Physics 02-01 Newton's Laws **Name: ______________________**

Force

- A ____________ or a ____________
- Is a ____________
- Unit: ____________ (N)
- Measured by a ________________________

Newton's First Law of Motion

A body at ____________ remains at ____________, or, if in motion, remains in ____________ at a ____________ unless acted on by a net external ____________.

Inertia

- Property of objects to remain in ____________ motion or rest.
- ____________ is a measure of inertia

Newton's Second Law of Motion

Acceleration of a system is directly proportional to and in the same ____________ of as the net ____________ and inversely proportional to the ____________.

$$a = \frac{F_{net}}{m} \text{ or } F_{net} = ma$$

Newton's Third Law of Motion

Whenever one body exerts a ____________ on a second body, the first body experiences a force that is equal in ____________ and opposite in ____________ to the force that it exerts.
Every force has an equal and opposite reaction force.

A football player named Al is blocking a player on the other team named Bob. Al applies a 1500 N force on Bob. If Bob's mass is 100 kg, what is his acceleration?

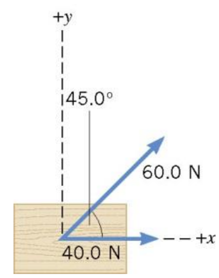
What is the size of the force on Al?

If Al's mass is 75 kg, what is his acceleration?

A 0.046 kg golf ball hit by a driver can accelerate from rest to 67 m/s in 1 ms while the driver is in contact with the ball. How much average force does the golf ball experience?

Physics 02-01 Newton's Laws	***Name: __________________________***
Homework	

1. Forces are vectors. Look back in previous lessons and explain how to add vectors.
2. You are riding in a car when it turns to the left abruptly. Why do you feel like you are being forced to the right?
3. Which statement is correct? (a) Net force causes motion. (b) Net force causes change in motion. Explain your answer and give an example.
4. A system can have a nonzero velocity while the net external force on it is zero. Describe such a situation.
5. An airplane has a mass of 3.1×10^4 kg and takes off under the influence of a constant net force of 3.7×10^4 N. What is the net force that acts of the plane's 78-kg pilot? (Cutnell 4.1) **93 N**
6. In the amusement park ride known as Magic Mountain Superman, powerful magnets accelerate a car and its riders from rest to 45 m/s (about 100 mph) in a time of 7.0 s. The mass of the car and riders is 5.5×10^3 kg. Find the average net force exerted on the car and riders by the magnets. (Cutnell 4.3) $\mathbf{3.5 \times 10^4}$ **N**
7. When a 58-g tennis ball is served, it accelerates from rest to a speed of 45 m/s. The impact with the racket gives the ball a constant acceleration over a distance of 44 cm. What is the magnitude of the net force acting on the ball? (Cutnell 4.5) **130 N**
8. A 1580-kg car is traveling with a speed of 15.0 m/s. What is the magnitude of the net force that is required to bring this car to a halt in a distance of 50.0 m? (Cutnell 4.6) **3560 N**
9. A person with a black belt in karate has a fist that has a mass of 0.70 kg. Starting from rest, this fist attains a velocity of 8.0 m/s in 0.15 s. What is the magnitude of the average net force applied to the fist to achieve this level of performance? (Cutnell 4.7) **37 N**
10. A 350-kg sailboat has an acceleration of 0.62 m/s^2 at an angle of 64° north of east. Find the magnitude and direction of the net force that acts on the sailboat. (Cutnell 4.12) **220 N at 64° N of E**
11. A force vector has a magnitude of 720 N and a direction of 38° N of E. Determine the magnitude and direction of the components of the force that point along the N-S line and the E-W line. (Cutnell 4.10) **440N, 570N**
12. Only two forces act on an object (mass = 3.00 kg), as in the drawing. Find the magnitude and direction (relative to the x axis) of the acceleration of the object. (Cutnell 4.13) **30.9** $\mathbf{m/s^2}$ **at 27.2° above x axis**



13. What net external force is exerted on a 1100-kg artillery shell fired from a battleship if the shell is accelerated at $2.40 \times 10^4\ m/s^2$? What force is exerted on the ship by the artillery shell? (OpenStax 4.15) $\mathbf{2.64 \times 10^7}$ **N,** $\mathbf{2.64 \times 10^7}$ **N**
14. Find the net force for the following forces: 3 N East, 2 N West, 5 N North, and 4 N South. (RW) **1.41 N at 45° N of E**
15. Find the net force for the following forces: 10 N up and 14 N at 30° above the horizontal. (RW) **20.9 N at 54.5° above horizontal**

