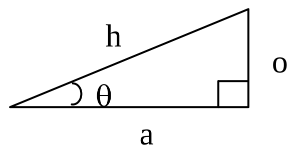
Portland State University
General Physics Workshop
Problem Set 3

Newton's laws

Equations and Relations:

Trigonometry:

sin θ = o/h
cos θ = a/h
tan θ = o/a



$a^2 + o^2 = h^2$

Kinematics

- Average Speed = distance traveled / time elapsed
- Instantaneous Velocity = slope of tangent to x-t graph
- Instantaneous Acceleration = slope of tangent to v-t graph
- Average Velocity:
  $$\bar{v} = \Delta x / \Delta t = (x_2 - x_1) / \Delta t$$
- Average Acceleration:
  $$\bar{a} = \Delta v / \Delta t = (v_2 - v_1) / \Delta t$$

Newton's Laws:

- 1st: An object will stay at rest or in motion with constant velocity unless acted on by a net force.
- 2nd: $\Sigma F_x = ma_x, \quad \Sigma F_y = ma_y$
- 3rd: Forces come in pairs. If A exerts a force on B, then B exerts a force on A with the same magnitude but in the opposite direction.

Friction: $f_s \le \mu_s N, \quad f_k = \mu_k N$

Weight: $F_g = mg$

1. On a horizontal road, a Lamborghini Diablo can accelerate from 0-60 mph with an average acceleration of about 6.8 m/s^2.

   (a) Assuming the mass of the car to be 1000 kg, what is the average net force on it as it accelerates, and how does this compare to the car's weight?
   (b) Approximately how many *pounds* of force is this? (Recall that 1 N ≈ ¼ lb.)
   (c) Think carefully before answering the following: describe and name the force that causes the car to accelerate forward.
   (d) Draw a sketch of the car and use an arrow to represent each force acting on it as it accelerates. Neglect air resistance, and don't include forces exerted *by the car* on other things. [A sketch like this is called a free-body diagram (FBD).]
   (e) Determine the magnitude (size) of each force on your sketch by applying Newton's 2nd Law to your FBD. Give your answers in Newtons.

Check Point

- *Why do you suppose you were asked about the average net force on the car in (a)?*
- *What does the word "normal" in "normal force" mean?*

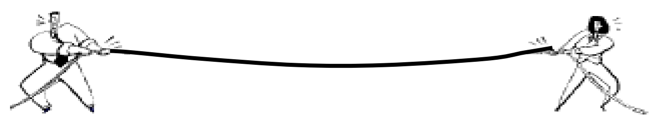
2. Make free-body diagrams showing the forces on the Lamborghini in the following situations:

   (a) The car is on a horizontal road, slowing down in order to stop at a red light.
   (b) The car is going down an uncurved hill at constant speed.
   (c) The car is parked on a steep hill in San Francisco, facing uphill.
   (d) Johnny has accidentally driven the car over the side of a bridge. Make your diagram for the time during which the car is falling through the air.

Check Point

- *Why don't forces like the "engine force" or "force of brakes" get included on your free-body diagrams for the car?*

3. Two people of about equal strength are having a tug of war with a rope:



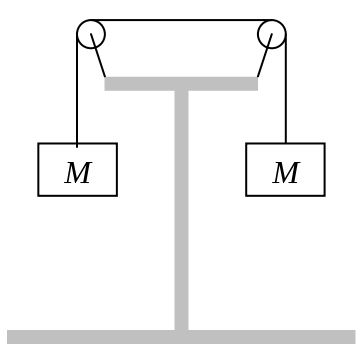
   (a) Since the tension in the rope is the same for each person, how can anyone ever win the tug of war? Which force or forces determine the winner?

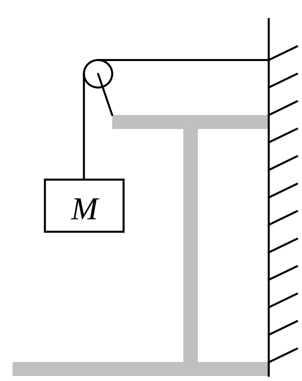
   (b) As the people pull harder and harder, the tension in the rope increases and the rope sags less and less in the middle. If they pull hard enough, can they cause the rope to become perfectly horizontal? (Hint: make a free-body diagram of the rope.)

Check Point

- *Is a tug of war really a test of strength? What is it a test of?*
- *A dog musher asks his dogs to pull the sled. The dogs refuse, referring to Newton's 3rd Law in their defense. They feel that since the sled will pull on them with the same force that they exert on it, they won't be able to go anywhere. "If we can never exert a forward force on the sled which is greater than the backward force it exerts on us, how can we ever get the sled moving?", asks the lead dog. Discuss the validity of this defense with your group, and construct a counterargument using Newton's Laws.*

4. Which of the following situations results in a greater tension in the string? In both cases, the strings can be considered massless and the pulleys frictionless. Prove your answer using Newton's Laws.

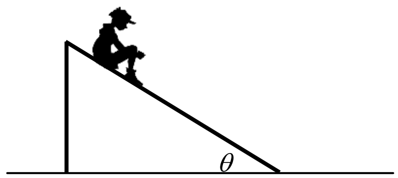




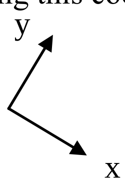
5. A 4.0-kg block is at rest on a horizontal floor. If you push horizontally on the 4.0-kg block with a force of 12.0 N, it just starts to move. (a) What is the coefficient of static friction? (b) A 7.0-kg block is stacked on top of the 4.0-kg block. What is the magnitude F of the force, acting horizontally on the 4.0-kg block as before, that is required to make the two blocks start to move?

6. A heavy lifting crane is being used to stack cargo containers on the deck of a ship. The heaviest container weighs 10 tons (= 20,000 pounds = 89,000 Newtons). How much force should the crane's cable be able to support if it lifts this container with an upward acceleration of 1 m/s^2? (Hint: make a FBD of the container.)

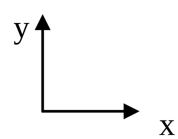
7. A child slides down a frictionless ramp as shown... The child's mass = M, and the angle of ramp with the horizontal = θ. Use Newton's 2nd Law to find the acceleration of the child down the ramp…



(a) …using this coordinate system:



(b) … using this coordinate system:



Check Point

- *According to your answer, who would slide down a frictionless slide faster: an oversized fifth grader, or a four year-old child?*

8. At the end of a long day of skiing, you are coasting down an easy slope at constant velocity. Your mass is M, and the slope makes an angle θ above the horizontal. There are no numbers in this problem, so write all of your equations in terms of the "known" quantities M, θ and g.

   (a) Make a FBD for the skier, including a convenient coordinate system.
   (b) Write out Newton's 2nd Law in each direction.
   (c) In terms of M, θ and g, find an expression for the combined force of friction and air resistance that opposes the motion down the slope.
   (d) In terms of M, θ and g, find an expression for the normal force between the skier and the slope.

Check Point

- *Under what conditions is the normal force on an object equal to the object's weight?*
- *In practice, how does a skier remain moving at constant speed?*
- *Do your answers make sense in the limiting cases $\theta = 0$ and $\theta = 90°$?*

Additional Questions

1. When driving, what are the different ways you know to accelerate your car? Come up with as many as possible.
2. You see a $20 bill on the ground, and run forward to get it. What force accelerated you forward, and why?
3. If a mosquito hits your windshield, which is greater, the force of your car on the mosquito, or the force of the mosquito on your car? Which accelerates more during the collision, the car or the mosquito
4. In choosing a coordinate system to use along with a free-body diagram, what should your primary considerations be?