Unit Two - Chapter 3 - Forces

Using Newton's Laws to Solve Problems

Let the thinking begin...mu ha ha.

Learning Goal: By the end of today, I will be able to use the Success Criteria (previous) to solve motion problems.

Forces - Success Criteria

1. Draw a FBD, choose your positive directions
2. Write an F_{net} equation based on the DIAGRAM
3. Substitute values and F=ma into the F_{net} equation

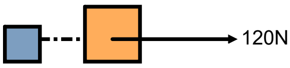
1. Draw a FBD, choose your positive directions
2. Write an F_{net} equation based on the DIAGRAM
3. Substitute values and F=ma into the F_{net} equation

Example

A 40kg mass has an external force of 120N [E] acting on it.

What is the acceleration of the object?

Example



1. Draw a FBD, choose your positive directions
2. Write an F_{net} equation based on the DIAGRAM
3. Substitute values and F=ma into the F_{net} equation

The 40k mass is broken up into two pieces, a 30kg piece and a 10kg piece and they are linked with a length of chain. If the same 120N force is applied, what is the tension force in the chain?

Parts

System

Sample Problem 1: Objects Hanging from Strings

(Pause and Try)

Each object in **Figure 5** has a force of gravity of 120 N [down] acting on it. Determine the tension in each string.

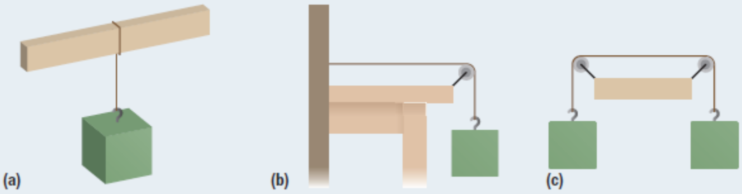
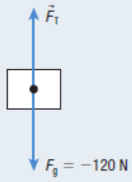


Figure 5

Solution

(a) First draw the FBD of the object. Choose up as positive.



The object is at rest, so it is not accelerating. Newton's first law implies that the net force must be zero.

$$\vec{F}_{net} = \vec{F}_T + \vec{F}_g$$
$$F_{net} = F_T + (-120\ \text{N})$$
$$0 = F_T - 120\ \text{N}$$
$$F_T = +120\ \text{N}$$

The tension in the string is 120 N [up].

(b) In this diagram, the force of gravity has not changed and the object is at rest. This means that the FBD is the same and we will find the same tension. This example reinforces the concept that pulleys only change the direction of force without changing the magnitude of the force.

(c) In this balanced system, both objects are at rest. By drawing an FBD for either object, you will get exactly the same result for the tension. This result is contrary to what most people would expect. Most people would incorrectly say the string is holding up twice as much mass and should have twice the tension. Others incorrectly think the tension is zero since both forces of gravity pull the string at each end and they should cancel. Neither statement is true. The second object is just providing the force necessary to hold up the first object. In other words, the second object is just doing the job of the wall or beam, but otherwise the situation is unchanged.

(Pulleys just change the direction of the force.

The tension force in an unbroken rope is constant along its length.)

Three sleds are tied together and pulled east across an icy surface with an applied force of 120 N [E] (**Figure 6**). The mass of sled 1 is 12.0 kg, the mass of sled 2 is 11.0 kg, and the mass of sled 3 is 7.0 kg. You may assume that no friction acts on the sleds.

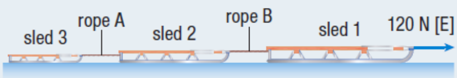


Figure 6

(a) Determine the acceleration of the sleds.

(b) Calculate the magnitude of the tension in rope A.

(c) Calculate the magnitude of the tension in rope B.

1. Draw a FBD, choose your positive directions
2. Write an F_{net} equation based on the DIAGRAM
3. Substitute values and F=ma into the F_{net} equation

Practice

(Pause and Try)

1. Examine each diagram in **Figure 8**. In each situation, which rope will have the greater tension? Explain your reasoning. K/U
2. A locomotive with a mass of 6.4×10^5 kg is accelerating at 0.12 m/s^2 [W] while pulling a train car with a mass of 5.0×10^5 kg. Assume that negligible friction is acting on the train. T/I
   (a) Calculate the net force on the entire train.
   (b) Determine the magnitude of the tension between the locomotive and the train car.

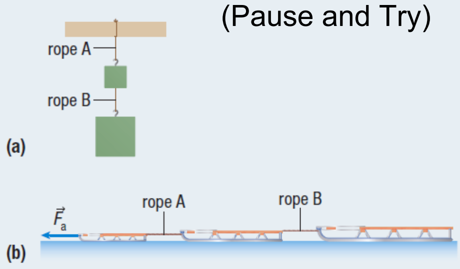


Figure 8

1. Draw a FBD, choose your positive directions
2. Write an F_{net} equation based on the DIAGRAM
3. Substitute values and F=ma into the F_{net} equation

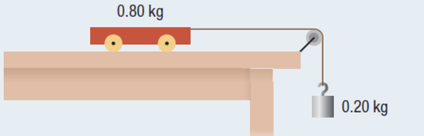
Acceleration of Falling Objects (2 different directions - using parts and system)

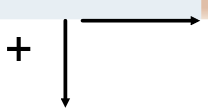
Sample Problem 1 (from Section 3.3)

In an investigation, students place a 0.80 kg cart on a table. They tie one end of a light string to the front of the cart, run the string over a pulley, and then tie the other end to a 0.20 kg hanging object (**Figure 6**). Assume that no friction acts on either object.

