VCAA Physics Unit 3 Exam 2005 Solutions

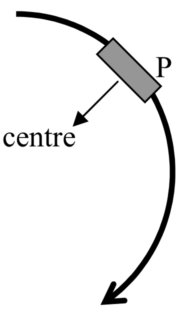
Area of Study 1 – Motion in 1 and 2 dimensions

Q1 Stored energy = area under graph from 0 to 0.20
$= \frac{1}{2} \times 1000 \times 0.2 = 100$ J

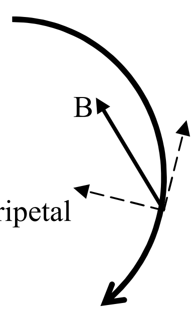
Q2 Kinetic energy = stored energy
$\frac{1}{2} \times 0.20 v^2 = 100$, $v = 32$ ms^{-1}.

Q3 Gravitational potential energy = stored energy
$0.20 \times 10 \times h = 100$, $h = 50$ m.

Q4 $t = 5, R = 1.8$ N. Take upward as +ve direction.
$a = \frac{F_{net}}{m} = \frac{^{-}mg + ^{+}R}{m} = \frac{^{-}0.20 \times 10 + ^{+}1.8}{0.20} = ^{-}1.0$
i.e. 1.0 ms^{-2} downward.

Q5


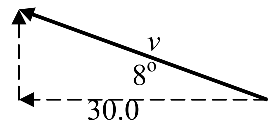
Q6 $F_a = F_b$, $\therefore \frac{mv_a^2}{r_a} = \frac{mv_b^2}{r_b}$, $\therefore \frac{v_a^2}{r_a} = \frac{v_b^2}{r_b}$,
$\frac{60^2}{200} = \frac{120^2}{r}$, $r = 800$ m.

Q7


Q8 Total momentum before = total momentum after
$3.0v + 1.0(0) = (3.0 + 1.0)(7.0)$, $v = 9.3$ ms^{-1}.

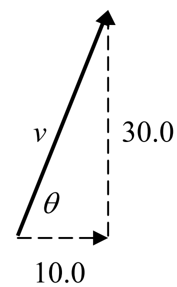
Q9 Chris is wrong because 'conservation of momentum' is a universal law that applies to all isolated system of particles in collision. The system is considered isolated as long as momenta are calculated immediately before and immediately after the collision.

Q10 Immediately before collision, total kinetic energy
$= \frac{1}{2} \times 3000 \times 9.3^2 = 1.3 \times 10^5$ J
Immediately after collision, total kinetic energy
$= \frac{1}{2} \times 4000 \times 7.0^2 = 9.8 \times 10^4$ J
$E_K(after) < E_K(before)$, $\therefore$ inelastic collision.

Q11


$v \cos 8^o = 30.0$, $v = 30.3$ ms^{-1}

Q12 Consider the vertical component:
$u = ^{+}30.0 \tan 8^o$, $a = ^{-}10$, $v = 0$, use $v^2 = u^2 + 2as$,
$s = \frac{v^2 - u^2}{2a} = ^{+}0.889$ m. $\therefore 3.0 + 0.889 = 3.9$ m above the deck.

Q13 a and b


$v = \sqrt{10.0^2 + 30.0^2} = 31.6$ ms^{-1}
$\theta = \tan^{-1}\left(\frac{30.0}{10.0}\right) = 71.6^o$

Q14 g is not a force, $\therefore$B

Q15 $F = gm = 10 \times 3.0 \times 10^{-26} = 3.0 \times 10^{-25}$ N

Q16 $G\frac{M}{r^2} = \frac{4\pi^2 r}{T^2}$,
$M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2 (3.8 \times 10^8)^3}{6.67 \times 10^{-11} (2.36 \times 10^6)^2}$
$= 5.8 \times 10^{24}$ kg

Area of Study 2 − Electronics and photonics

Q1 $V = IR = 40 \times 10^{-3} \times 100 = 4.0$ volts

Q2 Conventional current flows from high to low potential in a circuit external to the voltage source. A

Q3 $\Delta E = I^2 R \Delta t = (40 \times 10^{-3})^2 \times 100 \times 1 = 0.16$ J