Physics 02-02 Weight and Gravity **Name: ____________________**

Weight

- Force of __________ ($F = ma$)
- Objects near earth __________ downward at 9.80 m/s²

$$W = mg$$

- Unit: N
- Depends on local __________

Mass

- Measure of __________
- Unit: kg
- __________

Newton's Law of Universal Gravitation

Every __________ in the universe exerts a __________ on every other

$$F_G = \frac{Gm_1m_2}{r^2}$$

where:

$G = 6.673 \times 10^{-11} \frac{Nm^2}{kg^2}$

m_1 and m_2 = __________ of the objects

r = __________ between the __________ of the objects

What is the gravitational attraction between a 75-kg boy (165 lbs) and the 50-kg girl (110 lbs) seated 1 m away in the next desk?

Finding Acceleration Due to Gravity

Since weight is the __________ of __________

$$W = mg = \frac{Gmm_E}{r_E^2}$$

$$g = \frac{Gm_E}{r_E^2}$$

Force Problem Solving Strategy

1. Identify the ________________ involved and __________ a __________
2. List your ____________ and __________ a ______________ diagram
3. Apply __________
4. Check your __________ for ________________

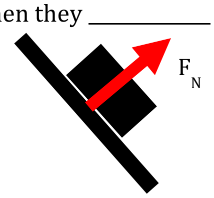
Free-body diagram

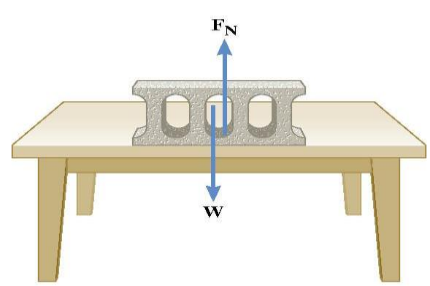
Draw only __________ acting _________ the object

Represent the forces with vector __________

Normal Force

- ____________________component force between two objects when they __________
- Weight pushes __________, so the table pushes __________
- Newton's __________Law
- Normal force doesn't always = weight
- Draw a ______________ diagram to find ________________



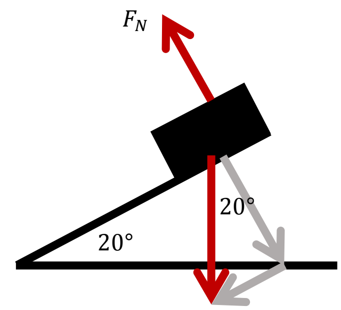


When a problem asks for apparent weight, find the __________________________

A lady is weighing some bananas in a grocery store when the floor collapses. If the bananas mass is 2 kg and the floor is accelerating at -2.25 m/s², what is the apparent weight (normal force) of the bananas?

Physics 02-02 Weight and Gravity **_Name: _____________________**

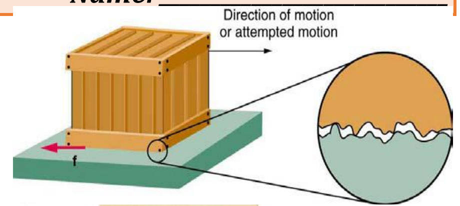
A box is sitting on a ramp angled at 20°. If the box weighs 50 N, what is the normal force on the box?



