2013 VCAA Physics Exam Solutions

Area of study – Motion in one and two dimensions

Q1a $a = g\sin 10° \approx 1.7$ m s^{-2}

Alternative method: $s = 3.5$, $u = 0$, $t = 2.0$, $s = ut + \frac{1}{2}at^2$

$a \approx 1.8$ m s^{-2}

Q1b $s = 3.5$, $u = 0$, $t = 2.0$, $s = ut + \frac{1}{2}at^2$, .: $a = \frac{3.5}{18}$

Let F_f be the force of friction on the block.

$F_{net} = ma$, $mg\sin\theta - F_f = ma$, $0.50 \times 10\sin 10° - F_f = 0.50 \times \frac{3.5}{18}$

.: $F_f \approx 0.77$ N

Q2a $F_{m1} = m_1 g = 2.0 \times 10 = 20$ N

Q2b *Net force on the system* $= F_{m1} = 20$ N

$F_{net} = (m_1 + m_2)a$, $a = \frac{F_{net}}{m_1 + m_2} = 2.5$ m s^{-2}

Consider m_2 only: $F_{net} = ma$, $T = 6.0 \times 2.5 = 15$ N

Q3a *Total momentum after = total momentum before*

$= 2.0 \times 6.0 + 4.0 \times 0 = 12$ kg m s^{-1}

Q3b $v_{after} = \frac{p}{m} = \frac{12}{2.0 + 4.0} = 2.0$ m s^{-1}

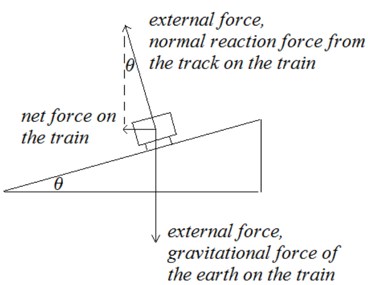
$E_{after} = \frac{1}{2}mv^2 = \frac{1}{2}(2.0 + 4.0) \times 2.0^2 = 12$ J

$E_{before} = \frac{1}{2} \times 2.0 \times 6.0^2 + 0 = 36$ J

$E_{after} \neq E_{before}$, .: inelastic

Q3c *Impulse on* $m_1 = \Delta p$ of $m_1 = 2.0 \times {}^{+}2.0 - 2.0 \times {}^{+}6.0 = {}^{-}8.0$ Ns, i.e. 8.0 Ns to the left.

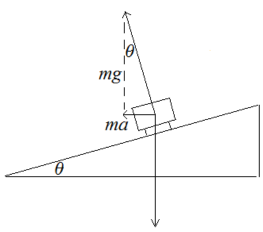
Q4a



Q4b

$a = \frac{v^2}{r} = \frac{50^2}{2000} = 1.25$

$\tan\theta = \frac{a}{g}$, $\theta = \tan^{-1}\left(\frac{1.25}{10}\right) \approx 7.1°$



Q5a The mass is in uniform (constant speed) circular motion.
.: the net force is centripetal, i.e. towards the centre of the circular path, .: direction D.

Q5b At the lowest point S the two external forces on the mass are the upward tension force T of the rod and the downward force of gravity mg, and $T - mg = \frac{mv^2}{r}$, $T - 2.0 \times 10 = \frac{2.0 \times 7.0^2}{1.0}$

.: $T \approx 1.2 \times 10^2$ N

Q6a $E_{bottom} = E_{spring} = \frac{1}{2}k(\Delta x)^2 = \frac{1}{2} \times 10 \times 2.0^2 = 20$ J

Q6b The total energy of the system is constant 20 J.

$E_{midpoint} = E_{kinetic} + E_{spring} + E_{gravity} = E_{total}$

$\frac{1}{2} \times 1.0 \times v^2 + \frac{1}{2} \times 10 \times 1.0^2 + 1.0 \times 10 \times 1.0 = 20$, .: $v \approx 3.2$ m s^{-1}

Q6c The mistake made by the student was to take the spring potential energy as zero at position Q.

It should be $\frac{1}{2} \times 10 \times 0.5^2 = 1.25$ J at position Q and

$\frac{1}{2} \times 10 \times 1.5^2 = 11.25$ J at position P.

The total energy is 11.25 J at both positions.

Q7a *Period* = 24 hours = 86400 s

Q7b $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$, $T = 86400$ s, $r = \left(\frac{GMT^2}{4\pi^2}\right)^{\frac{1}{3}} \approx 4.2 \times 10^7$ m

Q7c The astronaut is not weightless because the force of gravity is on her.
The force of gravity, i.e. her weight is given by 65g newtons and g is the gravitational field strength of the earth at the orbit.
She is on board the orbiting satellite, .: she is in free fall and experiences apparent weightlessness.

