2013 - 2016 VCAA Physics Sample Exam Solutions

SECTION A

Area of study – Motion in one and two dimensions

Q1a Conservation of momentum: $(80+40)v = 80\times 4.0$,
$v = 2.7$ ms^{-1}.

Q1b The total kinetic energy after collision is different from that before collision. Hence the collision is inelastic.

Before: $E_k = \frac{1}{2}(80)(4.0^2) = 640$ J

After: $E_k = \frac{1}{2}(80+40)(2.7^2) \approx 430$ J

Q2 $F_{net} = \frac{mv^2}{r} = \frac{250\times 32.0^2}{100} = 2.56\times 10^3$ N

Q3a *Change in elastic potential energy = change in kinetic energy*
$\frac{1}{2}k(0.10^2) = \frac{1}{2}(0.20)(5.0^2)$, $k = 500$ Nm^{-1}

Q3b *Work done by friction = change in kinetic energy*
$F_{friction}\times 2.5 = \frac{1}{2}(0.20)(5.0^2)$, $F_{friction} = 1.0$ N

Q4a Constant velocity, zero acceleration, same as when Helen is at rest.
Apparent weight = *reaction force* = $mg = 60\times 10 = 600$ N.

Q4b Take upward as the positive direction.
$F_{net} = ma$, $\vec{R} + {}^{-}mg = ma$, $\vec{R} + {}^{-}600 = 60\times {}^{-}2.0$, $\vec{R} = {}^{+}480$ N
Apparent weight = 480 N

Q4c The gravitational force on Helen (her weight) remains the same but Helen experiences apparent weightlessness, i.e. she feels weightless because there is no reaction force on her while she is in free fall (falling under gravity only).

Q5a Take upward as the positive direction.
Vertical component: $a = {}^{-}10$, $u = {}^{+}60\sin 30° = {}^{+}30$, $v = 0$
$v^2 = u^2 + 2as$, .: $s = {}^{+}45$.
Hence the ball is 45 m above the top of the cliff.

Q5b Take upward as the positive direction.
Vertical component: $a = {}^{-}10$, $u = {}^{+}30$, $t = 9.0$.
$s = ut + \frac{1}{2}at^2$, .: $s = {}^{-}135$.
Hence the height of the cliff is $h = 135$ m.

Q6a *Resultant force* $= 22 - 0.50\times 10 = 17$ N

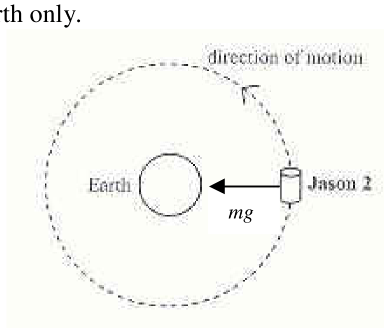
Q6b *Impulse of the gunpowder force* $= 22\times 1.5 = 33$ N s

Q6c *Acceleration* $= \frac{17}{0.50} = 34$ m s^{-2}

$a = {}^{+}34$, $u = 0$, $t = 1.5$, $s = ut + \frac{1}{2}at^2 = \frac{1}{2}\times {}^{+}34\times 1.5^2 \approx {}^{+}38$ m
.: *height above the ground* ≈ 38 m

Q7 At the point of leaving the rails (minimum speed) at A, $R = 0$, i.e. trolley is in free fall and $a = g$, $\therefore \frac{v^2}{7.0} = 10$,
$v \approx 8.4$ m s^{-1}.

Q8a Jason 2 in orbit is in free fall, i.e. it moves under the gravity of Earth only.



Q8b $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$, $T = \sqrt{\frac{4\pi^2 r^3}{GM}} \approx 1.53\times 10^4$ s.

