2014 VCAA Physics Examination Solutions

Area of study – Motion in one and two dimensions

Q1a $u=0$, $t=5$, $a={}^{+}0.20$, $s=ut+\frac{1}{2}at^2=\frac{1}{2}\left({}^{+}0.20\right)\left(5^2\right)=2.5$

.: distance travelled $=2.5$ m

Q1b Tension in the coupling

$=$ mass of the two trucks $\times$ acceleration $=20\,000\times0.20=4\,000$ N

Q1c Total momentum after $=$ total momentum before collision

$80\,000v=40\,000\left({}^{+}4.0\right)$, .: $v={}^{+}2.0$, .: the speed is 2.0 m s^{-1}

Q1d Total kinetic energy after $=\frac{1}{2}(80\,000)\left(2.0^2\right)=160\,000$ J

Total kinetic energy before $=\frac{1}{2}(40\,000)\left(4.0^2\right)=320\,000$ J

Kinetic energy is not conserved, .: the collision is inelastic.

Q2a From the given table extension is proportional to the force of gravity, .: the spring follows Hooke's law and its spring constant is given by the constant of proportionality $k=\frac{0.050\times10}{0.10}=5.0$ Nm^{-1}

Q2b When the 0.20-kg masses are released from the unstretched position, they move downwards and the gravitational potential energy decreases. At the lowest point (x metres below the released position) the gravitational potential energy is converted to elastic potential energy, .: $0.20\times10\times x=\frac{1}{2}\times5.0\times x^2$, .: $x=0.8$ m

The extension at the lowest point is 0.8 m.

Q2c The graphs are correct but they do not add to a constant because kinetic energy of the system is not included in the total energy.

Q2d The speed is maximum when the acceleration and hence the net force is zero, .: $5.0x+{}^{-}0.20\times10=0$, .: $x=0.40$ m

The total energy of the system $=\frac{1}{2}\times5.0\times0.8^2=1.6$ J

At extension 0.40 m extension:

$\frac{1}{2}\times0.20v^2+\frac{1}{2}\times5.0\times0.4^2+0.2\times10\times0.4=1.6$

.: $v=2.0$, .: the maximum speed is 2.0 m s^{-1}

Q3a Vertical component: $u={}^{+}20\sin30°={}^{+}10$, $v=0$, $a={}^{-}10$

$v^2=u^2+2as$, .: $0=100-20s$, $s={}^{+}5.0$

.: maximum height reached is 5.0 m.

Q3b Horizontal component: $t=\frac{26}{20\cos30°}\approx1.5011$ s

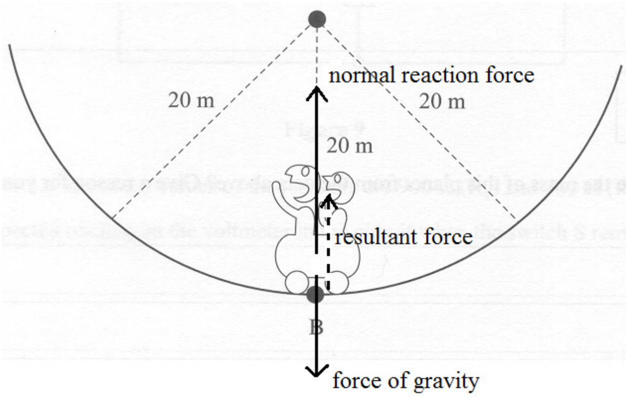
Vertical component: $t=1.5011$, $a={}^{-}10$, $u={}^{+}10$, $s=ut+\frac{1}{2}at^2$

.: $s={}^{+}10\times1.5011+\frac{1}{2}\times{}^{-}10\times1.5011^2\approx{}^{+}3.74$, .: $h\approx3.7$ m

Q4a Mary and Bob feel weightless when they move under gravity only, .: $a=mg$, $\frac{mv^2}{r}=mg$, $v=\sqrt{gr}=\sqrt{10\times20}\approx14$ m s^{-1}

Q4b At point A they are in free fall and gravity is the only force on them. There is no contact reaction force on them, .: they cannot feel their own weights, i.e. they feel weightless.

