2012 VCAA Physics Exam 1 Solutions

Area of study 1 – Motion in one and two dimensions

Q1a $E_k = \frac{1}{2}mv^2$, $5.4 = \frac{1}{2}(1.2)v^2$, $v = 3.0$ m s^{-1}

Q1b $Work\ done = \Delta E_k = 5.4 - 0 = 5.4$ J

Q1c $Elastic\ potential\ energy = \Delta E_k$, $\frac{1}{2}kx^2 = 5.4$,

$\frac{1}{2}k(0.080)^2 = 5.4$, $k = 1687.5 \approx 1.7\times10^3$ N m^{-1}

Q1d $|Impulse| = |\Delta p| = 1.2\times3.0 - 0 = 3.6$ N s

Q2 Momentum is a vector quantity.
Before the collision, the 2.4 kg mass was at rest , .: the total momentum was the momentum of the 1.2 kg mass.

$\vec{p}_{total,before} = \vec{p}_{1.2,before}$, .: $\vec{p}_{total,before} = {}^{+}p_{1.2,before}$

After the collision, the total momentum was the vector addition of the momentum of the 1.2 kg mass and the momentum of the 2.4 kg mass, $\vec{p}_{total,after} = \vec{p}_{1.2,after} + \vec{p}_{2.4,after} = {}^{-}p_{1.2,after} + {}^{+}p_{2.4,after}$

According to the principle of conservation of momentum,

$\vec{p}_{total,after} = \vec{p}_{total,before}$, .: ${}^{-}p_{1.2,after} + {}^{+}p_{2.4,after} = {}^{+}p_{1.2,before}$

.: ${}^{+}p_{2.4,after} = {}^{+}p_{1.2,before} - {}^{-}p_{1.2,after}$

.: $p_{2.4,after} = p_{1.2,before} + p_{1.2,after}$, .: $p_{2.4,after} > p_{1.2,before}$

Q3 B The force vectors in B only could add to zero, i.e. the net force in B could be zero and hold the metal ring stationary.

Q4a Cable A supports both spheres.
.: $tension\ in\ Cable\ A = (2.0 + 1.0)g = 30$ N
.: Cable A applies a force of 30 N upwards to the 2.0 kg sphere.

Q4b Action force: Gravitational force by Earth on the 2.0 kg sphere downwards.
Reaction force: Gravitational force by the 2.0 kg sphere on Earth upwards.

Q5a Rope 1 is pulling the two logs at constant speed.
.: $F_{net} = 0$, $T_1 - 400 - 400 = 0$, $T_1 = 800$ N

Q5b The last log accelerates with the truck at 0.50 m s^{-2}. It is pulled by rope 2.
$F_{net} = ma$, $T_2 - 400 = 600\times0.50$, $T_2 = 700$ N

Q5c Constant acceleration $a = 0.50$ m s^{-2}, $u = 4.0$ m s^{-1},
$s = 20$ m, $v^2 = u^2 + 2as$, $v = 6.0$, .: $speed = 6.0$ m s^{-1}

Q5d Rope 1 is about to break.
Just before the breaking point: $F_{net} = ma$,

$2400 - 400 - 400 = (600 + 600)a$, $a = \frac{4}{3} \approx 1.3$ m s^{-2}

Q6a Let V m s^{-1} be the speed at which the ball leaves Fred's hand. Consider the vertical component of the upward motion.
$u = V\sin60°$, $s = 15$, $v = 0$, $a = {}^{-}10$
$v^2 = u^2 + 2as$, $0 = (V\sin60°)^2 - 300$, $V = 20$, $speed = 20$ m s^{-1}

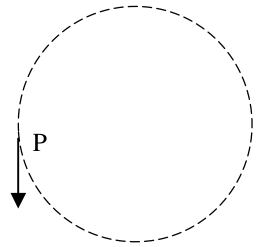
Q6b Time to reach the maximum height:
$s = 15$, $v = 0$, $a = {}^{-}10$, $s = vt - \frac{1}{2}at^2$, $t = \sqrt{3}$

