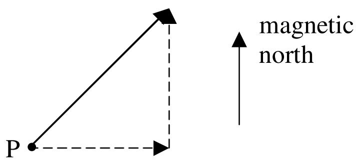
2012 VCAA Physics Exam 2 Solutions

Area of study 1 – Electric power

Q1a The magnetic field produced by the solenoid points to the right (east) at point P. Earth's magnetic field points upwards (north).



Q1b The magnetic field produced by the solenoid points to the left (west) at point Q. .: the bar magnet aligns itself with the magnetic field, and its north pole points to the left, assuming Earth's magnetic field is zero. .: C

Q2a When the current is switched on, it flows from J to K, .: the magnetic force on side KJ is downwards. .: B

Q2b $F = nBIL = 50\times 0.050\times 2.0\times 0.060 = 0.30\text{ N}$

Q3 AC supply: $P_{av} = \frac{V_{rms}{}^2}{R} = \frac{\left(\frac{150}{\sqrt{2}}\right)^2}{6.0} = 1875\text{ W}$

DC supply: $P = \frac{V^2}{R} = \frac{120^2}{7.0} \approx 2057\text{ W}$

.: DC supplies the most power to the caravan.

Q4a $P_{av} = V_{rms} I_{rms} = 900\times 50 = 45000\text{ W} = 45\text{ kW}$

Q4b *Total resistance of the circuit* $R = 7.0 + 18 = 25\ \Omega$

$I_{rms} = \frac{V_{rms}}{R} = \frac{1000}{25} = 40\text{ A}$

Q4c Across the motor, $V_{rms} = 40\times 18 = 720\text{ V} < 900\text{ V}$,

.: the pump will not operate correctly. The motor needs 900 V.

Q4d 1st change: Use a step-up transformer to increase the voltage for transmission. This will reduce the transmission current for the same power delivered and thus lower the power loss because $P_{loss} \propto I^2$. A step-down transformer is then used to restore the high voltage to the correct level.

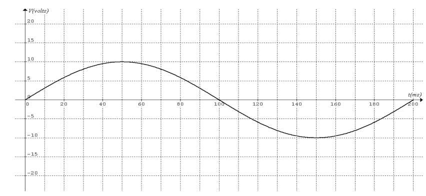
2nd change: Since $P_{loss} \propto R$, .: replace the transmission wires to those with lower resistance, e.g. wires of the same metal with greater diameter or wires of a different metal with lower resistivity.

Q5a *Period* $T = 100\text{ ms} = 100\times 10^{-3}$ s, read from the graph.

.: *frequency* $f = \frac{1}{T} = \frac{1}{100\times 10^{-3}} = 10\text{ Hz}$

Q5b $V_{peak} = 20\text{ V}$, read from the graph, .: $V_{rms} = \frac{20}{\sqrt{2}} \approx 14\text{ V}$

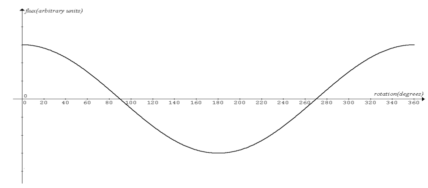
Q5c When the speed is halved, the peak voltage is halved and the period is doubled.



Q6a $V_{rms,s} = \frac{N_s}{N_p}\times V_{rms,p} = \frac{150}{600}\times 20 = 5.0\text{ V}$

Q6b The battery provides a constant voltage at the primary coil which produces a constant magnetic field in the transformer core. This constant magnetic field produces a constant magnetic flux through the secondary coil and thus no voltage is induced across the secondary coil according to Faraday's law of electromagnetic induction.

Q7a The flux is maximum initially.

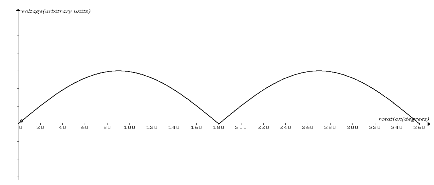


Q7b *Change in flux* $|\Delta\phi| = 0.030\times 0.30\times 0.40 = 0.0036\text{ wb}$

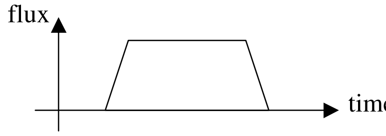
Time taken $\Delta t = \frac{T}{4} = \frac{1}{4f} = \frac{1}{4\times 2} = 0.125\text{ s}$

$|\xi_{av}| = n\frac{|\Delta\phi|}{\Delta t}$, $3.6 = n\times\frac{0.0036}{0.125}$, .: $n = 125$ turns

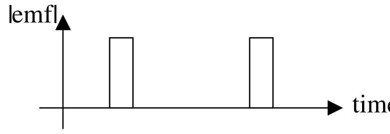
Q7c The output becomes dc when the slip rings are replaced with a split-ring commutator.



Q8a A



Q8b D



Q8c As the square loop moves out of the magnetic field, the (out of the page) magnetic flux decreases. To compensate for the decrease in flux an anticlockwise current (from Y to X through the microammeter) will be induced in the square loop to produce a magnetic field (out of the page) according to Lenz's law.

Area of study 2 – Interactions of light and matter

Q1a $\lambda_{\max} = \frac{c}{f_{threshold}} = \frac{3.0\times10^{8}}{7.40\times10^{14}} = 405\times10^{-9}\text{ m} = 405\text{ nm}$

Q1b Increased intensity produces more photons per unit time but does not change the energy of each photon. Hence the energy of an electron, after absorption of such a photon, remains insufficient for it to escape from the metal. The observation of no emission of photoelectrons contradicts the prediction of the wave model of light, which relates the energy of the light wave to the intensity of light. According to the wave model, bright light provides more energy to the electrons allowing them to escape.

