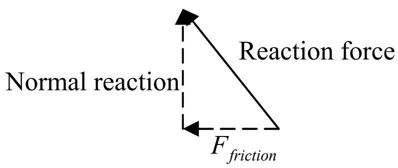
2006 Physics Trial Exam 1 Solutions

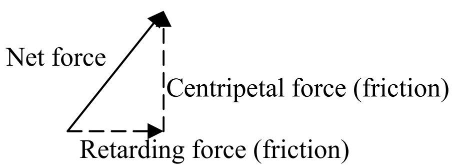
Motion in one and two dimensions

Q1 $F_{friction} = F_{net} = ma = m\dfrac{v^2}{r} = 80 \times \dfrac{5.0^2}{8.0} = 250\text{ N}$

Q2 B



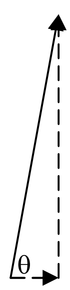
Q3 L



Q4 Conservation of energy in a gravitational field:
Total energy (point of projection) = total energy (highest point)
$\frac{1}{2}mv^2 + 0 = \frac{1}{2}m\left(2.0^2\right) + m(10)(3.0)$, $v^2 = 4.0 + 60 = 64$,
$v = 8.0\text{ ms}^{-1}$.

Q5 Horizontal component of velocity vector remains constant 2.0 ms^{-1}.

$\cos\theta = \dfrac{2.0}{8.0}$, $\theta = 76^o$



Q6 Strain energy = area under *F*-*x* graph $\approx \frac{1}{2}(40)(1.0) = 20\text{ J}$

Q7 All the strain energy is changed to heat energy due to friction when the block comes to a stop.
Work done by friction force = strain energy,
$F_{friction} \times 2.5 = 20$, $\therefore F_{friction} = 8.0\text{ N}$

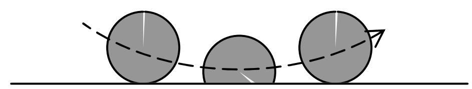
Q8 Maximum kinetic energy is reached when the net force on the block is zero. At that moment the force of the rubber cord equals the force of friction 8.0 N. From the graph the extension of the rubber cord is 0.35 m approximately $\therefore$ the distance travelled by the block against friction is 1.0 – 0.35 = 0.65 m. $\therefore$ work done by friction against motion is 8.0 × 0.65 = 5.2 J. At that moment the strain energy is changed to heat and kinetic energy. $\therefore KE(\max) + 5.2 = 20$, $KE(\max) = 14.8 \approx 15\text{ J}$.

Q9 Velocity of the car relative to the truck $v_{CT} = v_C - v_T$
$= {}^{+}30 - {}^{+}20 = {}^{+}10$, i.e. 10 ms^{-1} east.

Q10 To overtake the truck the car has to travel (20 + 4.0 =24) extra metres than the truck during the overtaking period, i.e. displacement of the car relative to the truck is ${}^{+}24$ m.
Time taken $= \dfrac{24}{10} = 2.4$ s.

Q11 A

Q12 During the time of contact:



Because the surface is frictionless, there is no horizontal friction force, $\therefore$ there is no change in the horizontal momentum and velocity.

The normal reaction of the floor on the ball changes the vertical momentum of the ball. Because the bounce is elastic, kinetic energy after the bounce remains the same as that before the bounce, $\therefore$ the speed remains the same.

Hence the magnitude of the vertical velocity remains constant.

Q13 The earth and the moon are at the same distance from the sun, $\therefore$ the gravitational field of the sun experienced by the earth is the same as that experienced by the moon, $\therefore$ ratio = 1.

Q14 $\dfrac{v^2}{r} = \dfrac{GM_{sun}}{r^2}$, $\therefore v = \sqrt{\dfrac{GM_{sun}}{r}} = 3.0 \times 10^4\text{ ms}^{-1}$.

Q15 During the 1 km fall, the change in the gravitational field is not significant, $\therefore g = 0.22\text{ Nkg}^{-1}$ and $a = 0.22\text{ ms}^{-2}$.
$u = 0$, $s = 1000$, $a = 0.22$, $v = ?$ Use $v^2 = u^2 + 2as$, $v = 21\text{ ms}^{-1}$

Q16 For each kilogram mass, $\Delta E_{kinetic}$ = area under the graph
$\approx \frac{1}{2}(0.23 + 0.22) \times 10^6 = 2.25 \times 10^5$ J, $\therefore \frac{1}{2}(1)v^2 \approx 2.25 \times 10^5$,
$\therefore v = 6.7 \times 10^2\text{ ms}^{-1}$.

Electronics and photonics

Q1 Current through resistor Y = 2.0 mA,
$\therefore V_{out} = V_Y = (2.0\times10^{-3})(2\times10^{3}) = 4.0$ v.

