2011 Physics Trial Exam 1 Solutions

Area of study 1 – Motion in one and two dimensions

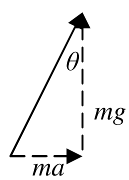
Q1 $u = 0$, $v = \frac{108}{3.6} = 30$, $t = 10$, $a = \frac{v-u}{t} = 3.0\ \text{ms}^{-2}$

Q2 $F_f - 200 = 1200 \times 3.0$, $F_f = 3800\ \text{N}$

Q3 The reaction force consists of two components, they are the normal force (perpendicular to the road) and the force due to friction (forward direction) exerted by the road on the tyre. ∴ R

Q4 $a = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 \times 250}{78.5^2} \approx 1.6$

Q5 $\tan\theta = \frac{ma}{mg} \approx \frac{1.6}{10}$, $\theta \approx 9°$



Q6 Same angle, $\theta \approx 9°$, independent of the mass of the parcel.

Q7 $u = 0$, $s = 300$, $a = 10$, $s = ut + \frac{1}{2}at^2$, $t \approx 7.7$ seconds

Q8 Conservation of energy (gravitational potential energy and kinetic energy): $m \times 10 \times 3.50 = \frac{1}{2}mv^2$, $v \approx 8.37\ \text{ms}^{-1}$

Q9 When the spring is compressed by 1.00 m, the sledge moves further down vertically by $1.00 \times \sin 30° = 0.50$ m.
Conservation of energy (gravitational potential energy and elastic potential energy): $120 \times 10 \times (3.50 + 0.50) = \frac{1}{2}k \times 1.00^2$

$k = 9600\ \text{Nm}^{-1}$

Q10 Hooke's law: $F = kx = 9600x$
$F_{net} = 0$, $120 \times 10 \times \sin 30° - 9600x = 0$, $x = 0.0625$ m

Q11 Maximum speed occurs when $a = 0$, i.e. when the spring is compressed by 0.0625 m, and the sledge moves further down vertically by $0.0625 \times \sin 30° = 0.03125$ m.
Conservation of energy (gravitational potential energy, kinetic energy and elastic potential energy):
$120 \times 10 \times (3.50 + 0.03125) = \frac{1}{2} \times 120 \times v^2 + \frac{1}{2} \times 9600 \times 0.0625^2$
$v \approx 8.39\ \text{ms}^{-1}$

Q12 Conservation of energy (gravitational potential energy and kinetic energy): $m \times 10 \times 3.50 = m \times 10 \times 2.00 + \frac{1}{2}m \times v^2$
$v \approx 5.48\ \text{ms}^{-1}$

Q13 Down motion: $s = {}^{-}2.5$, $a = {}^{-}10$, $u = 0$, ∴ $v = {}^{-}\sqrt{50}$
Up motion: $s = {}^{+}1.5$, $a = {}^{-}10$, $v = 0$, ∴ $u = {}^{+}\sqrt{30}$
Impulse $= \Delta p = 0.058 \times {}^{+}\sqrt{30} - 0.058 \times {}^{-}\sqrt{50} = {}^{+}0.7278$ Ns
$|\text{impulse}| \approx 0.73$ Ns

Q14 $|\text{impulse}| = |F_{average}| \times 0.025$, $0.7278 = |F_{average}| \times 0.025$
$|F_{average}| \approx 29$ N

Q15 $|F_{maximum}| \approx 29 \times 3 \approx 90$ N

Q16 $mv_A + mv_B = m(2.0)$, $\therefore v_A + v_B = 2.0$
$\frac{1}{2}mv_A^2 + \frac{1}{2}mv_B^2 = \frac{1}{2} \times \frac{1}{2}m(2.0)^2$, $\therefore v_A^2 + v_B^2 = 2.0$

Q17 $v_B = 2.0 - v_A$, $\therefore v_A^2 + (2.0 - v_A)^2 = 2.0$
$\therefore v_A^2 - 2v_A + 1 = 0$, $\therefore v_A = 1.0$ and $v_B = 1.0$

Q18 Since $g \propto \frac{1}{r^2}$, $\therefore \frac{g_B}{g_A} = \frac{r_A^2}{r_B^2} = \left(\frac{4R}{3R}\right)^2 = \frac{16}{9}$

Q19 Since $\frac{r^3}{T^2}$ is a constant, $\therefore \frac{r_B^3}{T_B^2} = \frac{r_A^3}{T_A^2}$
$\therefore \frac{T_A^2}{T_B^2} = \frac{r_A^3}{r_B^3}$, $\therefore \frac{T_A}{T_B} = \left(\frac{r_A}{r_B}\right)^{\frac{3}{2}} = \left(\frac{4}{3}\right)^{\frac{3}{2}}$

Q20 $g_A = \frac{GM}{r_A^2} = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{(4 \times 6.37 \times 10^6)^2} \approx 0.6144\ \text{N kg}^{-1}$
The variation in g within the km is insignificant.
$\therefore \Delta E_p \approx mg_A \Delta h = 1 \times 0.6144 \times 1000 \approx 610\ \text{J}$

Area of study 2 – Electronics and photonics

Q1 R_1 and R_3 are parallel, total resistance $= \frac{1}{\frac{1}{R_1} + \frac{1}{R_3}} = 0.4\ \text{k}\Omega$
R_2 and R_4 are parallel, total resistance $= \frac{1}{\frac{1}{R_2} + \frac{1}{R_4}} = 0.5\ \text{k}\Omega$
The two parallel connections form a voltage divider.
$V_{PQ} = \frac{0.4}{0.4 + 0.5} \times 9.0 = 4.0\ \text{V}$

Q2 $I = \frac{V}{R_{total}} = \frac{9.0}{0.9k} = 10\ \text{mA}$

Q3 $P_1 = \frac{V_1^2}{R_1} = 0.032$ W, $P_3 = \frac{V_3^2}{R_3} = 0.008$ W

$P_2 = P_4 = \frac{V_4^2}{R_4} = 0.025$ W, $\therefore P_1$ is the highest.

