Zach, whose mass is 60 kg, is in an elevator descending at 10 m/s. The elevator takes 3 seconds to come to a stop at the first floor.

1. What is Zach's weight before the elevator starts slowing down?

\[ n - mg = 0 \]
\[ n = mg = 600 \text{ N} \]

2. What is the magnitude of the acceleration during the time it took the elevator to come to a stop?

\[ a = \frac{v_f - v_i}{t_f - t_i} = -\frac{10}{3} \text{ m/s}^2 \]

3. Draw a free-body diagram for Zach during the time the elevator is slowing down.

\[ n - mg = ma \]
\[ n = ma + mg \]
\[ n = 60 \left( \frac{10}{3} + 10 \right) = 60 \cdot \frac{40}{3} = 800 \text{ N} \]

4. What is Zach's weight during the time the elevator is slowing down?

\[ 800 \text{ N} \]
A physicist builds a turntable with a 10 m radius to use for a series of experiments. The turntable can be made to rotate with any angular velocity between 0 and 2 rad/s.

In the first experiment, the physicist covers the turntable with perfectly smooth frictionless ice and carefully places a well trained 20 kg penguin 9 m from the center of the turntable.

The angular speed of the turntable is slowly increased from 0 rad/s to 1 rad/s.

1. Draw a free-body diagram showing all the forces acting on the penguin when the turntable is spinning at the constant rate of 1 rad/s.

2. Describe the motion of the penguin during the time it took the turntable to reach its final angular speed of 1 rad/s. When friction = 0, penguin is stationary while the turntable spins!

In the next experiment, the turntable is carefully sprinkled with sand so that the surface is no longer frictionless. The speed of the turntable is increased very slowly so that the angular acceleration is negligible. The maximum angular speed is 2/3 rad/s = 0.67 rad/s. If the turntable spins any faster than that, the penguin, standing 9 m from the center, slips off the turntable.

3. Draw a free-body diagram for the penguin when the turntable is spinning at a constant rate.

4. Use the above information to find the coefficient of static friction between the penguin and the sand-covered ice.

\[ \mu_s = \frac{\omega^2 r}{g} = \frac{\frac{4}{9} \cdot 9}{10} = \frac{4}{10} = 0.40 \]

5. Would the maximum angular velocity that the turntable could spin before the penguin began to slip _______ decrease _______ if the angular acceleration was 1 rad/s² instead of being negligible? (Choices are INCREASE, DECREASE, or STAY THE SAME.)

Max. acceleration = \( \mu_s mg = m (\omega^2 + \alpha) \)
A 1 meter tall spring with \( k = 500 \text{ N/m} \) is sitting on a table which is taken as the origin of the \( y \)-axis. A 20 kg mass is held right at the top of the uncompressed spring as shown below.

1. What is the total initial mechanical energy of this system?
   (Gravitational and spring potential energy and kinetic energy)
   \[
   E_i = mg y = 20 \cdot 10 \cdot 1 = 200 \text{ J}
   \]

2. If you suddenly remove your hand and let the mass fall, what is the maximum compression of the spring?
   \[
   E_f = mg (1 - \Delta y) + \frac{1}{2} k \Delta y^2 = E_i = mg l
   \]
   \[
   mg = \frac{1}{2} k \Delta y, \quad \Delta y = \frac{2mg}{k} = \frac{4}{5} l
   \]

3. How much does the spring compress if you slowly lower the mass until you can remove your hand without the mass moving either up or down?
   \[
   l - \Delta y = \frac{2}{5} l
   \]

4. In question 3), when the spring is maximally compressed, what are the values of the gravitational and spring potential energies?
   \[
   U_g = mg (1 - \frac{4}{5}) = 200 \cdot \frac{1}{5} = 40 \text{ J}
   \]
   \[
   U_{sp} = \frac{1}{2} k (\frac{4}{5})^2 = 250 \cdot \frac{16}{25} = 160 \text{ J}
   \]