Q8a Vertical component: $s = -15$, $u = 20\sin 30° = 10$, $a = -10$,

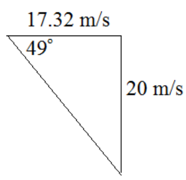
$s = ut + \frac{1}{2}at^2$, $5t^2 - 10t - 15 = 0$, $5(t-3)(t+1) = 0$, $t = 3.0$ s

Q8b Vertical component: $u = 10$, $a = -10$, $t = 3.0$,
$v = u + at = -20$

Horizontal component: $v = 20\cos 30° \approx 17.32$

.: *magnitude of velocity* $\approx \sqrt{20^2 + 17.32^2} \approx 26$ m s^{-1}

direction $\approx \tan^{-1}\left(\frac{20}{17.32}\right) \approx 49°$ to the horizontal



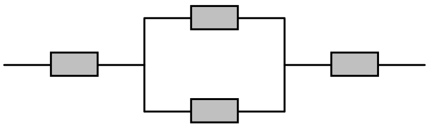
Area of study – Electronics and photonics

Q9 When $R_{variable} = 0$, $V_{max} = 15$ V; when $R_{variable} = 10\ \text{k}\Omega$,

$V_{min} = \frac{5.0}{5.0 + 10} \times 15 = 5.0\ \text{V}$

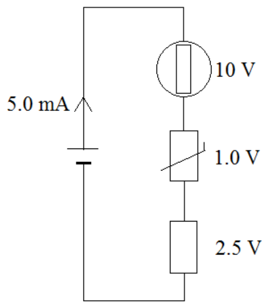
The output ranges from 5.0 to 15 V.

Q10



$\textit{Total resistance} = 50 + \frac{1}{\frac{1}{50} + \frac{1}{50}} + 50 = 125\ \Omega$

Q11a $R = \frac{V}{I} = \frac{2.5}{5.0 \times 10^{-3}} = 500\Omega$



Q11b $R_{therm} = \frac{1.0}{5.0 \times 10^{-3}} = 200\Omega$

$\textit{Temperature} = 20°$ C from graph

Q11c $R_{LDR} = \frac{10}{5.0 \times 10^{-3}} = 2000\Omega$

$\textit{Light intensity} = 15$ lux from graph

Q11d The buzzer will turn off when the voltage across the resistor is 2.4 V or lower.
A possible change: Decrease the light intensity to increase R_{LDR}, .: higher voltage across the LDR and lower voltage across the resistor.
Another possible change: Increase the temperature to increase R_{therm}, .: higher voltage across the thermistor and lower voltage across the resistor.

Q12a $I = 10$ mA, $V_{LED} = 2.0$ V from graph

$V_R = (10 \times 10^{-3}) \times 450 = 4.5$ V, .: $V_{battery} = 2.0 + 4.5 = 6.5$ V

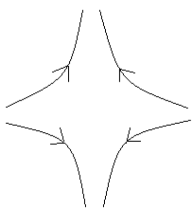
Q12b Electric potential energy of the charges is transferred to the LED and emitted in the form of light, and to the resistor and emitted as heat.

Q13a $|gain| = |gradient| = \frac{8}{20 \times 10^{-3}} = 400$

Q13b It is described as inverting because it gives an output which is the inversion of the input.

Area of study – Electric power

Q14



Q15a $V_R = V_{secondary}$, $\frac{V_{secondary}}{V_{primary}} = \frac{N_{secondary}}{N_{primary}}$, $\frac{V_R}{3.0} = \frac{6000}{1000}$

.: $V_R = 18$ V RMS

Q15b $V_R = 18\sqrt{2} \approx 25$ V peak

Q15c $P_{av} = \frac{V_{RMS}^2}{R} = \frac{18^2}{1200} = 0.27$ W

Q15d As the switch is closed, current in the primary coil increases to a constant value in a short interval and the magnetic field in the core increases. This causes a change in the magnetic flux through the secondary coil and a short pulse of current is induced in the secondary coil and the resistor according to Faraday's law of electromagnetic induction. When the current in the primary coil becomes constant, the magnetic field in the core becomes constant, the magnetic flux through the secondary coil becomes constant and .: no induced current in the resistor.

Q16a The current flows from W to X and the magnetic field is to the right, .: the force on WX is downwards and the force on YZ is upwards. The two forces cause the rectangular coil to rotate anticlockwise as viewed by Mary.