.: $time\ of\ flight = 2\sqrt{3} \approx 3.5$ s

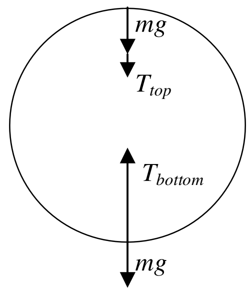
Q7a Horizontal circular motion, just before the breaking point: (Assuming the increase in speed is done over a 'long' period of time)

$F_{net} = \frac{mv^2}{r}$, $4.0 = \frac{0.20v^2}{1.8}$, $v = 6.0$ m s^{-1}

Q7b



Q7c Vertical circle at constant speed:
It is a uniform circular motion, the magnitude of the acceleration, and hence the net force, is constant.



|net force on the ball at the top| = |net force on the ball at the bottom|

.: $T_{bottom} - mg = T_{top} + mg$, $T_{bottom} = T_{top} + 2mg$, .: $T_{bottom} > T_{top}$

Q8a $Period\ of\ Apollo\ 11 = 2.0\times60\times60 = 7200$ s

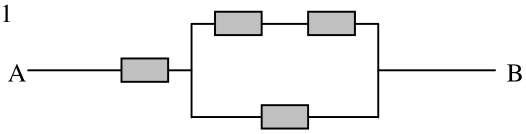
$a = g$, $\frac{4\pi^2 r}{T^2} = \frac{GM}{r^2}$, $r = \left(\frac{GMT^2}{4\pi^2}\right)^{\frac{1}{3}} = 1.86\times10^6$ m

$height = 1.86\times10^6 - 1.74\times10^6 = 1.2\times10^5$ m

Q8b Weightlessness means the force of gravity on an object is zero. In the case of apparent weightlessness, force of gravity still acts on the object, but the object seems weightless only because it is in a free fall.
The term *apparent weightlessness* applies to the astronauts in *Apollo 11* during its orbit of the moon because they are in free fall with the spacecraft. .: no reaction forces from the spacecraft on the astronauts, .: they experience weightlessness, i.e. they have zero apparent weight.

Area of study 2 – Electronics and photonics

Q1



Total resistance $= 150 + \dfrac{1}{\frac{1}{150+150} + \frac{1}{150}} = 250\ \Omega$

Q2a D1 is in conductive mode, .: $V_{D1} = 2$, $V_{R1} = 12 - 2 = 10$,

$I_{R1} = \dfrac{V_{R1}}{R_1} = \dfrac{10}{100} = 0.10\text{ A} = 100\text{ mA}$, .: $I_{ammeter} = 100\text{ mA}$

Q2b D2 is in conductive mode, .: $V_{D2} = 3$, $V_{R2} = 8 - 3 = 5\text{ V}$

Q2c D1 is in conductive mode, .: $V_{D1} = 2$, $V_{R1} = 8 - 2 = 6$,

$I_{R1} = \dfrac{V_{R1}}{R_1} = \dfrac{6}{100} = 0.060\text{ A} = 60\text{ mA}$

$I_{R2} = \dfrac{V_{R2}}{R_2} = \dfrac{5}{150} = 0.033\text{ A} = 33\text{ mA}$

.: $I_{ammeter} = I_{R1} + I_{R2} = 93\text{ mA}$

Q2d $\textit{Electric power of D1} = V_{D1}I_{D1} = V_{D1}I_{R1} = 200\ \text{mW}$