Homework

1. A rock is thrown straight up. What is the net external force acting on the rock when it is at the top of its trajectory?
2. When a body is moved from sea level to the top of a mountain, what changes—the body's mass, its weight, or both?
3. Object A weighs twice as much as object B at the same spot on the earth. Would the same be true at a given spot on Mars? Explain.
4. A bowling ball (mass = 7.2 kg, radius = 0.11 m) and a billiard ball (mass = 0.38 kg, radius = 0.028 m) may each be treated as uniform spheres. What is the magnitude of the maximum gravitational force that each can exert on the other? (Cutnell 4.18) $\mathbf{9.6 \times 10^{-9}\ N}$
5. On earth, two parts of a space probe weight 11000 N and 3400 N. These parts are separated by a center-to-center distance of 12 m and may be treated as uniform spherical objects. Find the magnitude of the gravitational force that each part exerts on the other out in space, far from any other objects. (Cutnell 4.19) $\mathbf{1.8 \times 10^{-7}\ N}$
6. A space traveler whose mass is 115 kg leaves earth. What are his weight and mass (a) on earth and (b) in interplanetary space where there are no nearby planetary objects? (Cutnell 4.21) **m=115 kg, W=1130 N; m=115 kg, W=0 N**
7. What is the acceleration due to gravity on the surface of the Moon? (OpenStax 6.35a) **1.62 $\mathbf{m/s^2}$**
8. What is the acceleration due to gravity on the surface of Mars? The mass of Mars is 6.418×10^{23} kg and its radius is 3.38×10^{6} m. (OpenStax 6.35b) **3.75 $\mathbf{m/s^2}$**
9. (a) Calculate the acceleration due to gravity on the surface of the Sun. (b) By what factor would your weight increase if you could stand on the Sun? (Never mind that you cannot.) (OpenStax 6.36) **274 $\mathbf{m/s^2}$, 28 times**
10. What is the acceleration due to gravity as an altitude of 2.0×10^{6} m above the earth's surface? (RW) **5.68 $\mathbf{m/s^2}$**
11. A rock of mass 45 kg accidentally breaks loose from the edge of a cliff and falls straight down. The magnitude of the air resistance that opposes its downward motion is 250 N. What is the magnitude of the acceleration of the rock? (Cutnell 4.20) **4.2 $\mathbf{m/s^2}$**
12. A 35-kg crate rests on a horizontal floor, and a 65-kg person is standing on the crate. Determine the magnitude of the normal force that (a) the floor exerts on the crate and (b) the crate exerts on the person. (Cutnell 4.34) **980 N, 640 N**
13. A rocket blasts off from rest and attains a speed of 45 m/s in 15 s. An astronaut has a mass of 57 kg. What is the astronaut's apparent weight during takeoff? (Cutnell 4.35) **730 N**
14. A 50-kg woman is riding on an elevator. What is her apparent weight when it is accelerating upward at 1.5 m/s^2? (RW) **565 N**
15. What is the apparent weight of a 80-kg man riding tower drop ride that is accelerating at 8.9 m/s^2 downward? (RW) **72 N**
16. A 5-kg block rests on a frictionless plane inclined at 10°. What is the acceleration of the block as it slides down the incline? (RW) **1.70 $\mathbf{m/s^2}$**
17. A 0.05-kg cookie is on a non-stick (frictionless) cookie sheet inclined at 30°. What is the acceleration of the cookie as it slides down the cookie sheet? If the cookie sheet is 0.75 m long, how much time to you have to catch the cookie before it falls off the edge (Note: This is a review question.)? (RW) **4.9 $\mathbf{m/s^2}$, 0.55 s**

Physics 02-03 Friction **Name:** ____________________



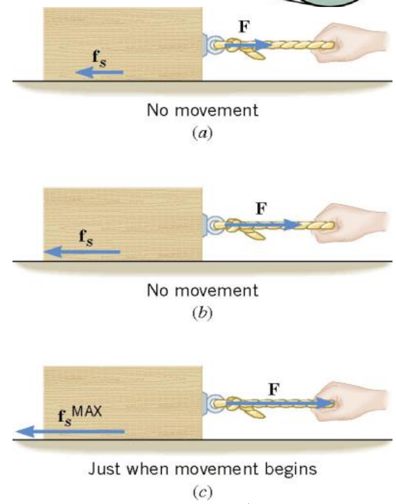
Normal force – _________________________ to surface

Friction force – _____________ to surface, and _____________ motion

Comes from __________________________

Not well understood

Static Friction



Keeps things from _________.

Cancels out ____________ force until the applied force gets too _________.