Q1c $E_{k,\max} = hf - w = (4.14\times10^{-15})(7.50\times10^{14}) - 2.28$
$= 0.825\text{ eV}$

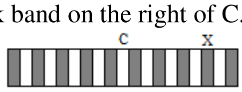
Q1d 0.825 eV

Q2a Laser photon energy:
$E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{612\times10^{-9}} = 3.25\times10^{-19}\text{ J}$
Laser energy in a second:
$E = P\times\Delta t = (5.0\times10^{-3})(1) = 5.0\times10^{-3}\text{ J}$

Number of photons $\frac{5.0\times10^{-3}}{3.25\times10^{-19}} = 1.5\times10^{16}$

Q2b Lights arriving at C from S_1 and S_2 are in phase because the path difference is zero. This results in constructive interference of the two light waves to produce a bright band.

Q2c *Number of wavelengths in* $2.142\times10^{-6}\text{ m}$
$= \frac{2.142\times10^{-6}}{\lambda} = \frac{2.142\times10^{-6}}{612\times10^{-9}} = 3.5$
.: it is the fourth dark band on the right of C.



Q2d Same path difference, .: $2\lambda = 1.5(612\times10^{-9})$
.: $\lambda = 459\times10^{-9}\text{ m} = 459\text{ nm}$

Q3a $E_k = \frac{1}{2}mv^2 = \frac{1}{2}(9.1\times10^{-31})(1.5\times10^{5})^2 = 1.024\times10^{-20}\text{ J}$
$= 0.064\text{ eV}$

Q3b Electron: $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{(9.1\times10^{-31})(1.5\times10^{5})} = 4.857\times10^{-9}\text{ m}$

X-ray photon: Same wavelength $\lambda = 4.857\times10^{-9}$ m to produce the same pattern.

X-ray photon energy $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{4.857\times10^{-9}}$
$= 4.095\times10^{-17}\text{ J} \approx 256\text{ eV}$

Q4a *Photon energy required* $= 12.8 - 10.2 = 2.6\text{ eV}$
.: $\lambda = \frac{hc}{E} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{2.6} \approx 478\times10^{-9}\text{ m} \approx 480\text{ nm}$

Q4b Electrons have wave behaviours. An electron in orbit around a hydrogen nucleus is a standing wave. Only standing waves of an integral multiple of wavelengths can be sustained around the nucleus. This explains why only certain energy levels are stable.

Detailed study 1 – Synchrotron and its applications

1	2	3	4	5	6	7	8	9	10	11	12
A	C	A	D	C	C	D	A	A	D	B	D

Q2 $F = \frac{eV}{d} = \frac{(1.6\times10^{-19})(2000)}{0.05} = 6.4\times10^{-15}\text{ N}$ C

Q3 $B = \frac{mv}{re} = \frac{(9.1\times10^{-31})(2.7\times10^{7})}{(1.6\times10^{-19})(0.14)} \approx 0.0011\text{ T} = 1.1\text{ mT}$ A

Q5 $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2(1.6\times10^{-19})(4000)}{9.1\times10^{-31}}} \approx 3.8\times10^{7}\text{ m s}^{-1}$ C

Q6 $d = \frac{n\lambda}{2\sin\theta} = 1\left(\frac{0.12\times10^{-9}}{2\sin 9.8°}\right) \approx 0.35\times10^{-9}\text{ m} = 0.35\text{ nm}$ C

Detailed study 2 – Photonics

1	2	3	4	5	6	7	8	9	10	11	12
C	D	B	A	C	B	B	C	D	B	A	D

Q1 $\lambda = \frac{hc}{E} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{2.6} \approx 480\times10^{-9}\text{ m} = 480\text{ nm}$ C

Q5 $\sin\theta_c = \frac{n_2}{n_{core}}$, $\sin 70° = \frac{n_2}{1.62}$, $n_2 \approx 1.52$ C

Q6 $\sin\theta = 1.62\sin(90° - 70°)$, $\sin\theta = 1.62\sin 20°$, $\theta \approx 34°$ B

Q7 The greatest $\frac{n_2}{n_{core}} \rightarrow$ smallest acceptance angle. B

Q8 *Speed of light in a medium* $= \frac{c}{n}$, higher n, lower speed. C

Detailed study 3 – Sound

1	2	3	4	5	6	7	8	9	10	11	12
B	C	C	A	D	C	D	A	B	C	A	C

Q1 $\lambda = \frac{v}{f} = \frac{340}{100} = 3.4\text{ m}$ B

Q3 $I = 10^{\frac{L}{10}-12} = 10^{\frac{63}{10}-12} = 2.0\times10^{-6}\text{ W m}^{-2}$ C

Q4 $\frac{1}{2}\times\text{distance} \rightarrow 4\times\text{intensity} \rightarrow +6\text{ dB}$, .: 69 dB A

Q5 5000 Hz 40 dB sound is on the 50 phon curve D

Q9 $L = \frac{\lambda}{4} = \frac{v}{4f} = \frac{340}{4\times170} = 0.5\text{ m}$ B

Q10 The next resonance has the same frequency,
.: $length = 3L = 1.5\text{ m}$ C

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