$\textit{Light power of D1} = 150\ \text{mW}$

$\textit{Fraction} = \dfrac{150}{200} = \dfrac{3}{4}$, i.e. 75%

$\textit{Electric power of D2} = V_{D2}I_{D2} = V_{D2}I_{R2} = 300\ \text{mW}$

$\textit{Light power of D2} = 200\ \text{mW}$

$\textit{Fraction} = \dfrac{200}{300} = \dfrac{2}{3}$, i.e. 67%

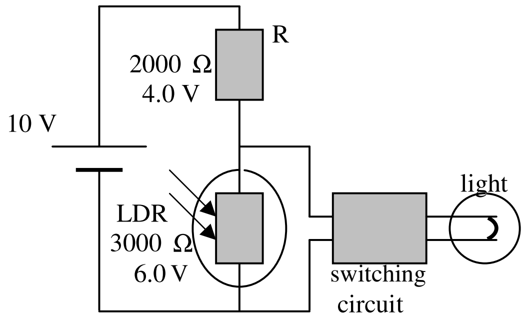
.: D1 coverts the largest fraction of its electrical input energy into output light energy in the same time interval.

Q3a $I_R = 2.5\ \text{mA}$, $V_R = I_R R = 7.5\text{ V}$, .: $V_{LDR} = 10 - 7.5 = 2.5\text{ V}$

Voltage divider: $\dfrac{R_{LDR}}{R} = \dfrac{V_{LDR}}{V_R}$, .: $R_{LDR} = 1000\ \Omega$

$\textit{Intensity of light} = 10$ lux (read from graph)

Q3b 2.5 lux $\rightarrow R_{LDR} = 3000\ \Omega$, $V_{LDR} = 6.0\text{ V}$



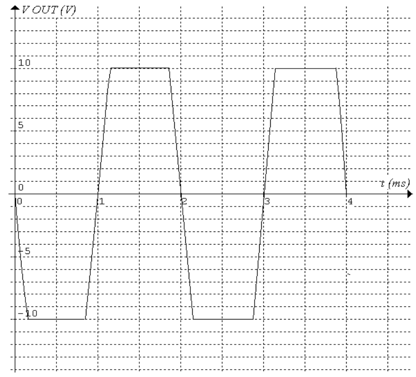
When the light intensity falls below 2.5 lux, $R_{LDR} > 3000\ \Omega$

.: $V_{LDR} > 6.0\text{ V}$ and triggers the switching circuit to turn on the light.

*Note: Inconsistent information - input is **greater than 6.0 V**, and light intensity is **2.5 lux or less**.*

Q4a $|\textit{voltage gain}| = \dfrac{10}{40\times10^{-3}} = 250$

Q4b



Q5 Modulation device: Converts the electrical signal to light signal in the form of light intensity variation.
Light beam: Serves as the carrier of signal by varying its intensity.
Demodulation device: Converts the light intensity variation to electrical signal.

Detailed study 1 – Einstein's special relativity

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

Q1 For example, light travels at a lower speed in water. A

Q2 The speed of *sound* is higher when one approaching the source than when one departing from the source. D

Q3 $\textit{Time taken} = \dfrac{2.5\times10^{25}}{3.0\times10^{8}} = 8.33\times10^{16}\text{ s} \approx 2.6\times10^{9}$ years C

Q4 An inertial reference frame is a non-accelerating frame. B

Q5 C

Q6 *Total energy*

$= E_k + m_o c^2 = 9.00\times10^{-11} + 1.67\times10^{-27}\times\left(3.0\times10^{8}\right)^2$

$= 2.40\times10^{-10}\text{ J}$ D

Q7

$$\frac{\gamma_{highspeed}}{\gamma_{lowspeed}} = \frac{\sqrt{1-\frac{v_{lowspeed}^2}{c^2}}}{\sqrt{1-\frac{v_{highspeed}^2}{c^2}}} = \sqrt{\frac{c^2 - v_{lowspeed}^2}{c^2 - v_{highspeed}^2}} = \sqrt{\frac{3.0^2 - 1.4^2}{3.0^2 - 2.8^2}}$$

≈ 2.5 C

Q8 A

Q9 Length is contracted in the direction parallel to the motion of the observer. D

Q10 *Time taken* $= \dfrac{10}{0.866\times3.0\times10^{8}} \approx 3.85\times10^{-8}$ s C