Q4 After the change: $R_{total} = \frac{1}{\frac{1}{0.5+1}+\frac{1}{2}} = \frac{6}{7}$ kΩ

$P_{total} = \frac{V^2}{R_{total}} = 0.0945$ W

Before the change: $P_{total} = \frac{V^2}{R_{total}} = 0.090$ W

The total power increases after the change.

Q5 When the LEDs are conducting, voltage across each one is 2.0 V. .: voltage across each resistor $= 6.0 - 2.0 - 2.0 = 2.0$ V

$I_{LED} = I_R = \frac{V}{R} = \frac{2.0}{100} = 0.020\text{ A} = 20\text{ mA}$

Q6 $I_{battery} = 10 \times 20\text{ mA} = 200\text{ mA}$

Q7 When only one 100-Ω resistor is used, the current in the resistor remains 20 mA and .: the current in each branch of LEDs becomes $\frac{1}{10} \times 20 = 2.0$ mA

.: the LEDs become dimmer, the total output of the LEDs is only $\frac{1}{10}$ of the original value.

Q8 To maintain the LED current at 20 mA, the resistor current must be 200 mA, and $R = \frac{V}{I} = \frac{2.0}{0.20} = 10\ \Omega$.

Q9 In general, it is not wise to use a single resistor for parallel LEDs. If a LED is burned, it cuts off the current in the branch instantaneously. The current and thus the voltage of the resistor decrease, resulting in an instantaneous voltage increase (> 2.05 V) in the LEDs. The increase in voltage will damage all the LEDs.

Total current through resistor = 180 mA instead of 200 mA

$V_R = IR = 0.18 \times 10 = 1.8$ V

$V_{LED} = \frac{1}{2} \times (6.0 - 1.8) = 2.1$ V

Another scenario: A short may occur across the resistor and the instantaneous voltage across a LED becomes 3.0 V. The voltage is much too high and will damage all the LEDs.

Q10 Read v_i and v_o from graphs at $t \approx 0.55$ ms,

voltage gain $= \frac{v_o}{v_i} \approx \frac{2.6}{-0.32} \approx -8$

Q11 |voltage gain| $\approx 8 = \frac{3.2}{v_i}$, $v_i \approx 0.4$ V

Q12 (i) Laser diode, (ii) photodiode

Q13 C

Detailed study 2– Investigating materials and their use in structures

1	2	3	4	5	6
D	D	C	C	A	C

7	8	9	10	11	12
C	C	B	C	A	C

Q1 The tension in the rope varies from $T = 19$ N at the end where the 19 N force is applied to $T = 15$ N at the other end. D

Q2 The value of Young's modulus for a material depends only on the type of material under consideration. D

Q3 The value of the constant $k \propto \frac{A}{\ell}$, where A is the cross-sectional area, and ℓ the length of the material. C

Q4 x-axis, $\varepsilon = \frac{0.1}{3} = 0.03$, y-axis, $\varepsilon = \frac{0.1}{5} = 0.02$, z-axis, $\varepsilon = \frac{0.1}{1} = 0.1$.

Since $\sigma \propto \varepsilon$, $\therefore \sigma$ is highest parallel to the z-axis. C

Q5 Material B has the highest tensile strength. A

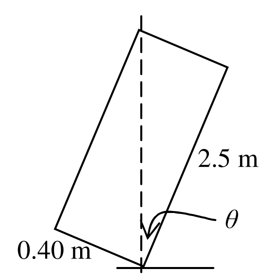
Q6 You cannot apply a tensile stress greater than T units to materials A and C because they break before the stress of T units is reached. C

Q7 $\sigma = \frac{F}{A} = \frac{mg}{A} = \frac{2000 \times 10}{220 \times 10^{-4}} \approx 0.9 \times 10^6\text{ Pa} \approx 1\text{ MPa}$ C

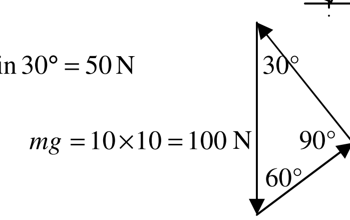
Q8 C

Q9 Area under the straight section of the graph $\approx \frac{1}{2}(0.003)(230 \times 10^6) = 345000\text{ J} \approx 0.345\text{ MJ}$ B

Q10 $\tan\theta = \frac{0.40}{2.5}$, $\theta \approx 9.1°$ C



Q11 $F_B = 100 \sin 30° = 50$ N A



Q12 C

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

