2009 VCAA Physics Exam 1 Solutions

Area of study 1 – Motion in one and two dimensions

Q1 Conservation of momentum: $(80+40)v = 80\times 4.0$,
$v = 2.7$ ms^{-1}.

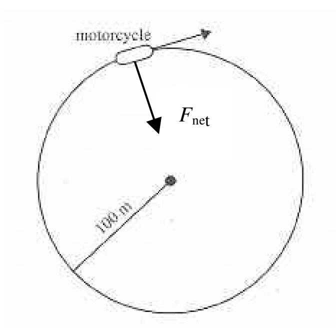
Q2 The total kinetic energy after collision is different from that before collision. Hence the collision is inelastic.

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.

Q3 $F_{net} = \frac{mv^2}{r} = \frac{250\times 32.0^2}{100} = 2560$ N.

Q4



Q5 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}.

Q6 Work done by friction = change in kinetic energy
$F\times 2.0 = \frac{1}{2}(0.20)(5.0^2) = 1.25$ N.

Q7 Constant velocity, zero acceleration, same as when Helen is at rest. Apparent weight = reaction force = $mg = 60\times 10 = 600$ N.

Q8 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.

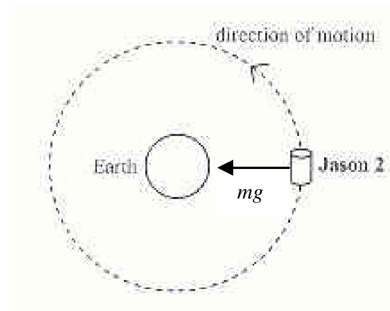
Q9 The gravitational force on Helen (her weight) remains the same but Helen experiences apparent weightlessness, i.e. she feels weightless because there is no reaction force on her while she is in free fall (falling under gravity only).

Q10 Take upward as the positive direction.
Vertical component: $a = {}^{-}10$, $u = {}^{+}60\sin 30° = {}^{+}30$, $v = 0$.
Apply $v^2 = u^2 + 2as$, $s = {}^{+}45$.
Hence 45 m above the top of the cliff.

Q11 Take upward as the positive direction.
Vertical component: $a = {}^{-}10$, $u = {}^{+}30$, $t = 9.0$.
Apply $s = ut + \frac{1}{2}at^2$, $s = {}^{-}135$.
Hence $h = 135$ m.

Q12 At the point of leaving the rails, $R = 0$,
i.e. in free fall and $a = g$, $\therefore \frac{v^2}{7.0} = 10$, $v \approx 8.4$ ms^{-1}.

Q13 Jason 2 in orbit is in free fall, i.e. it moves under gravity only.



Q14 $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$, $T = \sqrt{\frac{4\pi^2 r^3}{GM}} \approx 1.53\times 10^4$ s.

Area of study 2 – Electronics and photonics

Q1 $V_2 = \frac{R_2}{R_1+R_2}\times V = \frac{30}{70}\times 10 \approx 4.3$ V.

Q2 $I = \frac{V}{R} = \frac{10}{70}$, $P_1 = I^2R_1 = \left(\frac{10}{70}\right)^2\times 40 \approx 0.82$ W.

Q3 Total resistance $R_T = \frac{1}{\frac{1}{40}+\frac{1}{20}} + 30 \approx 43.3\ \Omega$,
$I = \frac{V}{R_T} = \frac{10}{43.3} \approx 0.23$ A.

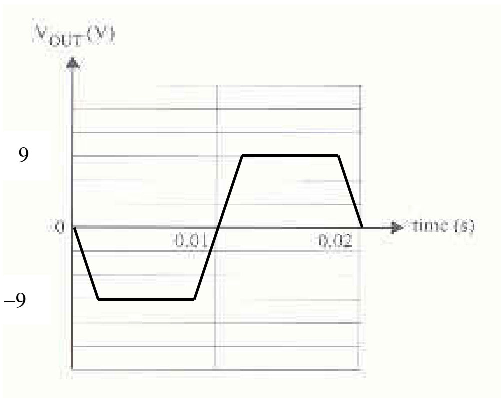
Q4 Each LED switch-on voltage = 3 V
1, 2 and 3 LEDs are in series,
voltage across this series = $3\times 3 = 9$ V.
$\therefore V_2 = 12 - 9 = 3$ V.
$I_2 = \frac{V_2}{R_2} = \frac{3}{60} = 0.05$ A.

Q5 LED 2 is reverse biased, it stops the current flowing through the series. 4, 5 and 6 LEDs are not affected.

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

Q6 Voltage gain $= \dfrac{\Delta v_o}{\Delta v_i} = \dfrac{-9}{30\times10^{-3}} = -300$, minus sign means inverted output.

Q7

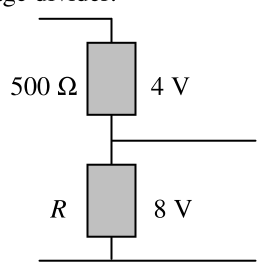


Q8

Location	Signal
P	B
Q	A
R	C
S	B

Q9 Read graph: $R_{therm} = 5000\,\Omega$ at 5°C.

Q10 Read graph: $R_{therm} = 500\,\Omega$ at 25°C.
Voltage divider:



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

Q11 Read graph: $R_{therm} > 500\,\Omega$ at temperature < 25°C.

