Multiple Choice Solutions

1. (C) At any given position of the block there are two forces acting on it: 1) gravity (down) and 2) the Normal force (towards the center).

2. (A) Maximum static friction force is \( F_s = \mu_s mg = 0.5 \times 50 \times 9.8 = 245 \text{ N} \). Since this exceeds \( F \), the block will remain stationary.

3. (B) By conservation of energy, \(-\Delta U = \Delta KE + \Delta E_{therm} \) where the last term is the increase in thermal energy (heat) due to air resistance (think Space Shuttle reentry). Since \( \Delta E_{therm} > 0 \), \(-\Delta U > \Delta KE \).

4. (D) \( KE = \frac{1}{2}mv^2 \). If \( v' = 1.2v \), then \( KE' = \frac{1}{2}m(v')^2 = 1.44 \times K \).

4. (B) Conservation of energy: \( E_{e^-}^0 + E_{e^+}^0 = 3E_\gamma \).

\[
E_{e^-}^0 = E_{e^+}^0 = \frac{9.109 \times 10^{-31} \times (2.998 \times 10^8)^2}{1.602 \times 10^{-19}} = 511 \text{ keV}.
\]

\[E_\gamma = 2 \times 511/3 = 341 \text{ keV} \]
2) \[ Q_A = \frac{1}{4} 2\pi r_A = \frac{1}{2} \cdot 0.70 \text{ m} = 109.96 \text{ m} \] (2)

\[ Q_B = \frac{1}{2} \cdot 40 \text{ m} + 2.20 \text{ m} = 102.83 \text{ m} \] (1)

b) Maximum speed corresponds to centripetal force equal to maximum static friction force:

\[ M \omega c = \mu_s m g \Rightarrow \omega c = \frac{v^2}{r} = \mu_s g \Rightarrow v = \sqrt{\mu_s g r} \]

\[ v_A = \sqrt{0.95 \cdot 9.81 \text{ m}^2 \cdot 0.70 \text{ m}} = 25.54 \text{ m/s} \] (2)

\[ v_B = \sqrt{0.95 \cdot 9.81 \text{ m}^2 \cdot 4.0 \text{ m}} = 19.31 \text{ m/s} \] (3)

c) Time to drive is given by \( t = \frac{L}{v} \):

\[ t_A = \frac{109.96 \text{ m}}{25.54 \text{ m/s}} = 4.305 \text{ s} \]

\[ t_B = \frac{102.83 \text{ m}}{19.31 \text{ m/s}} = 5.326 \text{ s} \]

Consequently, trajectory A is faster despite being longer.
The friction force between the two blocks must be static if they are not slipping. Maximum static friction force is:

\[ f_{s,\text{max}} = \mu_s m g = 0.3 \cdot 2 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 5.886 \text{ N} \]

This corresponds to an acceleration of upper block of:

\[ a = \frac{f_{s,\text{max}}}{m} = \mu_s g = 2.943 \text{ m/s}^2. \]

Since \( F \) accelerates both blocks this becomes:

\[ F = (2m + 4 \text{ kg}) \cdot 2.943 \text{ m/s}^2 = 17.66 \text{ N} \]

b) Since \( 2N > 17.66 \text{ N} \) blocks are now slipping on one another!

On top block: \( f_k = \mu_k m g = 0.2 \cdot 2 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 3.924 \text{ N} \) to the right

On bottom block: \( f_k = 3.924 \text{ to the left} \) \( (N \text{ III}) \).

c) Use \( N_k \):

for top block: \( a = \frac{f_k}{m} = \mu_k g = 0.2 \cdot 9.81 \text{ m/s}^2 = 1.962 \text{ m/s}^2 \) to the right

for bottom block: \( a = \frac{(F - f_k)}{m} = \frac{(2N - 3.924)N}{4 \text{ kg}} = 5.019 \text{ m/s}^2 \) to the right
iv. a) Work by const. force:

\[ W = F \cdot d \Delta = 50N \cdot 0.1m = 5 \text{ J} \]

b) Potential energy of spring:

\[ U_s = \frac{1}{2} k \Delta x^2 = \frac{1}{2} \cdot 800 \text{ N/m} \cdot (0.1m)^2 = 4 \text{ J} \]

c) By energy conservation

\[ K = W - U_s = (5 - 4) \text{ J} \] (There is no friction)

Velocity then is:

\[ \Delta v = \sqrt{2k/\mu} = \sqrt{2 \cdot 1.5 \text{ J}} = 0.707 \text{ m/s} \]

d) At maximum elongation box is at rest. So by conservation of energy:

\[ W = \frac{1}{2} k \Delta x^2 \quad \text{but} \quad U = W = F \Delta x \]

\[ F \Delta x = \frac{1}{2} k \Delta x^2 \quad \implies \quad \Delta x = \frac{2F}{k} = \frac{50N}{800 \text{ N/m}} = 12.5 \text{ cm} \]
a) The change in potential energy is:

\[ \Delta U = mg \Delta y = mg R (\cos \theta - 1) \]

\[ = 0.02 \times 10^{-3} \times 9.81 \times (\cos 40^\circ - 1) \]

\[ = -9.18 \text{ mJ} \]

b) Conservation of energy:

\[ \Delta K = -\Delta U = \frac{1}{2} m v^2 \]

\[ v = \sqrt{\frac{2 \Delta U}{m}} = \sqrt{\frac{2 \times 9.18 \times 10^{-3}}{0.02 \times 10^{-3}}} = 0.958 \text{ m/s} \]

c) Free-body diagram:

Net force directed towards center of sphere:

\[ mg \cos \theta - F_N \]

This must equal centripetal force

\[ F_c = \frac{mv^2}{R} = \frac{\frac{mv^2}{R}}{R} = \frac{2}{m} \frac{mgR}{1 - \cos \theta} \]

\[ = 2mg \left(1 - \cos \theta\right) \]

Combining we get:

\[ mg \cos \theta - F_N = 2mg \left(1 - \cos \theta\right) \]

\[ F_N = mg \left(3 \cos \theta - 2\right) = 0.02 \times 10^{-3} \times 9.81 \times \left(3 \cos 40^\circ - 2\right) \]

\[ = 58.5 \text{ mN} \]

d) Particle loses contact when \( F_N = 0 \). Using result from (c) we find that this corresponds to

\[ 3 \cos \theta - 2 = 0 \Rightarrow \cos \theta = \frac{2}{3} \Rightarrow \theta = 48.2^\circ \]