2007 VCAA Physics Exam 2 Solutions

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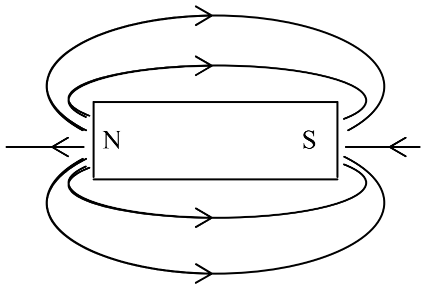
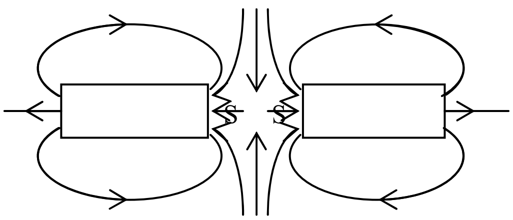
Area of study 1 – Electric power

Q1



Q2



Q3 $F = BIL = 4.0\times10^{-5}\times2000\times20 = 1.6$ N up.

Q4a B (anticlockwise)

Q4b When the switch is closed, current flows in the direction JKLM. The magnetic field is from N to S at right angle to JK. .: the magnetic force on the current-carrying wire JK is downward. Also the magnetic force on LM is upward. These two forces exert an anticlockwise torque on the coil, causing it to start turning anticlockwise. The forces on KL and MJ are zero (negligible).

Q5 The split-ring commutator makes the motor to rotate in the same direction continuously. Without the commutator the torque on the coil changes direction, causing the coil to slow to a stop and reverse its direction every half-turn. With the commutator the current switches direction, making the torque on the coil always in the same direction. Hence the motor keeps turning in the same direction.

Q6 $\phi = BA$, $B = \dfrac{\phi}{A} = \dfrac{3.0\times10^{-4}}{0.20\times0.30} = 5.0\times10^{-3}$ T

Q7 $|\xi_{av}| = n\left|\dfrac{\Delta\phi}{\Delta t}\right| = 1000\times\dfrac{3.0\times10^{-4}}{0.01} = 30$ V

Q8 $f = \dfrac{1}{T} = \dfrac{1}{80\times10^{-3}} = 12.5$ Hz

Q9 $V_{RMS} = \dfrac{V_p}{\sqrt{2}} = \dfrac{80}{\sqrt{2}} \approx 57$ V

Q10 The period decreases and the amplitude increases. .: C

Q11i $A_2 = 5\times0.50 = 2.5$ A

Q11ii $V_1 = 12 - 0.50\times4.0 = 10$ V

Q11iii $V_2 = \dfrac{1}{5}\times10 = 2.0$ V

Q12i Power supply $P = 12\times0.50 = 6.0$ W

Q12ii $P_P = 6.0 - 0.50^2\times4.0 = 5.0$ W

Q12iii $P_S = P_P = 5.0$ W

Q13 The globe will be off. The 12V battery supplies a constant voltage to the input of the transformer. This results in a constant magnetic field in the transformer core, which in turns results in a constant magnetic flux in the secondary coil of the transformer. According to Faraday's law of electromagnetic induction, $\xi_{av} = -n\dfrac{\Delta\phi}{\Delta t}$, the output voltage of the transformer is zero because $\Delta\phi = 0$.

Q14 B

Q15 When S is closed in the left coil, there is an increase in current flow resulting in an increasing magnetic field from right to left in the iron rod. Thus the flux through the coil on the right increases. Lenz's law says that the induced current in the coil on the right must flow in a direction such that the generated magnetic field of the induced current opposes the increase in magnetic field of the coil on the left. Hence the induced current flows from Y to X through the ammeter.

Area of study 2 – Interactions of light and matter

Q1 $W = 2.0$ eV (from graph)

Q2 $f = \dfrac{c}{\lambda} = \dfrac{3.0\times10^{8}}{400\times10^{-9}} = 7.5\times10^{14}$ Hz
Read from graph, $E_{max} = 1.0$ eV

Q3 The evidence supports the particle-like theory of light. According to this theory, light is a beam of particles called photons and the photon energy depends on the frequency of light only, i.e. $E = hf$. For the emission of photoelectrons, *f* must be greater than the cutoff frequency in order to supply enough energy to an electron. Changing the light intensity does not change the energy of the photons, it only increases the photon numbers in the beam.

Q4 $\lambda = \frac{h}{mv}$,

$\therefore v = \frac{h}{m\lambda} = \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times2.0\times10^{-10}} = 2.0\times10^{3}\ \text{ms}^{-1}$

Q5 De Broglie wavelength $\lambda = 2.0\times10^{-10}$ m and the interatomic spacing $w = 3.0\times10^{-10}$ m have the same order of magnitude, a diffraction pattern is expected.

Q6 Since the spacing between the fringes is $\propto \frac{1}{w}$, a wider slit (i.e. greater w) gives smaller spacing. B

Q7 $E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3.0\times10^{8}}{434.1\times10^{-9}} = 2.9$ eV

Q8 From $n = 6$ (13.2 eV) to $n = 2$ (10.2 eV).

Q9 As light travels from the sun to the earth, atoms and molecules (hydrogen and others) in the cooler outer atmosphere of the sun and in the atmosphere of the earth absorb light of frequencies that correspond to the difference between any two energy levels of the atoms and are re-emitted **in all directions**. Thus the light reaching the earth will have a reduced amount of those absorbed frequencies and dark lines appear in the spectrum of light from the sun.

Q10i Continuous wide spectrum.

Q10ii Discrete line spectrum.