Q11 A

Q12 *Work done = change in energy*

$= m_{final}c^2 - m_{initial}c^2 = m_o\gamma_{final}c^2 - m_o\gamma_{initial}c^2$

$= m_o(\gamma_{final} - \gamma_{initial})c^2 = 6.64\times10^{-27}(1.15-1.05)(3.0\times10^{8})^2$

$\approx 6\times10^{-11}$ J B

Detailed study 2 – Materials and their use in structures

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

Q1 Vertical component: $3\times100\cos45° = 212$ N B

Q2 The stiffest is Alloy A.
Young's modulus = gradient of the linear section
$= \dfrac{300}{4\times10^{-3}} = 75\times10^{3}$ MPa $= 7.5\times10^{10}$ Pa A

Q3 $F = \sigma A = (250\times10^{6})(2.0\times10^{-3}) = 5.0\times10^{5}$ N C

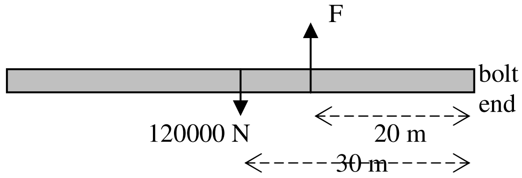
Q4 Alloy D shows elastic behaviour over the greatest range of **strain** values (0 to 7×10^{-3}) D

Q5 Alloy A shows plastic behaviour over the greatest range of **stress** values (300 to 390 MPa) A

Q6 The toughest material is the one which absorbs the most energy per cubic metre before breaking (area under $\sigma-\varepsilon$ graph up to the breaking point). A

Q7 *The area under the graph of Alloy C*
$\approx 100\times10^{6}\times22\times10^{-3} = 2.2\times10^{6}$ J m^{-3}
Total strain energy = area under the graph of Alloy C × *volume of material*
$= (2.2\times10^{6})(0.20\times2.0\times10^{-3}) \approx 900$ J C

Q8



Net torque about the bolt end $= 0$
$F\times20 - 120000\times30 = 0$, $F = 180000$ N D

Q9 *Net force* $= 0$
$^{+}180000 + ^{-}120000 + \vec{F}_{anchor} = 0$, $|\vec{F}_{anchor}| = 60000$ N B

Q10 B

Q11 C

Q12 C

Detailed study 3 – Further electronics

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

Q1 $f = \dfrac{1}{T} = \dfrac{1}{25\times10^{-3}} = 40$ Hz B

Q2 $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_P}$, $\dfrac{V_s}{240} = \dfrac{50}{1200}$, $V_s = 10$ V_{RMS} A

Q3 C

Q4 *Power to be dissipated* $= VI = (0.7)(140\times10^{-3}) = 0.098$ W
$100\times area = 0.098$, $area \approx 0.001\,m^2$ A

Q5 $V = 15.2 - 0.7 - 0.7 = 13.8$ V C

Q6 When the capacitor is fully charged, $V = 10$ V
63% of 10 V = 6.3 V, this corresponds to $t = 20\times10^{-3}$ s
$RC = \tau$, $100C = 20\times10^{-3}$, $C = 200\times10^{-6}$ F $= 200\mu$ F C

Q7 When the capacitor is fully charged, $V = 10$ V
63% of 10 V = 6.3 V, this corresponds to $t = 10\times10^{-3}$ s
$R_{total}C = \tau$, $R_{total}(200\times10^{-6}) = 10\times10^{-3}$, $R_{total} = 50$
$\dfrac{1}{R_{total}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$, $\dfrac{1}{50} = \dfrac{1}{R} + \dfrac{1}{100}$, $R = 100\ \Omega$ B

Q8 *Discharge time constant* $= RC = (100)(100\times10^{-6}) = 0.01$ s
C

Q9 C

Q10 D

Q11 Half of a cycle is missing in the voltage display. This occurs when one diode in the full-wave bridge rectifier fails. A

Q12 When the 1000 Ω is replaced with a 100 Ω, a larger current flows through resistor A. This results in a larger voltage drop across resistor A. D

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