2007 VCAA Physics Exam 1 Solutions

Area of study 1 – Motion in one and two dimensions

Q1 Vertical component: $u = 0$, $a = -10$, $t = 0.45$,
$s = ut + \frac{1}{2}at^2 = 0 - \frac{1}{2}(-10)(0.45^2) = -1.01$ m
About 1.0 m above the ground.

Q2

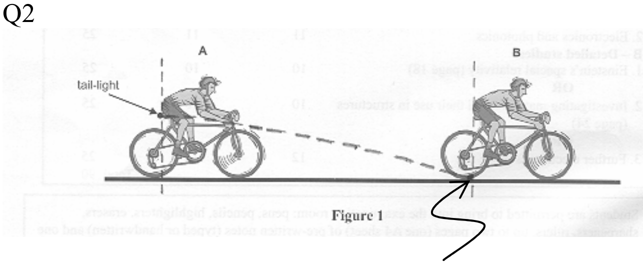


Figure 1

Q3 Total momentum after = total momentum before
$2\vec{v} + 1 \times {}^{+}4 = 2 \times {}^{+}3 + 0$, $\vec{v} = {}^{+}1\ \text{ms}^{-1}$

Q4 Total kinetic energy after = $\frac{1}{2}(2)(1^2) + \frac{1}{2}(1)(4^2) = 9$ J
Total kinetic energy before = $\frac{1}{2}(2)(3^2) + 0 = 9$ J.
Total kinetic energy after = total kinetic energy before.
$\therefore$ elastic collision.

Q5 Impulse = change in momentum
$F_{av}\Delta t = mv - mu$, $\therefore F_{av}(0.01) = 1(4) - 1(0)$, $\therefore F_{av} = 400$ N

Q6 When the terminal velocity is reached, acceleration is zero and $\therefore$ net force is zero.

Q7 When she has fallen 100 m,
net force = weight + air resistance $= {}^{+}600 + {}^{-}400 = {}^{+}200$ N
$a = \frac{F_{net}}{m} = \frac{{}^{+}200}{60} = {}^{+}3.3\ \text{ms}^{-2}$, i.e. 3.3 ms^{-2} downward.

Q8 Work done by air resistance = area under graph (0 to 500 m)
$\approx 500 \times 500 = 250000 = 2.5 \times 10^5$ J

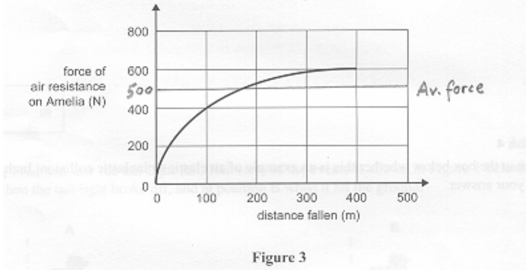


Figure 3

Q9 Stiffness $k = 20\ \text{Nm}^{-1}$, extension $x = 0.60 - 0.40 = 0.20$ m, force $F = mg = m(10)$ N.
Hooke's law $F = kx$, $10m = 20(0.20)$, $m = 0.40$ kg.

Q10 Change in elastic potential energy = final – initial
$= \frac{1}{2}(20)(0.30^2) - \frac{1}{2}(20)(0.20^2) = 0.5$ J.

Q11 Total energy remains constant. D

Q12 $\frac{F_E}{F_P} = \frac{\frac{1}{r_E^2}}{\frac{1}{r_P^2}} = \left(\frac{r_P}{r_E}\right)^2 = \left(\frac{6.0}{10.5}\right)^2 = 0.33$. A

Q13 $\frac{r_P^3}{T_P^2} = \frac{r_E^3}{T_E^2}$, $T_E^2 = \left(\frac{r_E}{r_P}\right)^3 T_P^2$,

$\therefore T_E = \left(\frac{r_E}{r_P}\right)^{\frac{3}{2}} T_P = \left(\frac{10.5}{6.0}\right)^{1.5} \times 248 = 574$ Earth-years.

Q14 Vertical component: $u = {}^{+}40\sin 25° = {}^{+}16.90$, $v = {}^{-}16.90$, $a = {}^{-}10$. Use $v = u + at$ to find $t = 3.4$ s.

Q15 Vertical component: $u = {}^{+}16.90$, $v = 0$, $a = {}^{-}10$. Use $v^2 = u^2 + 2as$ to find $s = {}^{+}14.3$ m. $\therefore h = 14.3$ m.

Q16 While the paintball is in flight, gravity is the only force on it. D

Q17 Acceleration due to gravity is the same, $a = {}^{-}10$.
To reach the same maximum height $h = 14.3$ m, where $v = 0$.
From $v^2 = u^2 + 2as$, the vertical component of the initial velocity must be the same, i.e. $u = {}^{+}16.90$.
From $v = u + at$, the time to reach the same maximum height must be the same. Hence the flight time is the same. A and C.
The initial speed and the angle of firing can vary to give the same vertical component of the initial velocity.

