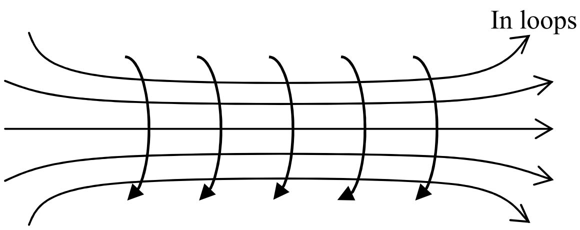
2006 VCAA Physics Exam 2 Solutions

Area of study 1 – Electric power

Q1



Q2 Section **cd** is parallel to B and $\therefore$ experiences no magnetic force. 0 N, none.

Q3 Section **bc** is perpendicular to B and experiences magnetic force $F = BIL = 2.0\times10^{-2}\times5.0\times0.020 = 2.0\times10^{-3}$ N in the direction Q.

Q4 $\phi_B = BA\cos\theta = BA\cos 90^0 = 0$ Wb

Q5 $\phi_B = \left(2.0\times10^{-4}\right)\left(5.0\times10^{-4}\right)\cos 0^0 = 1.0\times10^{-7}$ Wb

Q6 The motor has only one coil of wire and therefore a split-ring commutator is required to reverse the current direction every half-turn to keep the torque in the same direction, so that the coil can keep on turning in the same direction.
Effie's idea cannot make the motor to turn faster. It makes the coil to oscillate with decreasing amplitude and come to a stop very quickly due to friction and air resistance.

Q7 There is a change in magnetic flux when the loop enters or exits the magnetic field and thus a current is induced (in opposite direction) in each occasion. Choice A.

Q8 Entry (or exit) time $\Delta t = \dfrac{dist.}{speed} = \dfrac{2.0}{4.0} = 0.5$ s

$\Delta\phi_B = \left(3.7\times10^{-3}\right)\left(0.02\times0.02\right) - 0 = 1.48\times10^{-6}$ Wb

Max induced voltage $\left|\dfrac{\Delta\phi_B}{\Delta t}\right| = \dfrac{1.48\times10^{-6}}{0.5} = 3.0\times10^{-6}$ V

Q9 $P = 100\times10^3 W$, $V = 250$ V, $I = \dfrac{P}{V} = \dfrac{100\times10^3}{250} = 400$ A

Q10 Assume zero voltage drop in the power lines.
$V = 22000$ V, $P = 100\times10^3 W$, $I = \dfrac{P}{V} = \dfrac{100\times10^3}{22000} = 4.55$ A

Q11 $P_{loss} = I^2R = 4.55^2\times2.0 = 41$ W.

Q12 For the same amount of power delivered, i.e. *VI* is constant, $\therefore$ high-voltage transmission leads to low current in the power lines. Since $P_{loss} = I^2R$, low current leads to low power loss.

Q13 Step-up, $N_p < N_s$, $\dfrac{N_s}{N_p} = \dfrac{V_s}{V_p}$, $\dfrac{N_s}{500} = \dfrac{22000}{250}$,
$N_s = 44000$. Choice C.

Q14 An alternating current at the primary (input) coil produces an alternating *B* inside the soft iron core. The secondary (output) coil is linked to the primary through the core, $\therefore$ a changing *B* in the core results in a changing ϕ_B in the secondary coil.

According to Faraday's Law $\varepsilon = -N\dfrac{\Delta\phi_B}{\Delta t}$, an emf is induced in the secondary coil (output).

Q15 If the voltage produced by a DC generator is constant, the output of the transformer would be zero. Another point to consider is the electrical appliances. Many appliances are designed to operate with AC.

Q16 Increase power usage leads to increase current in the power lines, $\therefore$ higher voltage drop $V_{drop} = IR$. Hence the voltage at S would decrease slightly. Choice B.

Q17 $V_p = \sqrt{2}V_{rms} = \sqrt{2}\times250 = 354$ V

$T = \dfrac{1}{f} = \dfrac{1}{50} = 2.0\times10^{-2}$ s. Choice B.