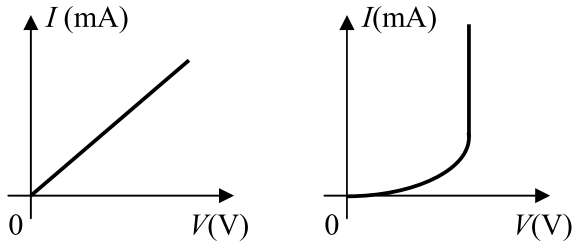
Q4 Resistance of A and B in parallel $= \frac{1}{\frac{1}{100} + \frac{1}{100}} = 50$.
Resistance of C in series with D and E in parallel = 100 + 50 = 150.
$V_{OUT} = \frac{150}{50 + 150} \times 20 = 15$ volts.

Q5 The circuit is symmetrical about resistor C. $\therefore$D

Q6 $I_C = 20\times10^{-3}$ A, voltage drop across R_C
$= I_C R_C = 20\times10^{-3}\times500 = 10$ volts.
$\therefore$ potential difference between C and Earth
= 30 − 10 = 20volts.
Q7 $I_C = 200\times I_B$, $\Delta I_C = 200\times\Delta I_B = 200\times5\ \mu$A
$= 1.0$ mA (increase)
$\therefore \Delta V_C = \Delta I_C \times R_C = 1.0\times10^{-3}\times500 = 0.5$ volts
(decrease)
$\therefore \Delta V_{OUT} = -0.5$ volts.

Voltage gain $= \dfrac{\Delta V_{OUT}}{\Delta V_{IN}} = \dfrac{-0.5}{+10\times10^{-3}} = -50$

(− means inverted output)
Q8i LED changes electrical signals to light signals.
ii Photodiode changes light signals to electrical signals.
Q9 $V_{OUT} = IR = 5\times10^{-6}\times100 = 5\times10^{-4}$ volts.
Q10



Detailed study 1 − Einstein's special relativity

Q1

The mass of an electron measured at rest	S
The time interval between two given events	D
The distance between two given events	D

Q2 Hilary's answer is consistent with Einstein's second postulate that light propagates through empty space with a definite speed $c = 3\times10^8$ ms^{-1} independent of the speed of the source or observer.
Q3 Only the dimension parallel to the direction of motion of the rocket ship is affected. Since
$L = L_o\sqrt{1-\frac{v^2}{c^2}}$, $\therefore L < L_o$. $\therefore$B
Q4 The null observation of the Michelson-Morley experiment indirectly led Einstein to reject (1) the existence of a transparent medium called ether taken as an absolute frame of reference; and (2) the presumption that the velocity of light given by Maxwell's equations must be with respect to this ether. In 1905 Einstein introduced the special theory of relativity.
Q5 $\Delta t = \gamma\Delta t_o$, $\Delta t = 20\times\Delta t_o$,

$\therefore \Delta t_o = \dfrac{6.10\times10^{-12}}{20} = 3.05\times10^{-13}$ s

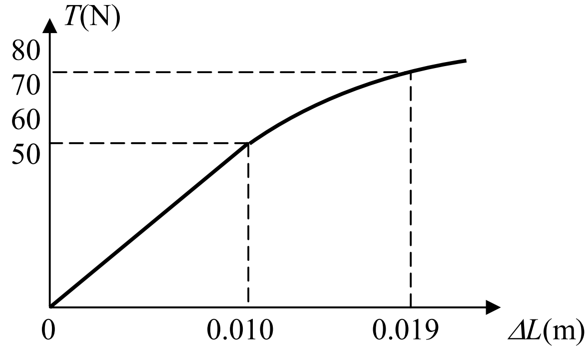
Q6 $d = v\Delta t = 0.998749c\times6.10\times10^{-12} = 0.00183$ m
Q7 As measured in the reference frame of the tau meson, $d = 0$ because creation and decay of the tau meson occur at the same point in space.
Q8
$E = m_o c^2 = 9.1\times10^{-31}\times(3.0\times10^8)^2 = 8.20\times10^{-14}$ J

Q9 $m = \gamma m_o$, $\gamma = \dfrac{m}{m_o} = 22$.