Area of study 2 – Electronics and photonics

Q1 Amplitude of $V_{OUT} = 80 \times 20$ mV = 1.6 V. Output signal is inverted.

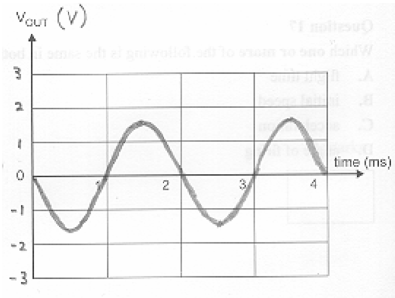


Figure 2b

Q2 At point Y, the signal voltage $V_Y = 3.0 \pm 3.0$ volts and $\therefore V_{OUT} = \pm 3.0$ volts.

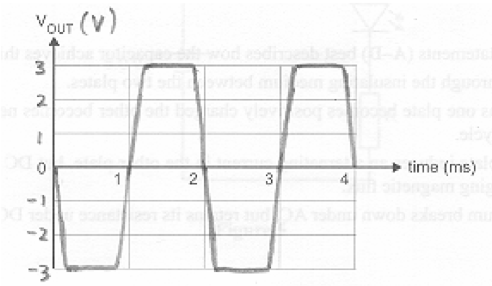


Figure 3b

Q3 Saturation and cutoff are terms used to describe the conduction mode of a npn transistor. It is said to be saturated if it is in its maximum conducting condition. At cutoff the current through the transistor is negligible.
For the npn transistor amplifier under consideration,
$\frac{V_{OUT,pp}}{V_{IN,pp}} = 80$, $\frac{6.0}{V_{IN,pp}} = 80$, $V_{IN,pp} = 0.075$ V, $\therefore$maximum amplitude of input signal $= \frac{0.075}{2} = 0.0375$ V.
If $V_{IN} \geq 0.0375$ V, the npn transistor is at saturation, I_C is maximum and $V_Y \approx 0$.
If $V_{IN} \leq -0.0375$ V, the npn transistor is at cutoff, $I_C \approx 0$ and $V_Y \approx 6$ V.
$\therefore V_{OUT} = \pm 3$ V.
Clippings occur to the output signal due to saturation and cutoff.

Q4 B

Q5 When $I = 10$ mA, voltage across diode = 1.0 V (from graph)
$\therefore$ voltage across resistor $R = 6.0 - 1.0 = 5.0$ V.
$\therefore R = \frac{V}{I} = \frac{5.0}{10 \times 10^{-3}} = 500\,\Omega$.

Q6 LED does not conduct, $I = 0$.
Voltage across resistor $= IR = 0$.
$\therefore$voltage across LED = 6.0 – 0 = 6.0 V.

Q7 Resistance = 3000Ω = 3.0 kΩ.
Light intensity = 10 lux (from graph).

Q8 For the LDR, 20 lux corresponds to $R_{LDR} = 1.5$ kΩ and $V_{OUT} = 4.0$ V.
For the resistor R, $V_R = 6.0 - 4.0 = 2.0$ V.
$\therefore \frac{R}{1.5 \times 10^3} = \frac{2.0}{4.0}$, $\therefore R = 750\,\Omega$.

Q9 For light to turn on, the voltage ratio and hence the resistance ratio remain constant, i.e. $\frac{R}{R_{LDR}} = \frac{2.0}{4.0} = 0.5$.
$\therefore R = 0.5 R_{LDR}$, $\therefore R \propto R_{LDR}$.
At higher light intensity, R_{LDR} decreases, $\therefore R$ decreases.

Q10 At point X, the brightness (always positive) fluctuates the same way as the voltage at point W. D

Q11 C

Detailed study 1 – Einstein's special relativity

Q1 light, interference, no.

Q2 Speed of sound relative to the control tower depends on the medium and the speed of the medium (wind speed) but not on the speed of the source (siren).
Relative to the control tower,
speed of sound = 340 – 50 = 290 ms^{-1}.
Time taken $= \frac{d}{v} = \frac{3000}{290} = 10.3$ s.

Q3 According to the pilot, speed of light $= c = 3.000 \times 10^8$ ms^{-1} and distance 9.0000×10^7 m. $\therefore$time taken $= \frac{9.0000 \times 10^7}{3.000 \times 10^8} = 0.3000$ s. B

Q4 $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{(0.1000c)^2}{c^2}}} = \frac{1}{\sqrt{1 - 0.1000^2}} = 1.005$

Q5 L is smaller than L_0 due to length contraction. B

Q6 Not correct. L is always smaller than or equal to L_0 for any observer.

Q7 According to GPS receiver, the satellite clock (moving) runs more slowly than the GPS receiver clock (at rest) due to time dilation. B

Q8 $t = t_0 \gamma$, $4.16 \times 10^{-7} = t_0 \times 16$, $t_0 = 2.60 \times 10^{-8}$ s. A

Q9 $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$, $16 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$, $\sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{16}$,

$1 - \left(\frac{v}{c}\right)^2 = \left(\frac{1}{16}\right)^2$, $\frac{v}{c} = \sqrt{1 - \left(\frac{1}{16}\right)^2} = 0.998$, $\therefore v = 0.998c$.