Depends on force pushing _________ and ___________________ of surface.

$$f_s \leq \mu_s F_N$$

μ_s is _________ _________ of static friction (0.01 to 1.5)

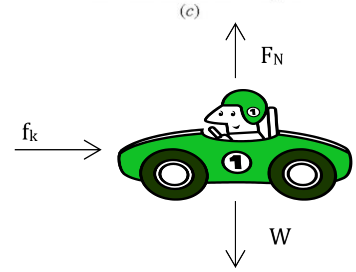
Kinetic Friction

Once motion _________

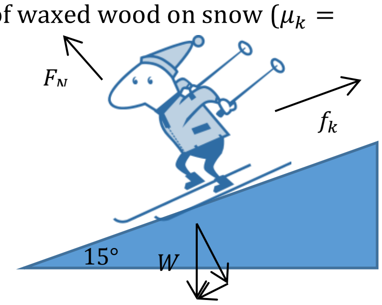
$$f_k = \mu_k F_N$$

f_k is usually _______________ f_s

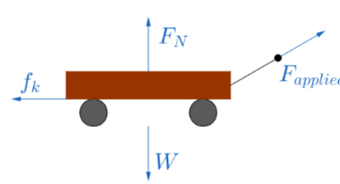
A car skids to a stop after initially going 30.0 m/s. μ_k = 0.800. How far does the car go before stopping?



A 65-kg skier is coasting downhill on a 15° slope. Assuming the coefficient of friction is that of waxed wood on snow (μ_k = 0.1), what is the skier's acceleration?



While hauling firewood to the house, you pull a 100-kg wood-filled wagon across level ground at a constant velocity. You pull the handle with a force of 230 N at 30° above the horizontal. What is the coefficient of friction between the wagon and the ground?



Physics 02-03 Friction	**_Name: ______________________**
Homework	

1. A box rests on the floor of an elevator. Because of static friction, a force is required to start the box sliding across the floor when the elevator is (a) stationary, (b) accelerating upward, and (c) accelerating downward. Rank the forces required in these three situations from smallest to largest.
2. Define normal force. What is its relationship to friction?
3. When you learn to drive, you discover that you need to let up slightly on the brake pedal as you come to a stop or the car will stop with a jerk. Explain this in terms of the relationship between static and kinetic friction.
4. A block whose weight is 45.0 N rests on a horizontal table. A horizontal force of 36.0 N is applied to the block. The coefficients of static and kinetic friction are 0.650 and 0.420, respectively. Will the block move under the influence of the force, and, if so, what will be the block's acceleration? (Cutnell 4.37) **3.72 m/s²**
5. A 20.0-kg sled is being pulled across a horizontal surface at a constant velocity. The pulling force has a magnitude of 80.0 N and is directed at an angle of 30.0° above the horizontal. Determine the coefficient of kinetic friction. (Cutnell 4.39) **0.444**
6. A cup of hot chocolate is sitting on the dashboard of a car that is traveling at a constant velocity. The coefficient of static friction between the cup and the dashboard is 0.30. Suddenly, the car accelerates. What is the maximum acceleration that he car can have without the cup sliding backward off the dashboard? (RW) **2.94 m/s²**
7. An 81-kg baseball player slides into second base. The coefficient of kinetic friction between the player and the ground is 0.49. (a) What is the magnitude of the frictional force? (b) If the player comes to rest after 1.6 s, what was his initial velocity? (Review) (RW) **389 N, 7.68 m/s**
8. What is the maximum frictional force (μ =0.016) in the knee joint of a person who supports 66.0 kg of her mass on that knee? (OpenStax 5.3) **10 N**
9. Suppose you have a 120-kg wooden crate resting on a wood floor (μ_s = 0.5, μ_k = 0.3). (a) What maximum force can you exert horizontally on the crate without moving it? (b) If you continue to exert this force once the crate starts to slip, what will its acceleration then be? (OpenStax 5.4) **588 N, 1.96 m/s²**
10. (a) If half of the weight of a small 1.00×10^3 kg utility truck is supported by its two drive wheels, what is the maximum acceleration it can achieve on dry concrete ($\mu_s = 1.0$)? (b) Will a metal cabinet lying on the wooden bed of the truck slip if it accelerates at this rate ($\mu_s = 0.5$)? (OpenStax 5.5) **4.9 m/s², No**
11. Calculate the deceleration of a snow boarder going up a 5.0° slope assuming the coefficient of friction for waxed wood on wet snow ($\mu_k = 0.1$). (OpenStax 5.10) **1.83 m/s²**
12. (a) Calculate the acceleration of a skier heading down a 10.0° slope, assuming the coefficient of friction for waxed wood on wet snow ($\mu_k = 0.1$). (b) Find the angle of the slope down which this skier could coast at a constant velocity. (OpenStax 5.11) **0.737 m/s², 5.71°**
13. A contestant in a winter sporting event pushes a 45.0-kg block of ice across a frozen lake as shown in the picture ($\mu_s = 0.1, \mu_k = 0.03$). (a) Calculate the minimum force F he must exert to get the block moving. (b) What is its acceleration once it starts to move, if that force is maintained? (OpenStax 5.18) **51.0 N, 0.720 m/s²**