Q11i Discrete energy levels do not exist in a solid (filament of an incandescent light globe. Electrons can emit any amount of available energy.

Q11ii Mercury vapour lamp consists of individual mercury atoms and they have discrete energy levels. Light of certain frequencies are emitted during the transitions of electrons from high to low energy levels.

Detailed study 1 – Synchrotron and its applications

Q1 accelerates electrons from the linac, travel around curved segments, the bending magnets in circular sections

Q2 $eV = \frac{1}{2}mv^2$,

$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.60\times10^{-19}\times2000}{9.11\times10^{-31}}} = 2.65\times10^{7}\ \text{ms}^{-1}$.

Q3 $r = \frac{mv}{eB} = \frac{9.11\times10^{-31}\times5.0\times10^{6}}{1.60\times10^{-19}\times1.2\times10^{-4}} = 0.237\ \text{m}$

Q4 B

Q5 $F = evB = 1.60\times10^{-19}\times2500\times0.50 = 2.0\times10^{-16}$ N down page.

Q6 C

Q7 $E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3.0\times10^{8}}{0.120\times10^{-9}} = 10350\ \text{eV} = 10.35\ \text{keV}$

Q8 $n\lambda = 2d\sin\theta$,

$d = \frac{n\lambda}{2\sin\theta} = \frac{1\times0.120\times10^{-9}}{2\sin17.5°} = 0.19953\times10^{-9} \approx 0.200\ \text{nm}$

Q9 $\sin\theta = \frac{n\lambda}{2d}$.

When $n = 2$, $\theta = \sin^{-1}\left(\frac{2\times0.120\times10^{-9}}{2\times0.19953\times10^{-9}}\right) = 37.0°$

When $n = 3$, $\theta = \sin^{-1}\left(\frac{3\times0.120\times10^{-9}}{2\times0.19953\times10^{-9}}\right) = 64.4°$

D

Q10 D

Q11 In Bragg diffraction, $\sin\theta = \frac{n\lambda}{2d}$,

$\therefore \sin\theta \propto \lambda$ for constant n and d.
By measuring θ one can determine whether to increase or decrease the electron energy in the storage ring in order to produce synchrotron light of the right wavelength for experimental use.

Detailed study 2 – Photonics

Q1 population inversion, photons, the same

Q2 For a LED to conduct, certain forward bias voltage (2.64 V in this case) is required. This decreases the effective potential barrier and narrows the pn depletion layer in order for conduction to occur.

Q3 $eV = \frac{hc}{\lambda}$,

$\lambda = \frac{hc}{eV} = \frac{4.14\times10^{-15}\times3.0\times10^{8}}{2.64} = 4.70\times10^{-7}\ \text{m}$

Q4 Less than 2.64 V is required for a red LED to conduct.
.: the voltage across the resistor is higher and .: the current is greater than 5.00 mA. A

Q5 $i_c = \sin^{-1}\left(\frac{1.43}{1.46}\right) = 78.36°$ D

Q6 Apply Snell's law: $\sin\alpha = \frac{1.46\times\sin(90°-70°)}{1.00}$,

$\alpha = \sin^{-1}\left(\frac{1.46\sin20°}{1.00}\right) = 30°$ B

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Q7 Material dispersion occurs because the refractive index of a material varies with the frequency/wavelength of the incident light. This results in light rays of different frequencies to travel through the optic fibre at slightly different speeds, giving rise to pulse spreading.

Q8 (a) Laser signal has a very narrow spectral spread.
(b) The angle of incidence for laser signal entering the optic fibre can be accurately controlled to reduce the number of internal reflections and thus decrease the travelling time through the fibre.

Q9 C

Q10 Infrared laser would be best because red laser suffers more attenuation (6 units due to Rayleigh scattering and absorption combined) in comparison with infrared laser (1.5 units approx.).

Q11 The detector will detect higher intensity light.
With no bending of the concrete beam, the light hits the interface just below the critical angle on the most curved sections, allowing some light to escape the fibre at all the most curved sections.
When the concrete beam is bent, light will hit the interface above the critical angle on the most curved sections near the top of the beam. Total internal reflection will occur and more light will arrive at the detector.

Detailed study 3 − Sound

Q1 out of phase, interfere destructively, intensity

Q2 $\lambda = \frac{v}{f} = \frac{340}{100} = 3.4$ m

Q3 $f = \frac{v}{4L} = \frac{340}{4 \times 0.50} = 170$ Hz

Q4 A louder sound is heard. This is because the amplitude of the standing wave formed in resonance is greater than the amplitude of the combined wave when there is no resonance.

Q5 At the third harmonic, $f = 3 \times 170 = 510$ Hz D

Q6 Sound wave causes the diaphragm to vibrate, which in turns causes the wire coil that is attached to the diaphragm to move between the poles of a permanent magnet, and thus inducing a voltage in the coil.

Q7 The flat response in the frequency range, 200 to 3000 Hz, makes the microphone particularly suitable for use by a singer.

Q8 $I = 10^{\frac{L}{10} - 12} = 1.0 \times 10^{-6}$ Wm^{-2}.

Q9a 200 Hz

Q9b Extent of diffraction $\propto \frac{\lambda}{w}$.

Since w is constant, the extent of diffraction $\propto \lambda$ or $\frac{1}{f}$.

.: lower frequency diffracts more than higher frequency sound.

Q10 $\frac{I(before)}{I(after)} = 10^{\frac{\Delta L}{10}} = 10^{\frac{9}{10}} \approx \frac{8}{1}$ C

Q11 Intensity at Z is $\frac{1}{4}$ of that at X

.: the sound intensity level at Z is 6 dB less than that at X, i.e. L at Z is 54 dB approx. B

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