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

Detailed study 1 – Einstein's special relativity

1	2	3	4	5	6	7	8	9	10	11	12	13
C	A	B	C	D	B	D	D	C	C	A	D	C

Q1 The speed of light is constant in space and does not depend on the motion of the observer. C

Q2 Relative to Joel, Benji moves to the left (in the picture) at the same high speed, thus Benji's ruler is contracted to 0.6 m. A

Q3 Proper length of Joel's ruler is the length measured by Joel, 1.0 m. B

Q4 Consider Joel's ruler observed by Benji.

$L = L_o\sqrt{1-\dfrac{v^2}{c^2}}$, $0.6 = 1.0\sqrt{1-\left(\dfrac{v}{c}\right)^2}$, $1-\left(\dfrac{v}{c}\right)^2 = 0.6^2$,

$\dfrac{v}{c} = 0.8$, $v = 0.8c$. C

Q5 The speed of light is constant in space and does not depend on the motion of the observer. D

Q6 Same speed whether parallel or perpendicular to the Earth's motion. Ratio = 1. B

Q7 $E = mc^2 = 1\times\left(3.0\times10^8\right)^2 \approx 10^{17}$ J. D

Q8 As speed approaches c, the body's relativistic mass approaches infinity. D

Q9 Time measured in muon's own frame of reference is its proper time t_o.

$t = \gamma t_o$, $4.8\times10^{-6} = 3.2t_o$, $t_o = 1.5\times10^{-6}$ s. C

Q10 Distance between two points measured in muon's frame of reference is contracted because that distance is moving at a speed of 0.95c relative to the muon.

$L = \dfrac{L_o}{\gamma} = \dfrac{1370}{3.2} \approx 428$ m. C

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

$E_k = m_o\gamma c^2 - m_oc^2 = (\gamma-1)m_oc^2$

$= (2.29-1)(1.67\times10^{-27})(3.0\times10^8)^2 = 1.9\times10^{-10}$ J. A

Q12 As speed approaches c, the body's relativistic mass approaches infinity. D

Q13 C

Detailed study 2 – Materials and their use in structures

1	2	3	4	5	6	7	8	9	10	11	12	13
D	D	A	D	D	B	B	D	A	D	C	C	C

Q1 Soft steel can withstand more deformation than hard steel before breaking. It is more ductile. D

Q2 D

Q3 Soft steel can withstand more deformation and absorb more energy than hard steel before breaking. It is tougher than hard steel. A

Q4 $\Delta L = \varepsilon L = (1.000\times10^{-3})(10.0000) = 0.01000\text{ m}$.
Final length $= L + \Delta L = 10.0100\text{ m}$. D

Q5 Young's modulus = gradient of linear section
$= \dfrac{400\times10^{6}}{2.4\times10^{-3}} \approx 1.7\times10^{11}\text{ Nm}^{-2}$. D

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

Q7 $E = \dfrac{1}{2}\sigma\varepsilon = \dfrac{1}{2}(200\times10^{6})(1.25\times10^{-3}) = 1.25\times10^{5}\text{ Jm}^{-3}$. B

Q8 $\tau = Fr = (100\times10)(1.20) = 1200\text{ Nm}$. D

Q9 The beam is in equilibrium, $\tau = 0$ Nm. A

Q10 $\tau = 0$, $T(0.80\sin 30°) - 1200 - 20\times10\times0.60 = 0$,
$\therefore T = 3300\text{ N}$. D

Q11 Concrete is weak in tension. The underside of the concrete walkway is in tension and requires reinforcement. C

Q12 Consider torques about pillar A. The beam is in equilibrium, $\tau = 0$,
$F_B \times 12.0 - 600\times10\times(12.0-3.0) - 1200\times10\times6.0 = 0$,
$F_B = 10500\text{ N}$. C

Q13 C

Detailed study 3 – Further electronics

1	2	3	4	5	6	7	8	9	10	11	12	13
D	A	B	C	A	C	C	C	B	C	A	B	C

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

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

Q3 $V_{av} \approx 10\text{ V}$, $I_{av} \approx \dfrac{V_{av}}{R_L} = \dfrac{10}{500} = 0.02\text{ A}$,
$P_{av} \approx V_{av} I_{av} = 0.2\text{ W}$. 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 Higher capacitance ensures input to the voltage regulator circuit to be higher than 6 V and thus reduces the ripple voltage. C

Q7 Read graph to find $\tau \approx 3$ s for 63% charging. $RC = \tau$,
$C = \dfrac{\tau}{R} = \dfrac{3}{1000} = 3\times10^{-3} = 3000\times10^{-6}\text{ F} = 3000\mu\text{ F}$. C

Q8 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, $I = \dfrac{V}{R} = \dfrac{10}{1000} = 0.01\text{ A} = 10\text{ mA}$. C

Q9 The capacitor discharges by 63% after 3 s, i.e. by 6.3 V. Voltage across capacitor = 3.7 V. B

Q10 It is a full-wave rectifier circuit. C

Q11 A multimeter set on AC volts measures RMS voltage.
$V_{RMS} = \dfrac{V_{peak}}{\sqrt{2}} = \dfrac{10}{\sqrt{2}} \approx 7\text{ V}$. A

Q12 $V_{Zener} = 6\text{ V}$, $\therefore V_2 = 10 - 6 = 4\text{ V}$. B

Q13 $I_2 = \dfrac{V_2}{R_2} = \dfrac{4}{100} = 0.04\text{ A}$. $I_1 = \dfrac{V_1}{R_1} = \dfrac{6}{3000} = 0.002\text{ A}$.
$I_{Zener} = I_2 - I_1 = 0.038\text{ A} = 38\text{ mA}$. C

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