Q16b $F = nBIL = 20 \times (500 \times 10^{-3}) \times 0.50 \times (5.0 \times 10^{-2}) = 0.25$ N

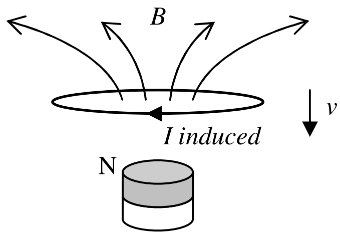
Q16c No, the operation would not improve. The rectangular coil will oscillate with decreasing (due to friction) amplitude and eventually come to a stop with the loop in a vertical position.

Q17a $\Delta t = 1.5 - 1.0 = 0.5$ s, $\Delta\phi = 0.6 - 0.2 = 0.4$ Wb

$|\xi_{av}| = \frac{0.4}{0.5} = 0.8$ V, .: $I_{av} = \frac{|\xi_{av}|}{R} = \frac{0.8}{0.1} = 8$ A

Q17b $\xi = 0$ when the rate of change of flux is zero, i.e. when $t = 0.5$, 1.0, 1.5 s

Q17c



When the ring moves downwards towards the N pole of the magnet, the upward flux through the ring increases and a current is induced in the ring. The induced current flows in the clockwise direction as predicted by Lenz's law, viewing from above.

Q17d. The magnetic flux through the ring is always upwards. It is the least at A and B, and the most at C.

Position of ring	Time (s)
at point A	0, 2.0
at point C	0.5, 1.5, 2.5
at point B	1.0

Q18a $V_{drop} = IR$, $24 = 6.0R$, $R = 4.0\Omega$

Q18b $P_{out} = V_{out}I$, $1200 = V_{out} \times 6.0$, $V_{out} = 200$ V

Q18c $P_{loss} = V_{drop}I = 24 \times 6.0 = 144$ W ≈ 140 W

.: $\frac{P_{loss}}{P_{in}} = \frac{P_{loss}}{P_{out}} = \frac{144}{1200} = 0.12 = 12\%$

Q18d $V_{drop} = IR$, $10 = I \times 2.0$, $I = 5.0$ A

$P_{out} = V_{out}I$, $1200 = V_{out} \times 5.0$, $V_{out} = 240$ V

Area of study – Interactions of light and matter

Q19a $E = hf = (6.63\times10^{-34})\times(6.7\times10^{14}) \approx 4.4\times10^{-19}$ J

Q19b $\lambda = \frac{c}{f} = \frac{3.0\times10^{8}}{6.7\times10^{14}} \approx 4.5\times10^{-7}$ m

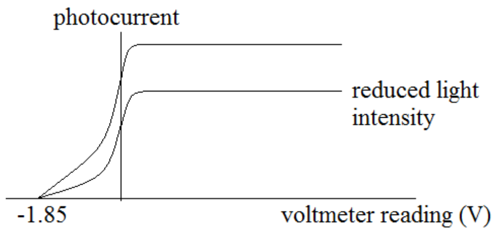
Q20a Longest wavelength corresponds to lowest energy which is $3.19 - 2.11 = 1.08$ eV.
$\lambda = \frac{hc}{E} = \frac{(4.14\times10^{-15})\times(3.0\times10^{8})}{1.08} \approx 1.15\times10^{-6}$ m

Q20b $E = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})\times(3.0\times10^{8})}{588.63\times10^{-9}} \approx 2.11$ eV
The spectral line at 588.63 nm comes from the transition of the sodium atom from the first excited state to the ground state.

Q21a $E_{K,\max} = (1.6\times10^{-19})\times1.85 = 3.0\times10^{-19}$ J

Q21b $E_{K,\max} = hf - W$, $1.85 = (4.14\times10^{-15})\times(1.00\times10^{15}) - W$
.: $W = 2.29$ eV

Q21c



Q21d Emission of electrons occurs when $E_{K,\max} = hf - W > 0$, i.e. $hf > W$. No electrons will be emitted if the frequency of light is reduced to a value $f < \frac{W}{h}$ regardless of the size or sign of the voltage.

Q22a Light from the same source passes through the two slits, .: light from S_1 and light from S_2 are in phase at the slits. At the exact centre of the pattern the distances from S_1 and S_2 are the same, .: a bright band is formed due to constructive interference of the lights arriving at the centre position in phase.

Q22b Lower frequency corresponds to longer wavelength.
Since $\Delta x = \frac{L\lambda}{d}$, .: the separation between two adjacent bright (or dark) bands Δx increases as λ increases. D

Q22c For the second bright band, *path difference* $= 2\lambda$.
.: $2\lambda = 1.4\times10^{3}\times10^{-9}$, $\lambda = 7.0\times10^{-7}$ m
For the first dark band,
path difference $= \frac{\lambda}{2} = \frac{7.0\times10^{-7}}{2} = 3.5\times10^{-7}$ m

Q22d The statement is incorrect. Interference is a typical property of waves. Young's double-slit experiment demonstrates that light interferes, showing the wave behaviour of light. .: It supports the wave model of light.