Physics 02-04 Tension, Hooke's Law, Drag, and Equilibrium   Name: ____________________

Hooke's Law

For ____________ or forces that ____________ (change shape)

For ____________ deformations (no permanent change)

$$F_S = k\Delta x$$

k = __________________________ and is unique to each spring

Δx = the ____________ the spring is stretched/compressed

Hooke's Law is the reason we can use a ____________ scale to measure ____________

Tension

____________ force from rope, chain, etc.

____________ the rope connects to something, there is an ____________ tension

Drag

____________ force from moving through a ____________

Size depends on area, speed, and properties of the fluid

For ____________ objects

$$F_D = \frac{1}{2}C\rho A v^2$$

Where

C = ____________ coefficient

ρ = ____________ of the fluid

A = ____________________ area of the object

v = ____________ of the object relative to the fluid

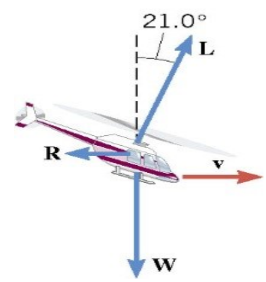
Equilibrium

No ____________

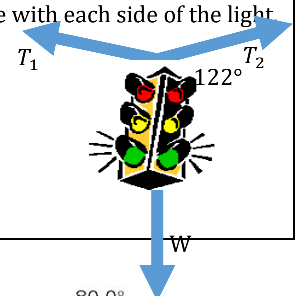
$$F_{net} = ma \rightarrow F_{net} = 0$$

Find the terminal velocity of a falling mouse in air (A=0.004 m^2, m=0.02 kg, C=0.5) and a human falling flat in air (A=0.7 m^2, m=85 kg, C=1.0). The density of air is 1.21 kg/m^3.

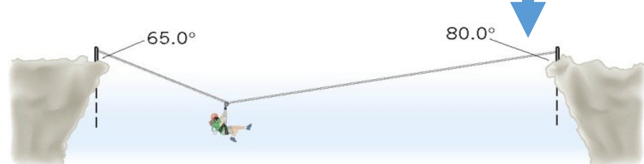
The helicopter in the drawing is moving horizontally to the right at a constant velocity. The weight of the helicopter is 53,800 N. The lift force L generated by the rotating blade makes an angle of 21.0° with respect to the vertical. What is the magnitude of the lift force?



A stoplight is suspended by two cables over a street. Weight of the light is 110 N and the cables make a 122° angle with each side of the light. Find the tension in each cable.



A mountain climber, in the process of crossing between two cliffs by a rope, pauses to rest. She weighs 535 N. Find the tensions in the rope to the left and to the right of the mountain climber.



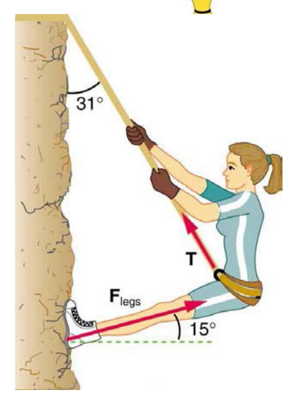
Physics 02-04 Tension, Hooke's Law, Drag, and Equilibrium *Name: ______________________*

A 10-g toy plastic bunny is connected to its base by a spring. The spring is compressed and a suction cup on the bunny holds it to the base so that the bunny doesn't move. If the spring is compressed 3 cm and has a constant of 330 N/m, how much force must the suction cup provide?