Q4c



Q5a $a=g$, $\frac{4\pi^2 r}{T^2}=\frac{GM}{r^2}$

$M=\frac{4\pi^2 r^3}{GT^2}=\frac{4\pi^2\left(7.0\times10^{10}\right)^3}{6.67\times10^{-11}(1200\times3600)^2}\approx1.1\times10^{31}$ kg

Q5b All objects around the star at the same orbital radius have the same period, independent of the mass of the objects. It is not possible to determine the mass of the planet from the given data.

Area of study – Electronics and photonics

Q6a 0 V

Q6b R_1 and R_2 form a voltage divider,

Voltmeter reading $=V_2=\frac{300}{900+300}\times8.0=2.0$ V

Q7a Power dissipated in the LED:

$P=VI$, $I=\frac{P}{V}=\frac{300\times10^{-3}}{2}=150\times10^{-3}$ A

$V_R=11-2=9$ V, .: $R=\frac{V_R}{I}=\frac{9}{150\times10^{-3}}=60\,\Omega$

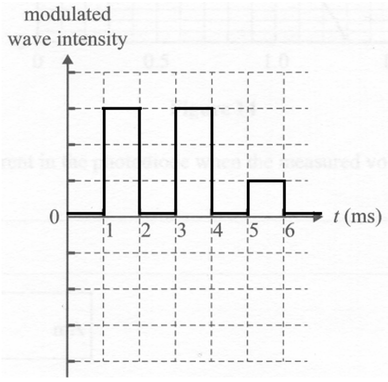
Q7b $V_R=12-3.0=9.0$ V, $I_R=0.50$ A, $P_R=9.0\times0.50=4.5$ W

Q8a Read from graph: $I=3.6$ mA

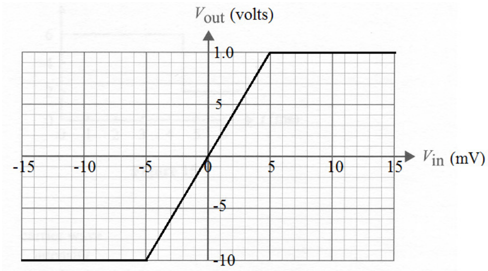
Q8b Read from graph: $V=1.3$ V

Q8c When $V=1.0$ V, $I=1.6$ mA, $R=\frac{V}{I}=\frac{1.0}{1.6\times10^{-3}}=625\,\Omega$

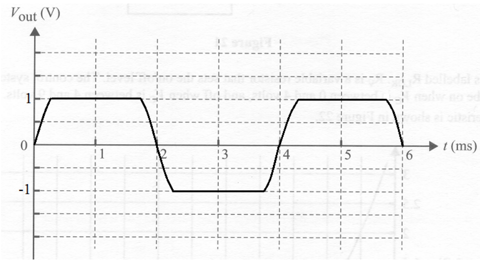
Q9



Q10a



Q10b



Q11 On/off voltage $V_C = 4\text{ V}$, $V_{LDR} = 9 - 4 = 5\text{ V}$

From graph, at 300 lux, $R_{LDR} = 0.5\ \text{k}\Omega$

.: $\dfrac{R_V}{0.5\times10^3} = \dfrac{4}{5}$, .: $R_V = 400\ \Omega$

Area of study – Electric power

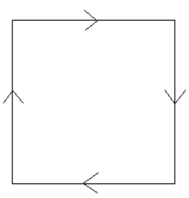
Q12a A

Q12b E

Q13a C and D

Q13b $|\xi_{av}| = \left|\dfrac{\Delta\phi}{\Delta t}\right| = \dfrac{0.050\times0.080}{10\times10^{-3}} = 0.40\text{ V}$, $R = \dfrac{0.40}{0.020} = 20\,\Omega$

Q13c



As the downward magnetic field decreases, according to Lenz's law, there is an induced current flowing in the clockwise direction (viewed from above) to generate a downward magnetic field inside the loop to make up for the decrease in magnetic flux.