Q10 KE$= (m - m_0)c^2 = (22m_o - m_o)c^2 = 21m_o c^2$
$= 21\times8.20\times10^{-14} = 1.72\times10^{-12}$ J. B

Detailed study 2 – Investigating materials and their use in structures

Q1



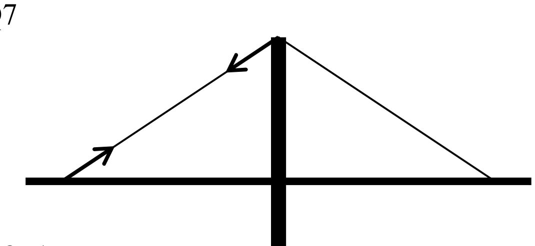
Q2 Elastic potential energy
$= \frac{1}{2}T\Delta L = \frac{1}{2}\times40\times0.008 = 0.16$ J B

Q3 $\sigma = \dfrac{T}{A} = \dfrac{40}{2.0\times10^{-8}} = 2.0\times10^9$ Nm^{-2}

Q4 Young's mod$= \dfrac{\sigma}{\varepsilon} = \dfrac{2.0\times10^9}{\frac{0.008}{0.500}} = 1.3\times10^{11}$ Nm^{-2}

Q5 Elastic limit
$\approx 1.3\times10^{11}\times\dfrac{0.010}{0.500} = 2.5\times10^9$ Nm^{-2} B

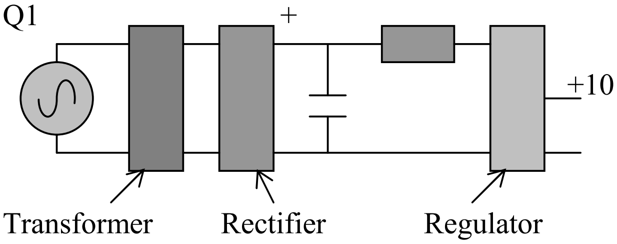
Q6 Ductile because the material shows plastic behaviour before it fractures.
Q7



Q8 A
Q9 Concrete is strong in compression and $\therefore$ a suitable material for the deck because the upper region of the deck is always under compressive stress. Steel is strong in tension and used to reinforce the lower region of the deck that is always under tensile stress.
Q10 $\tau = Fd = 2000\times0.50 = 1.0\times10^3$ Nm
Q11 $\sum\tau = 0$, ${}^{+}1.0\times10^3 + {}^{-}1000\times x = 0$, $x = 1.0$ m
Q12 x is independent of the height of the pedestal. B

Detailed study 3 – Further electronics

Q1



Q2 $V_{pp} = 2\sqrt{2}V_{RMS} = 2\sqrt{2} \times 240 = 678.8$ volts. A

Q3 $\frac{N_{OUT}}{N_{IN}} = \frac{V_{OUT}}{V_{IN}} = \frac{10.6}{240} = 0.0442$

Q4 C

Q5 Time constant > 50×10^{-3} s, $RC > 50 \times 10^{-3}$,
$1.0 \times 10^{3} C > 50 \times 10^{-3}$, $C > 50 \times 10^{-6}$ F, i.e. 50μF
D

Q6 The reverse biased Zener diode ensures the output voltage remains constant (10volts) when the load current varies. As the load current increases, the diode current decreases, so the voltage drop across *R* always is the difference between the Zener voltage and the supply voltage.

Q7 The input to the regulated DC power supply is AC at 50Hz. A multimeter is too slow to respond to the rapidly changing voltages at the input and output of the transformer. Hence an oscilloscope is a more suitable tool to display the AC voltages. It can also be used to measure the ripple at the output of the rectifier when the capacitor and the Zener diode are disconnected. The output of the regulated DC power supply is constant and hence can be measured with a multimeter.

Q8 The 5% decrease in the AC input voltage does not alter the working of the power supply. It causes a small decrease in the input voltage across the voltage regulator but still high enough to ensure the conduction of current in the reverse biased Zener diode. Hence the output voltage across the load resistor is virtually unchanged (10volts). A

Q9i Voltage remains the same (10volts).

ii Current decreases from $\frac{10}{1000} = 0.010$ A to

$\frac{10}{2000} = 0.005$ A.

Q10 Heat creates more thermal electrons in the semiconductors and thus affects the proper functions of the diodes. It is desirable to remove the generated heat with a heat sink.

Q11 Increases.

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