Q8c $v = \frac{2\pi r}{T} \approx 5.54\times 10^3$ m s^{-1}

Area of study – Electronics and photonics

Q9a $V_2 = \frac{R_2}{R_1 + R_2}\times V = \frac{30}{70}\times 14 = 6.0$ V

Q9b $V_1 = 14 - 6.0 = 8.0$ V, $P_1 = \frac{V_1^2}{R_1} = \frac{8.0^2}{40} = 1.6$ W

Q9c Total resistance $R_T = \frac{1}{\frac{1}{40} + \frac{1}{20}} + 30 = \frac{130}{3}$ Ω,
$I = \frac{V}{R_T} = \frac{14}{\frac{130}{3}} \approx 0.32$ A $= 320$ mA

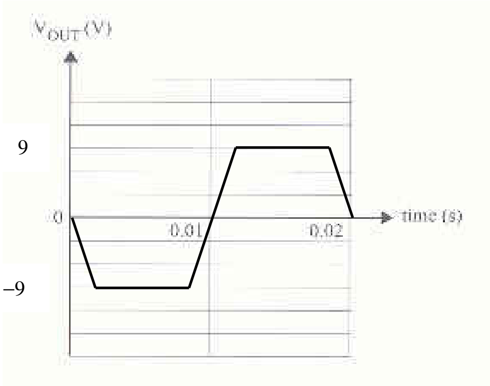
Q10a LED switch-on voltage = 3.0 V
1, 2 and 3 LEDs are in series
voltage across this series = $3.0\times 3 = 9.0$ V
$\therefore V_2 = 12 - 9.0 = 3.0$ V
$I_2 = \frac{V_2}{R_2} = \frac{3.0}{60} = 0.050$ A $= 50$ mA

Q10b LED 2 is reverse biased, it stops the current flowing through the series. LED 4, 5 and 6 are not affected.

LED 1	LED 2	LED 3	LED 4	LED 5	LED 6
OFF	OFF	OFF	ON	ON	ON

Q11a *Voltage gain* $= \dfrac{\Delta v_o}{\Delta v_i} = \dfrac{-9}{30\times10^{-3}} = -300$, minus sign means inverted output. The amplifier is inverting.

Q11b



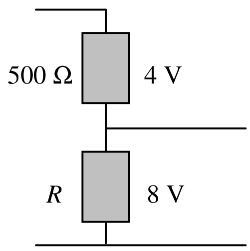
Q12

Location	P	Q	R	S
Waveform	B	A	C	B

Q13a From graph: $R_{therm} = 5000\,\Omega$ at 5°C

Q13b From graph: $R_{therm} = 500\,\Omega$ at 25°C

Voltage divider:



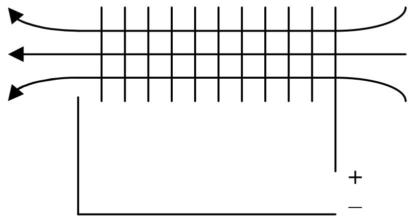
$\dfrac{R}{500} = \dfrac{8}{4}$, $R = 1000\,\Omega$.

Q13c From graph: $R_{therm} > 500\,\Omega$ at temperature < 25°C.

To keep the same ratio $\dfrac{8}{4}$, $R > 1000\,\Omega$. $\therefore$ the variable resistor should be increased.

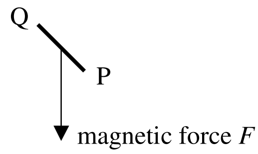
Area of study – Electric power

Q14a



Q14b The magnetic flux is zero because the magnetic field inside the solenoid is parallel to the plane of the rectangular loop.

Q14c



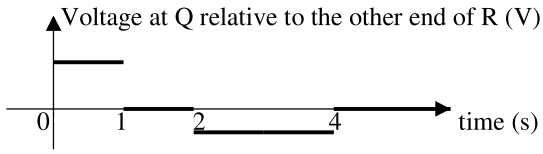
Q14d $F = nBIL = 3(5.0\times10^{-2})(4.0)(0.040) = 0.024\,\text{N}$

Q14e The force is zero because QR is parallel to the magnetic field inside the solenoid.