Q14a 0 V

Q14b $\dfrac{V_{in}}{V_{out}} = \dfrac{N_{primary}}{N_{secondary}}$, $\dfrac{V_{in}}{400} = \dfrac{130}{5200}$, $V_{in} = 10\text{ V (rms)}$

The peak value of $V_{in} = 10\sqrt{2} \approx 14.1\text{ V}$

Q15a Voltage drop (loss) in the wires $= 13 - 3.0 = 10\text{ V}$

Q15b For the light globe, $P = \dfrac{V^2}{R} = \dfrac{3.0^2}{1.5} = 6.0\ \text{W}$

Q15c $I = \dfrac{V}{R} = \dfrac{3.0}{1.5} = 2.0\text{ A}$

Q15d For the light globe, $I = \dfrac{V}{R} = \dfrac{6.0}{1.5} = 4.0\text{ A}$

For the wires, $V = IR = 4.0\times5.0 = 20\text{ V}$

.: the DC power supply $= 20 + 6.0 = 26\text{ V}$

Q16 At the generator end of the transmission lines, a step-up transformer increases the output voltage and thus decreases the output current to provide the same power supplied by the generator for transmission, $V_{out}I_{out} = V_{in}I_{in}$.

Lowering the current in the transmission lines reduces loss of power in the lines since $P_{loss} = I^2R$, where I is the current in the lines and R is the total resistance of the lines.

At the user's end of the transmission lines, a step-down transformer decreases the high voltage in the lines to suitable voltages for home or industrial uses.

Q17a

Side	Force direction
WX	down
XY	no force
YZ	up
ZW	no force

Q17b $F = nBIL = 75\times0.020\times2.0\times0.40 = 1.2\text{ N}$

Q17c The forces on WX and YZ produce a turning effect on the rectangular coil.

Q17d

Position	Current in side WX
before the vertical position	from W to X
at the vertical position	no current
after the vertical position	from X to W

Q18a Before the coil turns to the vertical position, the magnetic flux to the right increases and thus a current flowing in the clockwise direction (viewed from above) is induced according to Lenz's law. As the coil continues to rotate past the vertical position, magnetic flux to the right decreases and an induced current flows in the opposite direction. The induced current changes directions every half turn of the coil, .: AC

Q18b Period $T = 2\times25\text{ ms} = 50\text{ ms}$, .: $f = \dfrac{1}{T} = \dfrac{1}{50\times10^{-3}} = 20\text{ Hz}$

Q18c When the period of rotation of the coil decreases, the magnitude of the voltage output of the generator increases because $|\xi_{av}| = n\dfrac{\Delta\phi}{\Delta t}$, i.e. $|\xi_{av}| \propto \dfrac{1}{\Delta t}$ for constant n and $\Delta\phi$.

Area of study – Interactions of light and matter

Q19a P is on the second bright band from the central bright band, .: $S_1P - S_2P = 2\lambda = 2\times 420 = 840$ nm

Q19b Now P is on the second dark band from the central bright band, .: $S_1P - S_2P = \frac{3\lambda}{2} = 840$ nm, .: $\lambda = 560$ nm

Q20a
Work function $\phi = hf_{\text{threshold}} = (6.63\times 10^{-34})(1.8\times 10^{15}) \approx 1.2\times 10^{-18}$ J

Q20b According to the particle model of light, max $E_k = hf - \phi$, i.e. max E_k depends on the frequency of the light and the type of metal used. It does not depend on the intensity of the light. Thus the results of the second experiment provide evidence for the particle-like nature of light. In the equation, max $E_k = hf - \phi$, hf is the energy of a particle (photon). There will be no emission of electrons if the photon energy is lowered than the work function of the metal.

Q21a $\lambda = \frac{hc}{E} = \frac{(4.14\times 10^{-15})\times(3.0\times 10^{8})}{4.1} \approx 3.0\times 10^{-7}$ m

Q21b smaller than

Q21c The extent of diffraction $\propto \frac{\lambda}{w}$. If the same light beam is used, λ remains constant, .: the extent of diffraction is inversely proportional to the diameter of the aperture *w*, i.e. the pattern spreads out less when the aperture diameter increases.

Q21d Let $E_{\text{X-ray}} = E_{\text{electron}} = 5\times 10^{-15}$ J.

