

Week 6 Activities Problems

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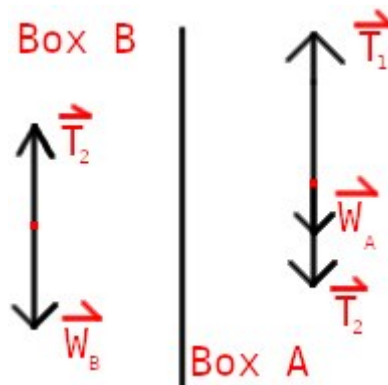
PHYS-111 2pm Lab

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Due: 9/25/2020

Forces And Newton's Second Law

1. A helicopter is lifting two crates simultaneously. Crate A with mass m_A , is attached to the helicopter by a light cable. Crate B, with a mass of m_B , hangs below crate A and is attached to crate A by a second light cable. The cables are not connected to each other. The helicopter accelerates upward with an acceleration of magnitude a . Ignore all frictional effects. Let \vec{T}_1 be the tension in cable 1, and \vec{T}_2 the tension in cable 2.



1. Which cable has greater tension? Don't do any math. Explain why.
Cable 1 will have more tension than cable 2. Cable 1 has to hold up both crates, while cable 2 only holds one crate.
2. Find T_2 . [^1]

$$T_2 = m_B(a + g) \quad (1)$$

3. Find T_1 . [^1]

$$T_1 = (m_A + m_B)(a + g) \quad (2)$$

4. Find T_1 and T_2 given:

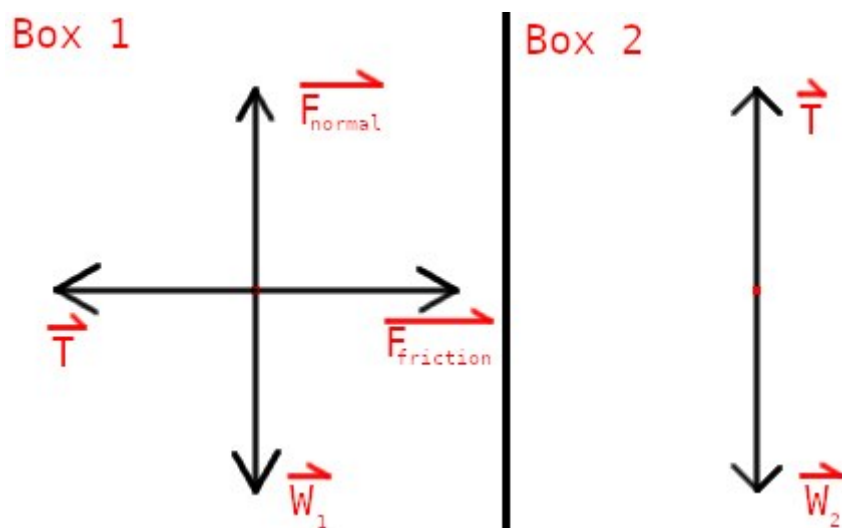
$$\begin{aligned}
 m_A &= 200\text{kg} \\
 m_B &= 250\text{kg} \\
 a &= 1.00\text{m/s}^2
 \end{aligned}
 \tag{3}$$

$$\begin{aligned}
 T_2 &= m_B(a + g); \quad T_1 = (m_A + m_B)(a + g) \\
 T_2 &= 250\text{kg}(1.00\text{m/s}^2 + (-9.81\text{m/s}^2)) \\
 T_2 &= -2.2025\text{kN} \\
 \hline
 T_1 &= (m_A + m_B)(a + g) \\
 T_1 &= (200\text{kg} + 250\text{kg})(1.00\text{m/s}^2 + (-9.81\text{m/s}^2)) \\
 T_1 &= -3.9645\text{kN} \\
 \hline
 |T_1| &= 4\text{kN}; \quad |T_2| = 2\text{kN}
 \end{aligned}
 \tag{4}$$

5. If the helicopter moves vertically upward with a constant velocity, which cable has greater tension? Why? Calculate the values.

The tension changes, but equally on each cable, so cable 1 will still have more tension.

2. Two blocks are connected by a light cord. The cord goes across a pulley, suspending Block 2. Block 1 is on the horizontal surface above Block 2. Block 1 has a weight $W_1 = 25.0\text{N}$, and block 2 has a weight $W_2 = 18.0\text{N}$. The pulley and cords are ideal. Block 1 is at rest.



1. What does rough surface mean?
There is friction.
2. Draw a free body diagram.
3. What is the magnitude of the tension in the cord?