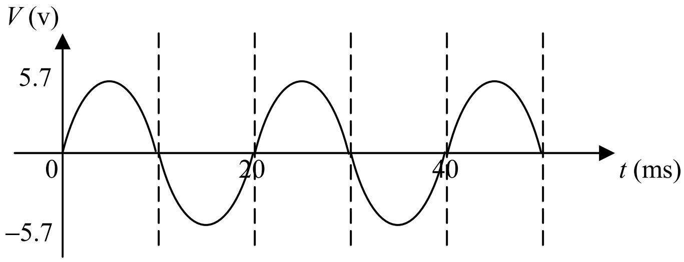
Q2 Current through resistor X = 2.0 mA,
$\therefore V_X = (2.0\times10^{-3})(1\times10^{3}) = 2.0$ v.
$\therefore \xi = V_X + V_Y = 6.0$ v.

Q3 Resistor Z.

Q4 Resistors X and Y form a voltage divider:

$$V_Y = \frac{R_Y}{R_X + R_Y}\times V,$$

$$\therefore V_Y = \frac{2\times10^{3}}{1\times10^{3} + 2\times10^{3}}\times 8.5 = 5.7 \text{ v}$$



Q5 A and B Q6 C

Q7 Current gain $\beta = 100$,
$i_c = \beta\times i_b = 100\times14.5\ \mu\text{A} = 1.45$ mA
$i_e = i_b + i_c = 1.46$ mA

Q8 Voltage across $R_c = i_c \times R_c = (1.45\times10^{-3})(4.7\times10^{3}) = 6.8$ v
$\therefore v_o = v_{cc} - 6.8 = 3.2$ v

Q9 $\Delta v_i = 0.705 - 0.700 = 0.005$ v, $\Delta v_o = 1.7 - 3.2 = -1.5$ v.

$$\text{Voltage gain} = \frac{\Delta v_o}{\Delta v_i} = \frac{-1.5}{0.005} = -300$$

Q10 $v_o = 0.3$ v, $\therefore$ voltage across $R_c = 10 - 0.3 = 9.7$ v,

$$\therefore i_c = \frac{9.7}{4.7\times10^{3}} = 2.06\times10^{-3}\text{ A} = 2.1\text{ mA}$$

Q11 Photodiode is in photoconductive mode when it is reverse biased, current $\approx 15\ \mu$A.

Q12 A photodiode is a transducer that converts the intensity modulated light signal into an electrical signal, which is then fed into a computer.

Investigating materials and their use in structures

Q1

Yield strength	Tensile strength	Breaking strength	Young's modulus
250 MPa	280 MPa	265 MPa	50 GPa

Q2 When the stress is 250 MPa, strain $\varepsilon = 0.005$ (from graph)

$$\varepsilon = \frac{\Delta\ell}{\ell},\ 0.005 = \frac{\Delta\ell}{5.00},\ \therefore \Delta\ell = 0.025 \text{ cm.}$$

Q3 Radius $r = 0.0065$ m. Stress $\sigma = \dfrac{F}{A} = \dfrac{F}{\pi r^2}$,

$$\therefore F = \pi r^2\sigma = \pi(0.0065^2)(250\times10^{6}) = 3.3\times10^{4}\text{ N}$$

Q4 Elastic strain energy per cubic metre $E = \dfrac{1}{2}\sigma\varepsilon$

$$= \frac{1}{2}(250\times10^{6})(0.005) = 6.3\times10^{5}\text{ J.}$$

Q5 When the H beam is used horizontally, its weight and the load it carries cause different types of stress to appear at different parts of the beam. The top flange has to resist horizontal compressive stress and the bottom flange to resist horizontal tensile stress, while the web in the middle is there to resist the vertical or shearing stresses.

Q6 A, B and C.

Q7 Members closest to the fixed end experience the highest stress. D.

Q8 No vertical translation because the vertical component of net force is zero.
Horizontal component of net force:
$^{+}340\sin30^{o} + {}^{-}170 = {}^{+}170 + {}^{-}170 = 0$.
$\therefore$ no horizontal translation.
$\therefore$ the crate is in translational equilibrium.
Torque of the pulling force about point O
$= 340\times1.8\sin30^{o} = 306$ Nm clockwise.
Torque of the weight force about point O
$= 50.0\times10\times0.6 = 300$ Nm anticlockwise.
$\therefore$ there is a net torque of 6 Nm clockwise causing the crate to topple over.

Q9 Torque of the pulling force about point O
$= 320\times1.8\sin30^{o} = 288$ Nm clockwise.
Torque of the weight force about point O
$= 50.0\times10\times0.6 = 300$ Nm anticlockwise.
$\therefore$ the clockwise torque of the pulling force is not high enough to overcome the stabilising anticlockwise torque of the weight force. Hence the crate is in rotational equilibrium.
No vertical translation because the vertical component of net force is zero.
Horizontal component of net force $= {}^{+}320\sin30^{o} = {}^{+}160$ N.
This causes the crate to accelerate along the surface,

$$a = \frac{F_{net}}{m} = \frac{^{+}160}{50.0} = 3.2\text{ ms}^{-2}.$$

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