Homework

1. A stone is thrown from the top of a cliff. As the stone falls, is it in equilibrium?
2. During the final stages of descent, a sky diver with an open parachute approaches the ground with a constant velocity. The wind does not blow him from side to side. Is the sky diver in equilibrium, and if so, what forces are responsible for the equilibrium?
3. Why can a squirrel jump from a tree branch to the ground and run away undamaged, while a human could break a bone in such a fall?
4. A supertanker ($m = 1.70 \times 10^8$ kg) is moving with a constant velocity. Its engines generate a forward thrust of 7.40×10^5 N. Determine (a) the magnitude of the resistive force exerted on the tanker by the water and (b) the magnitude of the upward buoyant force exerted on the tanker by the water. (Cutnell 4.47) $\mathbf{7.40 \times 10^5}$ **N,** $\mathbf{1.67 \times 10^9}$ **N**
5. A stuntman is being pulled along a rough road at a constant velocity, by a cable attached to a moving truck. The cable is parallel to the ground. The mass of the stuntman is 109 kg, and the coefficient of kinetic friction between the road and him is 0.870. Find the tension in the cable.(Cutnell 4.51) **929 N**
6. (a) Calculate the tension in a vertical strand of spider web if a spider of mass 8.00×10^{-5} kg hangs motionless on it. (b) Calculate the tension in a horizontal strand of spider web if the same spider sits motionless in the middle of it. The strand sags at an angle of 12° below the horizontal. (OpenStax 4.19) $\mathbf{7.84 \times 10^{-4}}$ **N,** $\mathbf{1.89 \times 10^{-3}}$ **N**
7. Superhero and Trusty Sidekick hanging motionless from a rope. Superhero's mass is 90.0 kg, while Trusty Sidekick's is 55.0 kg, and the mass of the rope is negligible. (a) Draw a free-body diagram of the situation showing all forces acting on Superhero, Trusty Sidekick, and the rope. (b) Find the tension in the rope above Superhero. (c) Find the tension in the rope between Superhero and Trusty Sidekick. (OpenStax 4.34)**1420 N, 539 N**

8. Consider the 52.0-kg mountain climber in the picture. (a) Find the tension in the rope and the force that the mountain climber must exert with her feet on the vertical rock face to remain stationary. Assume that the force is exerted parallel to her legs. Also, assume negligible force exerted by her arms. (b) What is the minimum coefficient of friction between her shoes and the cliff? (OpenStax 5.17) **273 N, 512 N; 0.268**



9. A monkey (m = 4 kg)is in a harness connected to a rope that goes up over a pulley on the ceiling. If the monkey pulls on the other end of the rope, it will go up. It is the climbing at a constant velocity, what is the tension in the rope? (RW) **19.6 N**
10. A toy dart gun uses a spring to shoot a dart. (a) If you have to use 25 N to compress the spring 6 cm, what is the spring constant? (b) If it fires a 50-g dart, what will be the acceleration of the dart assuming no air resistance? (RW) **417 N/m, 500 m/s²**
11. An 80-kg bungee jumper jumps off a bridge. Rubber bungee cords act as a large spring attaching the jumper to the bridge. A bear standing in the river below catches the jumper. If the spring constant of the bungees is 20 N/m and they stretch 50 m. How much force must the bear apply to keep the jumper from moving? (RW) **216 N**
12. To maintain a constant speed, the force provided by a car's engine must equal the drag force plus the force of friction of the road (the rolling resistance). (a) What are the drag forces at 100 km/h for a Toyota Camry? (Drag area is 0.70 m^2; C = 0.28) (b) If the friction is 235 N, what is force the engine provides to maintain a constant velocity? (RW) **91.5 N, 327 N**
13. The terminal velocity of a person falling in air depends upon the weight and the area of the person facing the fluid. Find the terminal velocity (in meters per second) of an 80.0-kg skydiver falling in a pike (headfirst) position with a cross-sectional area of 0.140m^2 and C = 0.70. (OpenStax 5.20) **115 m/s**
14. A 560-g squirrel with a cross-sectional area of 144 cm^2 falls from a 5.0-m tree to the ground C = 1.0. Estimate its terminal velocity. What will be the velocity of a 56-kg person hitting the ground, assuming no drag contribution in such a short distance? (Review) (OpenStax 5.22) **25.1 m/s, 9.90 m/s**

Physics 02-05 Nonequilibrium and Fundamental Forces *Name: ___________________________*

Four Basic Forces

All forces are made up of only _____________ forces

- __________________________– gravity
- ____________________– static electricity, magnetism
- __________________________– radioactivity
- __________________________– keeps nucleus of atoms together

All forces occur because _____________ with that force _____________play _____________with a different ____________

- Electromagnetic uses _____________
- Scientists are trying to combine all forces together in __________________________
- Have combined _______________________________________