Q15a Graph A, $\xi_{av} = -\dfrac{\Delta\phi}{\Delta t}$, $\xi = -\dfrac{d\phi}{dt}$, induced emf equals negative of the rate of change of magnetic flux (gradient).

Q15b A split-ring commutator alternates the contact of the loop terminals with the two brushes. This happens every half turn of the loop if the ring is split in halves. It is used in DC generators. Slip rings maintain the contact of each loop end with the same brush. It is used in alternators (AC generators).

Q16a



Q16b Faraday's law for the relative magnitude of emf, and Lenz's law for the polarity of the voltage at Q relative to the other end of resistor R.

Q16c $|\xi_{av}| = n\left|\dfrac{\Delta\phi}{\Delta t}\right| = 120\times\dfrac{3.0\times10^{-4}}{0.012} = 3.0\,\text{V}$

Q16d Direction: Q $\rightarrow$ P
According to Lenz's law, induced current flows in the direction so that it generates a magnetic field to *oppose* the reduction in the magnetic field of an external source.

Q17a $f = \dfrac{1}{T} = \dfrac{1}{80\times10^{-3}} = 12.5$ Hz

Q17b $\dfrac{\text{RMS voltage output}}{\text{peak-to-peak voltage output}} = \dfrac{\frac{80}{\sqrt{2}}}{160} \approx 0.35$

Q18a There is a drop in voltage in the transmission lines. .: the voltage across the globe is less than 2.0 V and does not operate at its optimal power of 5.0 W, .: the globe does not glow as brightly as expected from a 5.0 W globe.

Q18b $I = \dfrac{P}{V} = \dfrac{5.0}{2.0} = 2.5\,\text{A}$

$V_{drop} = IR = 2.5 \times 5.0 = 12.5\ \text{V}$

$V_{setting} = 12.5 + 2.0 = 14.5\ \text{V}$

Q18c $P_{loss} = I^2 R = 2.5^2 \times 5.0 \approx 31\ \text{W}$

Q18d AC is often used so that transformers can be employed to step up the voltage for transmission and thus lower the current in the transmission cables. Hence power loss due to heating $P_{loss} = I^2 R$ is reduced. Then the voltage is stepped down to the correct values for household/commercial usage.

Q18e Answer D.

$V_{peak} = \sqrt{2} \times 21.25 = 30.052\ \text{V}$

$V_{peak-to-peak} = 2 \times 30.052 \approx 60.10\ \text{V}$

Q18f $\dfrac{n}{1460} = \dfrac{1}{10}$, $n = 146$

Q18g $I_{secondary} = \dfrac{P}{V} = \dfrac{5.0}{2.0} = 2.5\,\text{A}$

$I_{primary} = \dfrac{1}{10} \times 2.5 = 0.25\,\text{A}$

$P_{loss} = I^2 R = 0.25^2 \times 5.0 \approx 0.31\,\text{W}$

Area of study – Interactions of light and matter

Q19 Young's double-slit experiment produced an interference pattern of alternating bright and dark bands of light from two very close parallel slits, instead of just two bright patches of light as suggested by the particle model. Interference pattern is a wave phenomenon and can be easily demonstrated using water waves from two dippers generating coherent circular waves at the surface of water. .: Young's experiment supports the wave model.

Q20 *Observation 2*: Einstein used Planck's photon (particle) model to explain the photoelectric effect in his equation $KE_{\max} = hf - W$, where *f* is the frequency of the light and *W* the work function for the metal. Intensity of the incident light does not appear in the equation. Clearly the energy of emitted electrons depends on the frequency of the light and is independent of its intensity. Only light, with frequency higher than certain value depending on the metal (called the threshold frequency), can cause the emission of photoelectrons.

Q21a $E = \dfrac{hc}{\lambda} = \dfrac{(6.63\times10^{-34})(3.0\times10^{8})}{580\times10^{-9}} = 3.43\times10^{-19}\ \text{J}$

Q21b $S_2X - S_1X = 2\lambda = 1160\ \text{nm}$, .: $\lambda = 580\ \text{nm}$

$S_2Y - S_1Y = 2.5\lambda = 1450\ \text{nm} = 1.45\times10^{-6}\,\text{m}$

Q22a Graph D. Intensity has no effects on the energies of photoelectrons.