Q23a $p = \frac{E}{c} = \frac{(80\times10^{3})\times(1.6\times10^{-19})}{3.0\times10^{8}} \approx 4.3\times10^{-23}$ kg m s^{-1}

Q23b Student A is correct.
Since the extent of diffraction is proportional to the wavelength, same fringe spacing means the wavelengths of X-rays and electrons are the same. Since $p = \frac{h}{\lambda}$.: X-rays and electrons have the same momentum.

Detailed study 1 – Einstein's special relativity

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

Q2 $(340 + v)\times0.0857 = 30$, $v = 10$
$(340 - v)\times0.0909 = 30$, $v = 10$ A

Q3 $E_k + E_{rest} = mc^2$, $E_k + m_o c^2 = mc^2$, $E_k = (m - m_o)c^2$
.: $E_k = (5.1\times10^{-27} - 1.7\times10^{-27})\times(3.0\times10^{8})^2 \approx 3.1\times10^{-10}$ J A

Q5 $L = \frac{L_o}{\gamma} = \sqrt{1 - \frac{v^2}{c^2}}\times L_o$
Given $L = \frac{1}{2}L_o$, .: $\sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{2}$, $\frac{v}{c} = \frac{\sqrt{3}}{2}$, $v = \frac{\sqrt{3}}{2}c$ C

Q6 $E_{total} = mc^2 = m_o\gamma c^2 = 2.17\times10^{-10}$
$m_o\times10.0\times(3.0\times10^{8})^2 = 2.17\times10^{-10}$, $m_o \approx 2.41\times10^{-28}$ kg A

Q10 $t = \gamma t_o = (1 + [5\times10^{-11}])\times1$ B

Q11 The measured vertical distance is not affected by the horizontal motion of the satellite. C

Detailed study 2 – Materials and their use in structures

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

Q1 *Young's modulus for steel* P
$= gradient = \frac{40\times10^{6}}{1.0\times10^{-3}} = 4.0\times10^{10}$ Pa D

Q2 $F = \sigma A = (50\times10^{6})\times(4.0\times10^{-2}) = 2.0\times10^{6}$ N
$Mass = \frac{F}{g} = \frac{2.0\times10^{6}}{10} = 2.0\times10^{5}$ kg C

Q3 *Strain energy of steel* S
$= \frac{1}{2}\sigma\varepsilon = \frac{1}{2}\times(20\times10^{6})\times(1.5\times10^{-3}) = 1.5\times10^{4}$ J m^{-3} B

Q5 $\sigma = \frac{F}{A} = \frac{mg}{A} = \frac{1000\times10}{4.0\times10^{-2}} = 2.5\times10^{5}$ Pa
Young's modulus for steel P $= gradient = \frac{30\times10^{6}}{1.5\times10^{-3}} = 2.0\times10^{10}$ Pa
.: $\varepsilon = \frac{\sigma}{\text{mod}} = \frac{2.5\times10^{5}}{2.0\times10^{10}} = 1.25\times10^{-5}$
.: $\Delta\ell = \varepsilon\ell = 20\times(1.25\times10^{-5}) = 2.5\times10^{-4}$ m $= 0.25$ mm A

Q6 $\tau = Fd_{\perp} = 20 \times 10 \times 3.0 = 600$ N m **C**

Q7 In equilibrium:
net anticlockwise torque about P = net clockwise torque about P
$4.0T = 100 \times 1.5 + 200 \times 3.0$, $T \approx 190$ N **C**

Q8 Let F_{beam} be the force on the beam by the support.
In equilibrium:
net anticlockwise torque about K = net clockwise torque about K
$F_{beam} \times 2.0 = 40000 \times 3.0 + 10000 \times 6.0$, $F_{beam} = 90000$ N
.: *force on the support* $= 90000$ N **D**

Q11 Cables cannot be in compression. **B**

Detailed study 3 – Further electronics

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

Q1 $Period = 10$ ms $= 1 \times 10^{-2}$ s,

$frequency = \frac{1}{period} = \frac{1}{1 \times 10^{-2}} = 100$ Hz **C**

Q3 $V = 12 - 0.7 \times 2 = 10.6$ V **B**

Q4 63% of 20 V = 12.6 V, this corresponds to $t \approx 2.1$ s
$RC = \tau$, $(10 \times 10^3) \times C \approx 2.1$, $C \approx 210 \times 10^{-6}$ F $= 210$ μF **D**