5. In question 4), after you remove your hand from the mass, what are the values of the gravitational and spring potential energies?
   \[
   U_g = mg (1 - \frac{2}{5}) = 200 \cdot \frac{3}{5} = 120 \text{ J}
   \]
   \[
   U_{sp} = \frac{1}{2} k (\frac{2}{5})^2 = 250 \cdot \frac{4}{25} = 40 \text{ J}
   \]

6. Explain whether or not your answers for 4 & 5 make sense.
   - Energy is conserved in 4) when mass is released.
   - Energy is lost in 5) because my work keeps the mass from gaining KE in 5.)
In a new version of cage fighting, a 100 kg sprinter is matched against a sumo wrestler in a circular ring with a radius of 20 m. They charge one another and collide at the center of the ring. Just before the collision the sumo wrestler was going west with a speed of 2.0 m/s while the sprinter was traveling 37° east of north at 10.0 m/s. Immediately after the collision, the entangled combatants are moving due north. They slide together for 2.0 m before coming to rest.

1. Draw a diagram showing the direction each was moving directly before the collision and the direction their combined mass was moving immediately after the collision. North is up and east points off to the right. The red dot represents the center of the ring, the point of impact.

2. What was the mass of the sumo wrestler?

\[ MU_0 \sin 37^\circ = 100 \cdot 10 \cdot \frac{3}{5} = 600 \]

\[ 600 = MV = M \cdot 2 \rightarrow M = 300 \text{ kg} \]

3. What was the speed of the intertwined combatants’ right after the collision?

\[ MV_0 \cos 37^\circ = 100 \cdot 10 \cdot \frac{4}{5} = 800 \]

\[ 800 = (M + M) V_f = (100 + 300) V_f \]

\[ V_f = \frac{800}{400} = 2 \text{ m/s} \]

4. The combatants slid for how much time before coming to a stop?

\[ d = 2 \text{ m with } \bar{V} = \frac{2 + 0}{2} = 1 \text{ m/s} \]

\[ d = \bar{V}T \rightarrow T = 2 \text{ s} \]

5. What was the value of the coefficient of kinetic friction that brought them to rest? Assume the value is constant everywhere inside the ring.

\[ a = \frac{0 - 2}{2} = -1 \text{ m/s}^2 \]

\[ \sqrt{5k} = \mu k(M + M)g = (M + M) a \rightarrow \mu k = \frac{9}{10} = \frac{1}{10} \]
A 3.0 kg block sits on top of a 2.0 kg block as shown below. A force $F$ pulls the 3.0 kg block to the right. The coefficient of static friction between the two masses is 0.5 while the coefficient of kinetic friction between the ground and the 2.0 kg block is 0.1. The two masses are sliding to the right together with an acceleration of 2.0 m/s$^2$.

1. Use the black circle below to show all the forces acting on 3.0 kg block and the red circle to show all the forces acting on the 2.0 kg block.

   \[ F = 30 \text{N} \quad \text{F}_G = 20 \text{N}, \quad \text{n}_2 = 50 \text{N} \]

2. Circle any and all action-reaction pairs of forces that are represented in the above two free-body-diagrams.

   S$_S$ and n$_1$ are action-reaction pairs.

3. Use the free-body-diagrams to write $F_x = m_a$ and $F_y = ma$ for the 2.0 kg block.

   \[ S_S - S_K = m_a a = 2.2 = 4 \quad S_K = \mu n n_2 = 5 \text{N} \]

   \[ n_2 = n_1 + 20 = 50 \]

4. Use the free-body-diagrams to write $F_x = ma$ and $F_y = ma$ for the 3.0 kg block.

   \[ F - S_S = m_a a = 6 \quad S_S,\text{max} = \mu S n = 15 \text{N} \]

5. Solve the equations in 4) and 5) for magnitudes of the static friction force acting between the masses and the force $F$ pulling the masses.

   \[ S_S - 5 = 4 \quad S_S = 9 \text{N} \]

   \[ F - S_S = 6 \quad F = 15 \text{N} \]

6. What is the maximum acceleration of the two masses assuming they continue to move without any slipping between them?

   \[ S_S,\text{max} - S_K = m_2 a_{\text{max}} = 2a_{\text{max}} \]

   \[ 15 - 5 = a_{\text{max}} \]

   \[ 5 \text{ m/s}^2 \]