$\lambda_{\text{X-ray}} = \frac{hc}{E_{\text{X-ray}}} \approx 4\times 10^{-11}$ m, $\lambda_{\text{electron}} = \frac{h}{\sqrt{2mE_{\text{electron}}}} \approx 7\times 10^{-12}$ m

i.e. $\lambda_{\text{X-ray}} > \lambda_{\text{electron}}$

The extent of diffraction $\propto \frac{\lambda}{w}$. If the same aperture is used, w remains constant, .: the extent of diffraction is directly proportional to the wavelength , i.e. the pattern spreads out more for the X-ray beam than for the electron beam.

Q22a Atoms can absorb or emit photons with energy corresponding to the difference between two energy levels. There is a level (the second excited state, 6.7 eV) 1.8 eV higher than the first excited state of 4.9 eV, but there is no level 1.8 eV lower than the first excited state.

Q22b The low values 0.9 eV, 1.5 eV and 2.2 eV suggest that the energy levels are close to the third excited state (*x* eV).
Let $9.8 - x = 0.9$, $x = 8.9$
The value $x = 8.9$ gives the other two emissions, $10.4 - 8.9 = 1.5$ and $8.9 - 6.7 = 2.2$.

Q23a $\lambda = \frac{h}{mv} = \frac{6.63\times 10^{-34}}{(9.1\times 10^{-31})(2.0\times 10^{6})} \approx 0.36\times 10^{-9}$ m, i.e. 0.36 nm

Q23b Electrons in stable orbits can be considered as circular standing waves. A circular standing wave can be sustained if the circumference is a whole number of wavelength. A different whole number of wavelengths corresponds to a different energy level. This explains the quantised energy levels in atoms.

Detailed study 1 – Einstein's special relativity

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

Q3 $L = L_o\sqrt{1-\frac{v^2}{c^2}}$, $2.00 - 0.010 = 2.00\sqrt{1-\frac{v^2}{c^2}}$, $v = 0.10c$ C

Q4 Classical (non-relativistic) treatment B

Q5 Distance $= ct = 3.0\times 10^{8}\times 0.0100 = 3.0\times 10^{6}$ m $= 3000$ km A

Q8 $L = \frac{L_o}{\gamma} = \frac{5.00}{1.25} = 4.00$ m C

Q9 $t = \gamma t_o = 1.25\times\frac{10.0}{3.0\times 10^{8}} \approx 42\times 10^{-9}$ s $= 42$ ns A

Q10 $E_{\text{total}} = mc^2 = m_o c^2$

$m_o\times(3.0\times 10^{8})^2 = 4.5\times 10^{-11}$, total mass $m_o \approx 5.0\times 10^{-28}$ kg

.: the rest mass of a pion $\approx \frac{5.0\times 10^{-28}}{2} = 2.5\times 10^{-28}$ kg B

Q11 $E_k + E_{\text{rest}} = mc^2$, $E_k + m_o c^2 = \gamma m_o c^2$,

Work done $= E_k = (\gamma - 1)m_o c^2 = (3.00 - 1)m_o c^2 = 4.5\times 10^{-11}$ J A

Detailed study 2 – Materials and their use in structures

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

Q1 $\varepsilon = \frac{\Delta x}{\ell} = \frac{2.0\times 10^{-3}}{2.0} = 1.0\times 10^{-3}$ A

Q2 $\sigma = \frac{F}{A} = \frac{mg}{A} = \frac{0.20\times 10}{4.0\times 10^{-8}} = 50\times 10^{6}$ Pa $= 50$ MPa C

Q3 Young's modulus for nichrome

$= \text{gradient} = \frac{200\times 10^{6}}{1.0\times 10^{-3}} = 2.0\times 10^{11}$ Pa (or N m^{-2}) C

Q4 Toughness of tungsten = area under σ - ε graph

$= \frac{1}{2}(2.0 + 2.5)(10^{-3})(400\times 10^{6}) = 9.0\times 10^{5}$ J m^{-3} D

Q6 $F = \sigma A = (400\times 10^{6})(1.0\times 10^{-8}) = 4$ N

Maximum number of 50 g masses $= \frac{4}{0.050\times 10} = 8$ B

Q7 Sum of torque about X = 0
$T\times 0.40\sin 30° - 0.050\times 10\times 0.40 = 0$, .: $T = 1.0$ N B