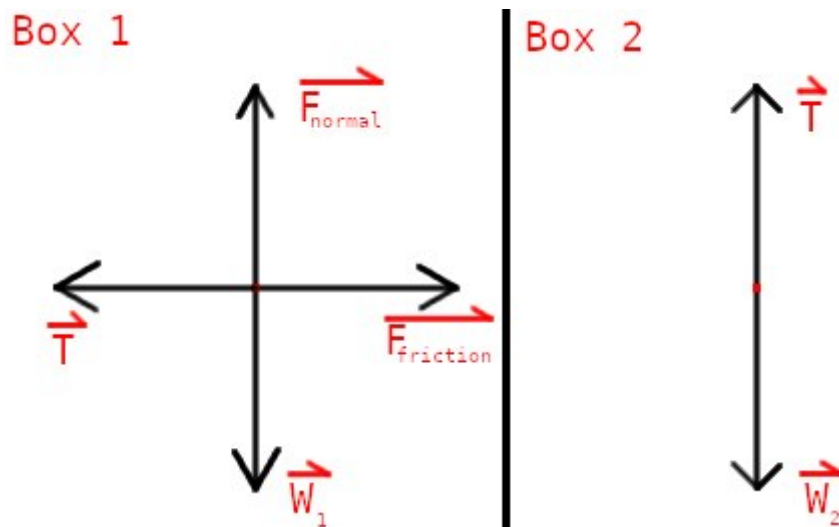
$$\begin{aligned}
 T &= W_2 \\
 T &= 18.0\text{N}
 \end{aligned}
 \tag{5}$$

4. What is the magnitude and direction of the friction force on W_1 ?

$$\begin{aligned} F_{\text{friction}} &= T \\ F_{\text{friction}} &= 18.0\text{N} \end{aligned} \quad (6)$$

The friction force is pointed in the opposite direction of the tension force.

3. A Mass m_1 is connected by a light rope passing over a pulley to a second mass m_2 , like before. Assume no friction and ideal components.



1. What does the term “light rope” mean?

The rope does not have to be accounted for.

2. Find the magnitude of the acceleration of each mass. [¹]

$$\begin{aligned} a_2 &= g \\ F &= ma; a_1 m_1 = m_2 a_2 \\ \hline |a_1 &= \frac{m_2 g}{m_1}; a_2 = g| \end{aligned} \quad (7)$$

3. Find the tension on the rope.[¹]

$$T = -m_2 g \quad (8)$$

4. Check if your results are reasonable by evaluating numerical values for acceleration and tension at these limits:

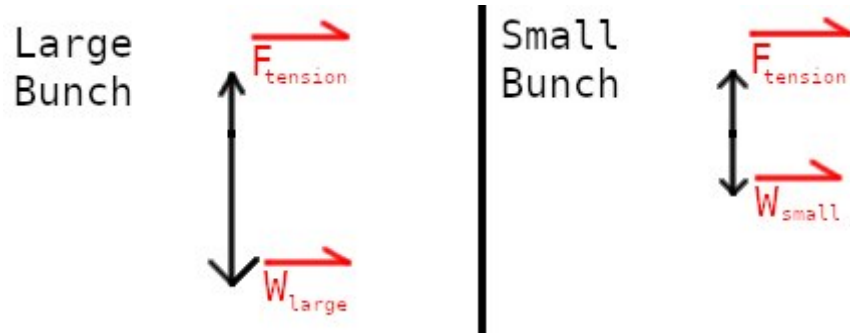
1. What are the values for a and T as m_1 approaches 0? Does this make sense?

Tension and a_2 do not change as m_1 changes. a_1 increases as m_1 decreases. All of these make logical sense because it takes less effort to move a lighter object.

2. What are the values for a and T as m_2 approaches 0? Does this make sense?

a_2 does not change. This makes sense, because acceleration due to gravity is mass-independent. Tension and a_1 do change, both decreasing as m_2 decreases. This makes sense, because the lighter object can't output as much force as a heavier object.

4. Two objects are connected by a light string that passes over an ideal pulley. The 200g bunch of bananas is initially 140cm above the floor. The bananas are released from rest. How long does it take for the 200g banana bunch to hit the floor?



$$F_{netL} = m_L g - m_s g \quad (9)$$

$$F_{netL} = m_L a$$

$$a_L = \frac{m_L g - m_s g}{m_L}$$

$$x_f = x_i + v_i t + \frac{1}{2} a t^2$$

$$x_f = x_i + v_i t + \frac{1}{2} \frac{m_L g - m_s g}{m_L} t^2$$

$$x_f = x_i + \cancel{v_i t} + \frac{1}{2} \frac{m_L g - m_s g}{m_L} t^2$$

$$x_f = x_i + \frac{1}{2} \frac{m_L g - m_s g}{m_L} t^2$$

$$x_f - x_i = \frac{1}{2} \frac{m_L g - m_s g}{m_L} t^2$$

$$2(x_f - x_i) = \frac{m_L g - m_s g}{m_L} t^2$$

$$\frac{2(x_f - x_i)m_L}{m_L g - m_s g} = t^2$$

$$\sqrt{\frac{2(x_f - x_i)m_L}{m_L g - m_s g}} = t$$

$$\sqrt{\frac{2(0 - 140\text{cm})(200\text{g})}{(200\text{g})(-9.81\text{m/s}^2) - (50\text{g})(-9.81\text{m/s}^2)}} = t$$

$$t = 35.2\text{ms}$$

Work and Kinetic Energy

1. The two ropes shown in a bird's-eye view of the diagram are used to drag a crate $3.00m$ horizontally across a rough floor. The tensions in the two ropes are $T_1 = 402N$; $T_2 = 275N$. The magnitude of the kinetic friction force is $f_k = 500N$.