Q10 In one second, $E = Pt = (4.0\times10^{26})(1) = 4.0\times10^{26}$ J.

$E = mc^2$, $m = \dfrac{E}{c^2} = \dfrac{4.0\times10^{26}}{(3.0\times10^{8})^2} = 4.4\times10^{9}$ kg.

Detailed study 2 – Investigating materials and their use in structures

Q1 length, shear, elasticity.

Q2 $\sum\tau = 0$ about cable with T_2 ,

$^{-}T_1\left(\dfrac{3L}{4}\right) + {}^{+}Mg\left(\dfrac{L}{4}\right) = 0$, $\therefore T_1 = \dfrac{Mg\left(\frac{L}{4}\right)}{\left(\frac{3L}{4}\right)} = \dfrac{1}{3}Mg$.

Q3 $x = \dfrac{T_2}{T_1} = \dfrac{Mg - T_1}{T_1} = \dfrac{Mg}{T_1} - 1 = 3 - 1 = 2$.

Q4 Tensile stress exists in the lower part of the section between the two cables, and in the upper part of the remainder. D

Q5 Tapping gently with a hammer does not exceed the elastic limits of the two objects, and both objects show elastic behaviour causing the hammer to bounce off. B

Q6 C

Q7 $\sigma = \dfrac{F}{A}$, $F = \sigma A = (240\times10^{6})(\pi\times0.005^{2}) = 1.9\times10^{4}$ N.

Q8 Strain energy per m^3:

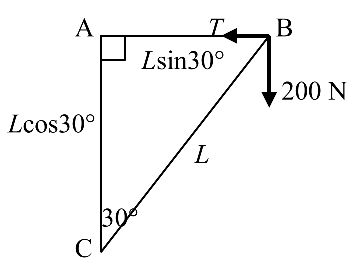
$E = \dfrac{1}{2}\sigma\varepsilon = \dfrac{1}{2}(240\times10^{6})(0.4\times10^{-3}) = 48000$ Jm^{-3}.

Total strain energy $= E\times$ volume

$= 48000\times(1.0\times\pi\times0.005^{2}) = 3.8$ J.

Q9 D

Q10 Let L metres be the length of the rod BC.



$\sum\tau = 0$ about point C.

$^{+}T\times L\cos30° + {}^{-}200\times L\sin30° = 0$

$\therefore T = \dfrac{200\sin30°}{\cos30°} = 115$ N.

Detailed study 3 − Further electronics

Q1 an oscilloscope, an audible hum, capacitor.

Q2 $\dfrac{N_S}{N_P} = \dfrac{V_S}{V_P} = \dfrac{6}{240} = \dfrac{30}{1200}$. C

Q3 C

Q4 B

Q5 After a time constant, remaining voltage $= 37\%\times12 = 4.4$ V.

From graph, $t \approx 40$ ms. $\therefore \tau \approx 40$ ms $= 40\times10^{-3}$ s.

$RC = \tau$, $100\times C = 40\times10^{-3}$, $\therefore C = 4.0\times10^{-4}$ F $= 400\mu$ F.

Q6 From the peak of a cycle to the start of the next cycle, the time is 15 ms approximately. The capacitor would discharge from 12 V to 8 V approximately. C

Q7 $V_{OUT} = 6$ V (from graph).

Q8 Voltage across resistor $= 9 - 6 = 3$ V.

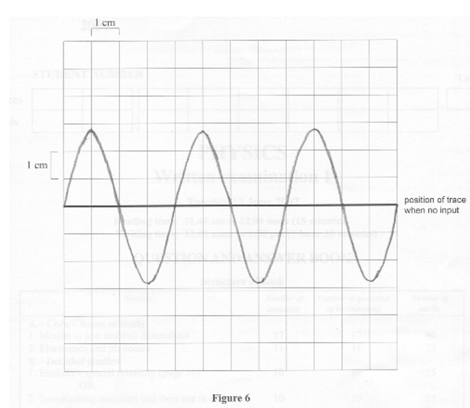
Q9 $I_{Zenerdiode} = I_{resistor} = \dfrac{V}{R} = \dfrac{3}{100} = 0.03$ A $= 30$ mA.

Q10 When the whole class uses the same power supply, all electrical devices are connected in parallel. Thus the load resistance at the output of the voltage supply decreases. ∴the capacitor discharges faster causing a lower voltage output of the power supply. The internal resistance of the power supply also contributes to the drop in voltage.

Q11 Increase the capacitance of the capacitor to compensate for the decrease in load resistance. Connect a Zener diode across the output of the power supply to regulate the output voltage.

Q12 $T = \dfrac{1}{f} = \dfrac{1}{50} = 0.02$ s $= 20$ ms.

$V_{peak} = \sqrt{2}\times V_{RMS} = \sqrt{2}\times4 = 5.7$ V



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