Q22b Graph A. Both graphs have the same gradient (same *h*), and the '*y*-intercept' for magnesium (-3.7 eV) is above that for selenium (-5.1 eV).

Q23a $\lambda = \dfrac{h}{mv} = \dfrac{6.63\times10^{-34}}{(9.1\times10^{-31})(1.5\times10^{7})} = 4.86\times10^{-11}\,\text{m}$

Q23b Option A. Higher speed $\rightarrow$ higher momentum $\rightarrow$ shorter wavelength $\rightarrow$ diffraction to a lesser extent, i.e. smaller ring radii.

Q23c X-rays are electromagnetic waves, and electrons have wave behaviours. .: diffraction can occur for both. If their wavelengths are equal, they will produce a pattern with similar spacing.

Q23d *Electron energy*

$= 500\ \text{eV} = 500 \times (1.6\times10^{-19}) = 8.0\times10^{-17}\ \text{J}$

Electron momentum $= p = \sqrt{2mE_k}$

$= \sqrt{2(9.1\times10^{-31})(8.0\times10^{-17})} = 1.207\times10^{-23}\ \text{kg ms}^{-1}$

Since the pattern are similar, .: same λ and .: same *p*.

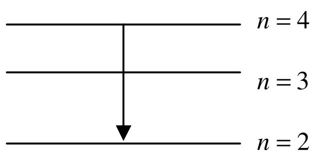
Photon energy $= E = pc = (1.207\times10^{-23})(3.0\times10^{8})$

$= 3.620\times10^{-15}\ \text{J} = \dfrac{3.620\times10^{-15}}{1.6\times10^{-19}} = 2.262\times10^{4}\ \text{eV}$

$\approx 23\ \text{keV}$

Q24 $E = \dfrac{hc}{\lambda} = \dfrac{(4.14\times10^{-15})(3.0\times10^{8})}{478\times10^{-9}} = 2.6\ \text{eV}$

$E_{n=4} - E_{n=2} = 12.8 - 10.2 = 2.6\ \text{eV}$



Detailed study 1 – Einstein's special relativity

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

Q1 *Time taken* = *distance/speed* $= \dfrac{1000}{3.0\times10^{8}} = 3.3\times10^{-6}\,\text{s}$. C

Q2 Length is contracted when it is measured from a moving frame. $L = L_o\sqrt{1-\dfrac{v^2}{c^2}} = 1.00\times\sqrt{1-0.9^2} = 0.44\,\text{km}$ A

Q3 Vicky and Susanna are at the same location when Susanna sends simultaneous flashes of light. .: Vicky also sees the flashes of light sent simultaneously by Susanna. C

Q4 B

Q5

$$Work\ done = \Delta E_k = E_{k,f} - E_{k,i} = E_{k,f} = m_o c^2\left(\frac{1}{\sqrt{1-\left(\frac{u}{c}\right)^2}} - 1\right)$$

$$.:\ 1.0754\times10^{-9} = 6.64424\times10^{-27}\times\left(3.0\times10^8\right)^2\left(\frac{1}{\sqrt{1-\left(\frac{u}{c}\right)^2}} - 1\right)$$

.: $u \approx 0.9339c$ B

Q6
$Distance = speed \times time$
$= 0.85\times\left(3.0\times10^8\right)\times\left(784\times10^{-6}\right) = 199920\text{ m} \approx 200\text{ km}$ B

Q7 The robot measures the proper time
$t_0 = \frac{t}{\gamma} = 784\times\sqrt{1-0.85^2} = 413$ microseconds. A

Q8 D

Q9 B

Q10 $E_{total} = mc^2$, $m = \frac{E_{total}}{c^2} = \frac{3.38\times10^{-11}}{\left(3.0\times10^8\right)^2} = 3.76\times10^{-28}$ kg