1. What is the direction of the displacement vector \vec{d} whose magnitude is $3.00m$?

$$F_{net} = f_k + \vec{T}_1 + \vec{T}_2 \quad (10)$$

$$F_{net} = 500N\angle 180^\circ + 402N\angle 20^\circ + 275N\angle -30^\circ$$

$$F_{net} = 115.92342\angle -0.0039061327^\circ$$

$$\boxed{F_{net} \approx 0.1kN\angle 0^\circ}$$

$$\boxed{F_{net} \approx 0.1kN \text{ in the } +x \text{ direction}}$$

2. How much work is done by the rope T_1 ?

$$W = Fd \cos(\theta) \quad (11)$$

$$W = (402N)(3.00m) \cos(20^\circ)$$

$$W = 1.1332693kJ$$

$$\boxed{W_{T_1} = 1.13kJ}$$

3. How much work is done by the rope T_2 ?

$$W = Fd \cos(\theta) \quad (12)$$

$$W = (275N)(3.00m) \cos(-30^\circ)$$

$$W = 714J$$

$$\boxed{W_{T_2} = 714J}$$

4. How much work is done by kinetic friction?

$$W = Fd \cos(\theta) \quad (13)$$

$$W = (500N)(3.00m) \cos(180^\circ)$$

$$W = -1.5kJ$$

$$\boxed{W_{f_k} = -2kJ}$$

5. What is the net work done on the crate?

$$\sum W = W_{T_1} + W_{T_2} + W_{f_k} \quad (14)$$

$$\sum W = 1.13kJ + 714J - 1.5kJ$$

$$\sum W = 347.74026J$$

$$\boxed{\sum W = 0.3kJ}$$

2. Sam's job at the amusement park is to slow down and bring to a stop the boats in a log ride. A boat and its riders have a total mass of $1.2Mg$ and drift with a speed of $1.20m/s$.

1. How much total work is done on the boat to slow it from $1.20m/s$ to $0.6m/s$?

$$W_{total} = \Delta K; K = \frac{1}{2}mv^2 \quad (15)$$

$$W_{total} = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$W_{total} = \frac{1}{2}(1.2Mg)((0.6m/s)^2 - (1.20m/s)^2)$$

$$W_{total} = (0.6Mg)((0.6m/s)^2 - (1.20m/s)^2)$$

$$W_{total} = -648J$$

$$\boxed{W_{total} = -0.65kJ}$$

2. How much total work is done to bring the boat to rest?

$$W_{total} = \Delta K; K = \frac{1}{2}mv^2 \quad (16)$$

$$W_{total} = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$W_{total} = \frac{1}{2}(1.2Mg)((0m/s)^2 - (1.20m/s)^2)$$

$$W_{total} = 864$$

$$\boxed{W_{total} = -0.86kJ}$$

3. What average power is expended in bringing one boat to rest in 8.00s?

$$P = Fv; F = ma; a = \frac{\Delta v}{t} \quad (17)$$

$$P = \frac{m(\Delta v)^2}{t}$$

$$P = \frac{(1.2Mg)(0 - 1.20m/s)^2}{8.00s}$$

$$P = 216W$$

$$\boxed{P = 0.22kW}$$

4. Instead of having Sam stop each boat by hand, a large spring is placed at the end of the ride such that each boat compresses the spring a distance x from its equilibrium as it comes to a halt. The work W required to stretch a spring from an initial position x_i to a final position x_f is $W = \frac{1}{2}k(x_f^2 - x_i^2)$. Assuming a boat is traveling as in part 2.2, find the spring constant required to stop the boat in no more than 2.00m.

$$W = \frac{1}{2}k(x_f^2 - x_i^2) \quad (18)$$

$$k = \frac{2W}{x_f^2 - x_i^2}$$

$$k = \frac{2(-0.86kJ)}{2.00m^2 - 0^2}$$

$$k = 432N/m$$

$$\boxed{k = 0.43kN/m}$$

3. A catapult launcher on an aircraft carrier accelerates a jet from rest to $72.0m/s$. The work done by the catapult during the launch is $76.0MJ$. During the launch, the system is considered ideal, and all work done on the jet is done by the catapult.

1. What is the mass of the jet?

$$\begin{aligned}
 W &= \frac{1}{2}mv^2 & (19) \\
 m &= \frac{2W}{v^2} \\
 m &= \frac{2(76.0MJ)}{(72.0m/s)^2} \\
 m &= 29.320988Mg \\
 \underline{m &= 29.3Mg}
 \end{aligned}$$

2. If the jet is in contact with the catapult for $2.00s$, what is the power output of the catapult?

$$\begin{aligned}
 P &= \frac{m(\Delta v)^2}{t}; m = \frac{2W}{\Delta v^2} & (20) \\
 P &= \frac{W}{t} \\
 P &= \frac{76.0MJ}{2.00s} \\
 P &= 38.0MW \\
 \underline{P &= 38.0MW}
 \end{aligned}$$