Q5 When the capacitor is fully charged, $V = 20$ V.
Discharged by 63% of 20 V = 12.6 V, i.e. to 7.4 V in $t \approx 2.1$ s. **B**

Q6 $\tau = RC = 100 \times (100 \times 10^{-6}) = 0.01$ s $= 10$ ms
$V_{peak} = 10\sqrt{2} - 0.7 \approx 13.4$ V **D**

Q8 Resistor R_1: $V = 9 - 5 = 4$ V, $I = 100$ mA $= 0.010$ A
.: $R_1 = \frac{V}{I} = \frac{4}{0.10} = 40\Omega$ **A**

Q9 Since $\tau = RC$, increase R_1 or C or both will decrease the magnitude of the ripple voltage. **B**

Q11 The Zener diode fails to regulate the voltage at 5 V. **B**

Detailed study 4 – Synchrotron and its applications

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

Q1 $F = \frac{eV}{d} = \frac{(1.6 \times 10^{-19}) \times (90 \times 10^3)}{0.20} = 7.2 \times 10^{-14}$ N **A**

Q2 $E_k = eV = 90$ keV or $(1.6 \times 10^{-19}) \times (90 \times 10^3) = 1.44 \times 10^{-14}$ J or 1.44×10^{-17} kJ **B**

Q6 $d = \frac{n\lambda}{2\sin\theta} = \frac{1 \times (0.25 \times 10^{-9})}{2\sin 9.3°} \approx 7.7 \times 10^{-10}$ m **D**

Q7 $n\lambda < 2d\sin 90°$, $n < \frac{2d}{\lambda} = \frac{2 \times (0.3 \times 10^{-9})}{0.4 \times 10^{-9}} = 1.5$, .: $n = 1$ **B**

Q8 $\frac{hc}{\lambda_{before}} = \frac{hc}{\lambda_{after}} + E_k$, $\frac{1}{\lambda_{after}} = \frac{1}{\lambda_{before}} - \frac{E_k}{hc}$,

$\frac{1}{\lambda_{after}} = \frac{1}{6.9 \times 10^{-12}} - \frac{74 \times 10^3}{(4.14 \times 10^{-15})(3.0 \times 10^8)}$,

.: $\lambda_{after} \approx 12 \times 10^{-12}$ m **D**

Q11 $r = \frac{mV}{eB}$, $B = \frac{p}{er} = \frac{1.6 \times 10^{-18}}{(1.6 \times 10^{-19}) \times 40} = 0.25$ T **A**

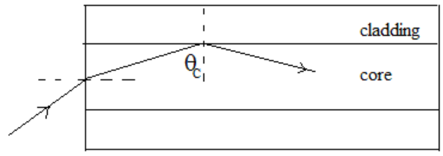
Detailed study 5 – Photonics

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

Q2 $\lambda = \frac{hc}{E} = \frac{(4.14 \times 10^{-15})(3.0 \times 10^8)}{2.1}$
$\approx 590 \times 10^{-9}$ m $= 590$ nm **D**

Q5 $\sin\theta_c = \frac{n_{cladding}}{n_{core}} = \frac{1.38}{1.45}$, $\theta_c = \sin^{-1}\left(\frac{1.38}{1.45}\right) \approx 72°$ **D**

Q6 A smaller cladding index (type X) will result in a smaller critical angle at the core-cladding interface, and .: a greater acceptance angle. **B**



Detailed study 6 – Sound

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

Q2 $\frac{\lambda}{2} = 0.67$, $\lambda = 1.34$ m **B**

Q3 *Fundamental frequency* $= \frac{v}{\lambda} = \frac{335}{1.34} = 250$ Hz
Second harmonic $f = 2 \times 250 = 500$ Hz **A**

Q5 $\frac{I_{2m}}{I_{20m}} = \frac{20^2}{2^2} = 100$ **C**

Q6 $I_{back} = 0.5\% \times I_{front}$, .: $\frac{I_{front}}{I_{back}} = 200$

$\Delta L = 10 \times \log_{10}\left(\frac{I_{front}}{I_{back}}\right) = 10 \times \log_{10} 200 \approx 23$ dB **D**

Q10 The 50 Hz sound at 80dB is on the 60 phon loudness curve. On the same curve the 10000 Hz sound is at 70 dB. **C**

Q11 $\frac{\lambda}{2} = 0.96$, $\lambda = 1.92$ m, $v = f\lambda = 500 \times 1.92 = 960$ m s^{-1} **C**

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