$Mass\ of\ a\ single\ muon = \frac{3.76\times10^{-28}}{2} = 1.88\times10^{-28}$ kg B

Q11 A

Detailed study 2 – Materials and their use in structures

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

Q1 Soft steel has greater strain beyond its elastic limit than hard steel has. D

Q2 D

Q3 The area under the graph is greater for soft steel than hard steel. A

Q4 $\Delta\ell = \varepsilon\ell = \left(1.000\times10^{-3}\right)(10.000) = 0.0100\text{ m}$
$Length\ under\ stress \approx 10.000 + 0.0100 \approx 10.010\text{ m}$ D

Q5 $Young's\ modulus = gradient\ of\ the\ linear\ section$
$\approx \frac{400\times10^6}{2.4\times10^{-3}} \approx 1.7\times10^{11}\text{ N m}^{-2}$ D

Q6 $F = \sigma A = \left(200\times10^6\right)\left(8.0\times10^{-5}\right) = 1.6\times10^4\text{ N}$ B

Q7 200 MPa is below the elastic limit, .: *strain energy per unit* $volume = \frac{1}{2}\sigma\varepsilon = \frac{1}{2}\left(200\times10^6\right)\left(1.25\times10^{-3}\right) \approx 1.3\times10^5\text{ J m}^{-3}$ B

Q8 $\tau = Fd = (100\times10)(1.20) = 1200\text{ N m}$ D

Q9 Equate clockwise and anti-clockwise torques:
$1200 + 200\times0.60 = T(0.80\sin30°)$, $T = 3300\text{ N}$ D

Q10 The lower half is in tension and requires placement of reinforcing steel rods. C

Q11 All the blocks are in compression. C

Detailed study 3 – Further electronics

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

Q1 $\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{240}{10.5} = \frac{2400}{105} = \frac{4800}{210}$ D

Q2 $V_{peak} = \sqrt{2}\times V_{RMS} = \sqrt{2}\times10.5 \approx 15\text{ V}$, i.e. 3 cm
$T = \frac{1}{f} = \frac{1}{50} = 0.02\text{ s} = 20\text{ ms}$, i.e. 4 cm A

Q3 $V_{av} \approx 10\text{ V}$, $I_{av} \approx \frac{V_{av}}{R_L} = \frac{10}{500} = 0.02\text{ A}$,
$P_{av} \approx V_{av}I_{av} = 0.2\text{ W}$ B

Q4 $V_{pp} = 13.6 - 5 \approx 8.6\text{ V}$ C

Q5 The Zener diode ensures 6 V maximum, and the input to the voltage regulator circuit dips to 5 V at times. Hence small ripples of 1 V approximately. A

Q6 Read the graph to find $\tau \approx 3$ s for 63% charging. $RC = \tau$,
$C = \frac{\tau}{R} = \frac{3}{1000} = 3\times10^{-3} = 3000\times10^{-6}\text{ F} = 3000\mu\text{ F}$ C

Q7 After 60 s, the capacitor is fully charged to 10 V approx. When the switch is moved to position Q, the capacitor starts to discharge, $I = \frac{V}{R} \approx \frac{10}{1000} = 0.01\text{ A} = 10\text{ mA}$ C

Q8 It is a full-wave rectifier circuit. C

Q9 A multimeter set on AC volts measures RMS voltage.
$V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = \frac{10}{\sqrt{2}} \approx 7\text{ V}$ A

Q10 $V_{Zener} = 6\text{ V}$, $\therefore V_2 = 10 - 6 = 4\text{ V}$ B

Q11 $I_2 = \frac{V_2}{R_2} = \frac{4}{100} = 0.04\text{ A}$. $I_1 = \frac{V_1}{R_1} = \frac{6}{3000} = 0.002\text{ A}$
$I_{Zener} = I_2 - I_1 = 0.038\text{ A} = 38\text{ mA}$ C