(a) Determine the magnitude of the acceleration of the cart and the hanging object.

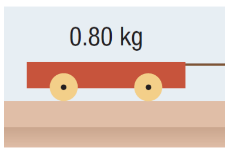
(b) Calculate the magnitude of the tension.





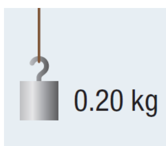
to accommodate the 2 different directions of motion, we will set the positive direction to be in the direction of travel of both the cart and the mass - we could use the standard convention but we would have to revisit the direction of F_{net} on the hanging mass

Free Body Diagrams



$$F_{Net} = F_T$$

$$m_1 a = F_T$$

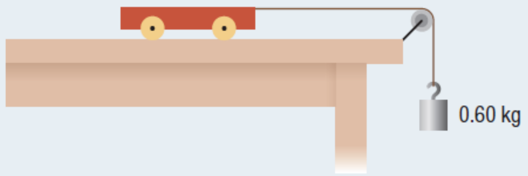


$$F_{Net} = F_g - F_T$$

$$m_2 a = m_2 g - F_T$$

Practice

1. Calculate the acceleration of the cart in **Figure 7**, given the following assumptions. T/I
   (a) No friction is acting on the cart.
   (b) A force of friction of 0.50 N acts on the cart opposite to the motion.



3.5 Questions

Section 3.5

#1 - 4

1. You hold one end of a rope and pull horizontally with a force of 65 N. Calculate the tension in the rope if the other end is
   (a) tied to a wall
   (b) held by a friend who pulls with 65 N in the opposite direction
   (c) tied to a 12 kg object on smooth ice T/I
2. A 72 kg sled is pulled forward from rest by a snowmobile and accelerates at 2.0 m/s^2 [forward] for 5.0 s. The force of friction acting on the sled is 120 N [backwards]. The total mass of the snowmobile and driver is 450 kg. The drag force acting on the snowmobile is 540 N [backwards]. T/I
   (a) Determine the tension in the rope.
   (b) Calculate the force exerted by the snowmobile that pushes the sled forward.
3. Two people, each with a mass of 70 kg, are wearing inline skates and are holding opposite ends of a 15 m rope. One person pulls forward on the rope by moving hand over hand and gradually reeling in more of the rope. In doing so, he exerts a force of 35 N [backwards] on the rope. This causes him to accelerate toward the other person. Assuming that the friction acting on the skaters is negligible, how long will it take for them to meet? Explain your reasoning. T/I
4. A 1200 kg car pulls an 820 kg trailer over a rough road. The force of friction acting on the trailer is 650 N [backwards]. Calculate the force that the car exerts on the trailer if
   (a) the trailer is moving at a constant velocity of 30 km/h [forward]
   (b) the trailer is moving at a constant velocity of 60 km/h [forward]
   (c) the trailer is moving forward at 60 km/h and starts accelerating at 1.5 m/s^2 [forward]
   (d) the trailer is moving forward at 60 km/h and starts accelerating at 1.2 m/s^2 [backwards] T/I
5. An old rope can now only safely suspend 120 kg. When the rope is tied to a beam, it hangs down with a vertical length of 12.0 m. Calculate the minimum time required for an 85 kg person starting from rest to climb the entire length of the rope without breaking it. T/I
6. Three dynamics carts have force sensors placed on top of them. Each force sensor is tied to a string that connects all three carts together (**Figure 10**). You use a sixth force sensor to pull the three dynamics carts forward. The reading on force sensor 2 is 3.3 N. Assume that the force sensors are light and that there is negligible friction acting on the carts. T/I

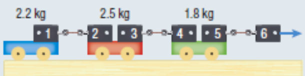


Figure 10

   (a) What is the acceleration of all the carts?
   (b) What is the reading on each force sensor?
   (c) What force are you applying to force sensor 6?
7. A locomotive (6.4×10^5 kg) is used to pull two railway cars (**Figure 11**). Railway car 1 (5.0×10^5 kg) is attached to railway car 2 (3.6×10^5 kg) by a locking mechanism. A railway engineer tests the mechanism and estimates that it can only withstand 2.0×10^5 N of force. Determine the maximum acceleration of the train that does not break the locking mechanism. Explain your reasoning. Assume that friction is negligible. T/I C

Figure 11

8. A skier (68 kg) starts from rest but then begins to move downhill with a net force of 92 N for 8.2 s. The hill levels out for 3.5 s. On this part of the hill, the net force on the skier is 22 N [backwards]. T/I
   (a) Calculate the speed of the skier after 8.2 s.
   (b) Calculate the speed of the skier at the end of the section where the hill levels out.
   (c) Calculate the total distance travelled by the skier before coming to rest.