Area of study 2 – Interactions of light and matter

Q1 Choice D.

Q2

Wave model	Particle model
Y	**Y**
Y	N
Y	**N**
Y	**N**

Q3 $E = hf = \left(4.14\times10^{-15}\right)\left(4.4\times10^{14}\right) = 1.8$ eV

Q4 Choice B.

Q5 Highest frequency means highest photon energy, $\therefore$ from $n = 4$ to $n = 1$. $E_4 - E_1 = 3.61 - 0 = 3.61$ eV.

$f = \dfrac{\Delta E}{h} = \dfrac{3.61}{4.14\times10^{-15}} = 8.7\times10^{14}$ Hz.

Q6 Electrons in a sodium atom can be pictured as particles orbiting the nucleus, or as standing waves around the nucleus. For a sustained standing wave its length must be a whole number multiple of its wavelength. For example, at ground state ($n = 1$) the length of the standing wave is 1λ , at the first excited state ($n = 2$) the length of the standing wave is 2λ etc. No other lengths of standing wave can be sustained and hence no other energy levels are possible.

Q7 $S_2P_2 - S_1P_2 = 2\lambda = 2\times 2.8 = 5.6$ cm.

Q8 Interference is an important property of waves. Light does interfere to produce bright (constructive interference) and dark (destructive interference) regions, $\therefore$ light exhibits wave nature.

Q9 $E = \frac{hc}{\lambda} = \frac{(4.14\times 10^{-15})(3.0\times 10^{8})}{250\times 10^{-12}} = 4968\,\text{eV} = 5.0\,\text{keV}$.

Q10 Moving electrons are particles that show wave-like behaviour and produce a diffraction pattern. The pattern is similar to that of the X-rays because the electron energy was chosen so that the deBroglie wavelength of the electrons matched the wavelength of the X-rays.

Q11 deBroglie wavelength of electrons = wavelength of X-rays
$p = \frac{h}{\lambda} = \frac{6.63\times 10^{-34}}{250\times 10^{-12}} = 2.65\times 10^{-24}$ $\therefore$ kg ms^{-1}.

Detailed study 1 – Synchrotron and its applications

Q1 linear accelerator; bending magnets; electromagnetic.

Q2 Advantage 1: Synchrotron X-rays are collimated and parallel, coherent and high intensity. Any required wavelength in the emittance spectrum can be selected. Conventional X-rays do not possess these features.

Advantage 2: Synchrotron X-rays have the right energies to interact with many light atoms, whereas conventional X-rays have specific energies to interact with heavier atoms.

These features make synchrotron X-rays more suited for a wide range of modern-day applications.

Q3 Choice B

Q4 Choice D

Q5 The process is called Compton's scattering. After hitting the carbon block some of the incoming X-ray photon energy is transferred to the electron (inelastic collisions), and the photons emerge with less energy and thus longer wavelength.

Q6 Wavelength shift $\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$,

$(75-71)\times 10^{-12} = \frac{6.63\times 10^{-34}}{(9.11\times 10^{-31})(3.0\times 10^{8})}(1-\cos\theta)$, $\theta \approx 130^0$.

Choice D.

Q7 $\frac{1}{2}mv^2 = E$,

$\frac{1}{2}\times 9.11\times 10^{-31}v^2 = 5000\times 1.6\times 10^{-19}$, $v = 4.2\times 10^7$ ms^{-1}.

Q8 $r = \frac{p}{eB}$, $p = reB = 7\times 1.6\times 10^{-19}\times 1.7 = 1.9\times 10^{-18}$ kg ms^{-1}.

Q9 Choice B.

Q10 For minimum glancing angle, $n = 1$ in the formula $2d\sin\theta = n\lambda$. $\therefore d = \frac{\lambda}{2\sin\theta} = \frac{35\times 10^{-12}}{2\sin 5^0} = 2.0\times 10^{-10}$ m.

Detailed study 2 – Photonics

Q1 greater than; lowest; reduced.