Detailed study 4 – Synchrotron and its applications

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

Q1 D

Q2 C

Q3 B

Q4 $eV = \frac{1}{2}mv^2$

$V = \frac{mv^2}{2e} = \frac{(9.1\times10^{-31})(4.6\times10^7)^2}{2(1.6\times10^{-19})} \approx 6017\ \text{V}$ C

Q5 $B = \frac{mv}{re} = \frac{(9.1\times10^{-31})(4.6\times10^7)}{0.40(1.6\times10^{-19})} \approx 6.5\times10^{-4}\,\text{T}$ B

Q6 $F = evB = (1.6\times10^{-19})(4.6\times10^7)(5.0\times10^{-4}) \approx 3.7\times10^{-15}\,\text{N}$ B

Q7 Same wavelength $\rightarrow$ same energy $\rightarrow$ elastic scattering A

Q8 $\lambda = \frac{2d\sin\theta}{n} = \frac{2(0.314\times10^{-9})\sin 15°}{1} \approx 0.163\times10^{-9}\ \text{m}$ A

Q9 $\frac{n\lambda}{2d} = \sin\theta$, $\theta < 90°$, $\sin\theta < 1$, .: $\frac{n\lambda}{2d} < 1$,

$\frac{n(0.200\times10^{-9})}{2(0.314\times10^{-9})} < 1$, $n < 3.14$ C

Q10 The vertical magnetic fields cause the electron beam to zigzag horizontally. B

Q11 D

Detailed study 5 – Photonics

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

Q1 C

Q2 $\lambda = \frac{hc}{Ve} = \frac{(6.63\times10^{-34})(3.0\times10^8)}{2.0(1.6\times10^{-19})} \approx 6.22\times10^{-7}\ \text{m} = 622\ \text{nm}$ C

Q3 $V_{diode} = 2.0\ \text{V}$, $V_R = 12 - 2.0 = 10\ \text{V}$,

$I_{ammeter} = I_R = \frac{V_R}{R} = \frac{10}{400} = 0.025\ \text{A} = 25\ \text{mA}$ B

Q4 $V_{diode} = \frac{hc}{e\lambda}$, blue light has shorter wavelength .: V_{diode} is higher .: V_R is lower and hence $I_{diode} = I_R$ is reduced. C

Q5 $i_c = \sin^{-1}\left(\frac{1.38}{1.44}\right) = 73.4°$ D

Q6 C

Q7 B

Q8 The refractive index of water (1.33) is higher than that of the plastic rod (1.20). Total internal reflection cannot now occur. C

Q9 D

Q10 Add up the attenuation due to Rayleigh scattering and absorption. At 1200 nm the sum is about 1.6 watt/km which is the least signal loss. C

Q11 B

Detailed study 6 – Sound

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

Q1 Sound waves in the air are longitudinal. B

Q2 $\lambda = \frac{v}{f} = \frac{330}{220} = 1.5\,\text{m}$ B

Q3 $L = 10\times\log_{10}\frac{I}{10^{-12}} = 10\times\log_{10}\frac{1.7\times10^{-3}}{10^{-12}} \approx 92.3\,\text{dB}$ C

Q4 $\frac{I_f}{I_i} = \frac{r_i^2}{r_f^2}$

$I_f = \frac{r_i^2}{r_f^2}\times I_i = \frac{20^2}{60^2}\times1.7\times10^{-3} \approx 1.9\times10^{-4}\,\text{W m}^{-2}$ B

Q5 The point, 10 000 Hz at 60 dB, is on the 40 phon curve. B

Q6 Sounds of different frequencies on the same phon curve will be perceived of equal loudness by human hearing. C

Q7 $f_1 = \frac{v}{4L}$, $L = \frac{v}{4f_1} = \frac{333}{4\times256} \approx 0.33\,\text{m}$ A

Q8 $f_3 = 3\times f_1 = 3\times256 = 768\,\text{Hz}$ C

Q9 It will sound louder. C

Q10 $L = \frac{\lambda}{2} = \frac{0.325}{2} \approx 0.163\,\text{m}$ A

Q11 High frequency sounds do not diffract much. A

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