Q8 Let the vertical component of the force of the wall on the beam at point X be F_X. Vertically,
$F_X + T\sin 30° - 0.050\times 10 = 0$ and $T = 1.0$.: $F_X = 0$ B

Q9 Torque on the beam about point X due to the 150 g mass
$= (150\times 10^{-3})\times 10\times 0.80 = 1.2$ N m B

Detailed study 3 – Further electronics

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

Q2 $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{6}{24} = \frac{1}{4}$ **B**

Q3 Time constant τ = time taken to charge up the capacitor by 63%. From graph, $\tau \approx 20\times10^{-3}$ s.

$C = \frac{\tau}{R} \approx \frac{20\times10^{-3}}{1.0\times10^{3}} = 20\times10^{-6}$ F (or 20 μF) **C**

Q4 Frequency $= \frac{1}{\text{period}} = \frac{1}{10\times10^{-3}} = 100$ Hz **A**

Q8 Power loss (heat) = input power − output power

$= 11\times5 - 6\times5 = 25$ W **B**

Detailed study 4 – Synchrotron and its applications

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

Q1 $E = \frac{F}{q} = \frac{7.2\times10^{-14}}{1.6\times10^{-19}} = 4.5\times10^{5}$ N C^{-1} (or V m^{-1}) **A**

Q3 $a = \frac{qvB}{m} = \frac{(1.6\times10^{-19})(2.5\times10^{8})(0.27)}{9.1\times10^{-31}} \approx 1.2\times10^{19}$ m s^{-2} **B**

Q4 $r = \frac{v^2}{a} \approx \frac{(2.5\times10^{8})^2}{1.2\times10^{19}} \approx 5.3\times10^{-3}$ m **D**

Q7 Photon: $\Delta p = p_{\text{final}} - p_{\text{initial}}$

$= \frac{^{-}(6.63\times10^{-34})(2.30\times10^{18})}{3.0\times10^{8}} - \frac{(6.63\times10^{-34})(2.22\times10^{18})}{3.0\times10^{8}}$

$\approx {}^{-}10\times10^{-24}$ kg m s^{-1}

Electron: $\Delta p \approx 10\times10^{-24}$ kg m s^{-1}

.: speed $\approx \frac{10\times10^{-24}}{9.1\times10^{-31}} \approx 1.1\times10^{7}$ m s^{-1} **B**

Q9 $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right) = \sin^{-1}\left(\frac{1\times0.082\times10^{-9}}{2\times2.7\times10^{-10}}\right) \approx 8.7°$ **B**

Q10 $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$, .: θ is greater when d is smaller and .: less intensity peaks. **C**

Detailed study 5 – Photonics

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

Q1 $1.40\times\sin(90-\theta_c)° = 1.00\times\sin15°$, $\theta_c \approx 79°$ **B**

Q2 $\theta_c = \sin^{-1}\left(\frac{n_{\text{cladding}}}{n_{\text{core}}}\right)$, smaller n_{cladding}, smaller θ_c. **D**

Q4 $\Delta E = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{800\times10^{-9}} \approx 1.6$ eV **B**

Q8 $\theta = \tan^{-1}\left(\frac{1.0}{10}\right) \approx 5.7°$, a wide fibre collects more light **A**

Detailed study 6 – Sound

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

Q2 $I = 10^{\frac{L}{10}-12} = 10^{-6}$ **C**

Q3 When distance is doubled, intensity becomes a quarter of the original, .: level drops by 6 dB from 60 dB to 54 dB. **C**

Q6 $f = \frac{v}{\lambda} = \frac{340}{2\times1.7} = 100$ Hz **C**

Q7 $\frac{3}{4}\lambda = 1.7$, $\lambda = 2.267$, $f = \frac{340}{2.267} = 150$ Hz **B**

Q9 Without a baffle board the lower frequencies from the back of the loudspeaker diffract more and interfere destructively with those from the front of the loudspeaker. The baffle board stops this process and John will hear the lower frequencies more loudly than without it. **B**

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