Q2 $E = \frac{hc}{\lambda} = \frac{(4.14\times 10^{-15})(3.0\times 10^{8})}{5.8\times 10^{-7}} = 2.14$ eV. Choice A.

Q3 Choice A, blue, green, red.

Q4 Red HeNe laser is a coherent source while red LED is incoherent. Laser is more superior than LED in studying wave behaviour of light. Laser is more directional than LED and thus can easily enter an optical fibre within the cone of acceptance. LED has a wider spectrum than laser and likely to suffer chromatic dispersion in an optical fibre.

Q5 The graded index allows the lowest-order mode to travel the shortest distance at the slowest speed and the highest-order mode to travel the longest distance at the greatest speed. Hence all modes travel in about the same time resulting in less modal dispersion.

Q6 Snell's law: $n_{air}\sin\theta_{air} = n_{core}\sin\theta_{core}$.
$1.00\sin\theta = 1.48\sin 10^0$, $\theta = \sin^{-1}(1.48\sin 10^0) = 14.9^0$.

Q7 $\sin\theta_c = \frac{n_{clad}}{n_{core}} = \frac{1.47}{1.48}$, $\theta_c = \sin^{-1}\left(\frac{1.47}{1.48}\right) = 83.3^0$.

Q8 The acceptance angle will change; the critical angle will remain the same.

Q9 Same medium, same speed, $\therefore$ same arrival time. Choice A.

Q10 Both IR (1200 nm) and RD (650 nm) are bordering the windows for minimum attenuation resulting from absorption by impurities. So very little attenuation is caused by absorption. The overall attenuation is mainly due to greater Rayleigh scattering that increases with decreasing wavelength (from IR to RD).

Q11 Water has a higher refractive index than air. $\therefore$ total internal reflection can occur at the interface of water and air in the stream, provided the angle of incidence of the laser beam is greater than the critical angle $\theta_c = \sin^{-1}\left(\frac{1.00}{1.33}\right) = 48.8^0$.

From the diagram, all the angles of incidence are clearly greater than θ_c.

Detailed study 3 − Sound

Q1 diffraction; less; increase

Q2 Sound waves in air are longitudinal. Choice D.

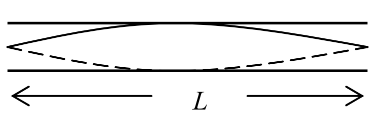
Q3 Uniformally? $\lambda = \frac{v}{f} = \frac{340}{476} = 0.714$ m

Q4 $I = 10^{\frac{L}{10}-12} = 10^{\frac{64}{10}-12} = 2.5\times10^{-6}$ Wm^{-2}.

Q5 8.0 m is 4 times 2.0 m. Final intensity is $\frac{1}{16}$ of the initial intensity. $\frac{1}{16} = \left(\frac{1}{2}\right)^4$. Each time the intensity is halved the level drops by 3 dB, $\therefore$ a total of 12 dB.
$\therefore$ at 8.0 m, $L = 64 - 12 = 52$ dB. Choice D.

Q6 The box prevents low frequency sound waves from the back of the loudspeaker cone to diffract and interfere destructively with the sound waves from the front of the loudspeaker cone. By careful design and introduction of port to the box the phase of the back wave can be reversed to make it in phase with the front wave, resulting in constructive interference.

Q7 $L = \frac{\lambda}{2} = \frac{v}{2f} = \frac{340}{2\times200} = 0.85$ m.



Q8 $f_1 = 200$, $f_2 = 2\times f_1 = 400$, $f_3 = 3\times f_1 = 600$.
Choices B and D.

Q9 Two sound waves of the same frequency (200 Hz) travelling in opposite directions inside the open tube interfere to produce a standing wave (i.e. resonance). This continues to occur due to reflection of the waves at both open ends.

Q10 Choice C.

Q11 Sound waves move the cone and the attached coil of wire in the magnetic field of a permanent magnet to and fro. Electromagnetic induction produces an emf (signal) at the terminals of the coil.

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