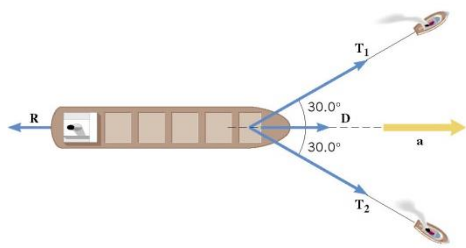
_____________ is the weakest

We feel it because the electromagnetic _____________ out over _____________ areas

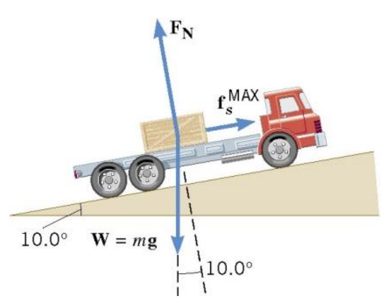
_____________ forces are _____________ but only over _____________ distance

A 1380-kg car is moving due east with an initial speed of 27.0 m/s. After 8.00 s the car has slowed down to 17.0 m/s. Find the magnitude and direction of the net force that produces the deceleration.

A supertanker of mass $m = 1.50 \times 10^8$ kg is being towed by two tugboats, as in the picture. The tensions in the towing cables apply the forces T_1 and T_2 at equal angles of 30.0° with respect to the tanker's axis. In addition the tanker's engines produce a forward drive force D, whose magnitude is $D = 75.0 \times 10^3$ N. Moreover, the water applies an opposing force R, whose magnitude is $R = 40.0 \times 10^3$ N. The tanker moves forward with an acceleration of 2.00×10^{-3} m/s². Find the magnitudes of the tensions T_1 and T_2.

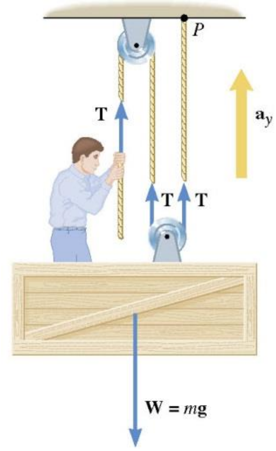


A flatbed truck is carrying a crate up a 10.0° hill as in the picture. The coefficient of the static friction between the truck bed and the crate is $\mu_s = 0.350$. Find the maximum acceleration that the truck can attain before the crate begins to slip backward relative to the truck.



Physics 02-05 Nonequilibrium and Fundamental Forces *Name:* ___________________________

A window washer on a scaffold is hoisting the scaffold up the side of a building by pulling downward on a rope, as in the picture. The magnitude of the pulling force is 540 N, and the combined mass of the worker and the scaffold is 155 kg. Find the upward acceleration of the unit.



Homework

1. A circus performer hangs stationary from a rope. She then begins to climb upward by pulling herself up, hand over hand. When she starts climbing, is the tension in the rope less than, equal to, or greater than it is when she hangs stationary? Explain.
2. Only two forces act on an object (m = 4.00 kg): 60.0 N in the +y direction and 40.0 N in the +x direction. Find the magnitude and direction (relative to the x axis) of the acceleration of the object. (Cutnell 4.63) **18 m/s² at 56.3°**
3. A falling skydiver has a mass of 110 kg. What is the magnitude of the skydiver's acceleration when the upward force of air resistance (drag) has C = 1.0, A = 0.85 m², and v = 11 m/s? (RW) **9.23 m/s²**
4. A 292-kg motorcycle is accelerating up along a ramp that is inclined at 30.0° above the horizontal. The propulsion force pushing the motorcycle up the ramp is 3150 N, and air resistance produces a force of 250 N that opposes the motion. Find the magnitude of the motorcycle's acceleration. (Cutnell 4.68) **5.03 m/s²**
5. A rescue helicopter is lifting a man (weight = 822 N) from a capsized boat by means of a cable and harness. (a) What is the tension in the cable when the man is given an initial upward acceleration of 1.10 m/s²? (b) What is the tension during the remainder of the rescue when he is pulled upward at a constant velocity? (Cutnell 4.70) **914 N, 822 N**
6. To hoist himself into a tree, a 72.0-kg man ties one end of a nylon rope around his waist and throws the other end over a branch of the tree. He then pulls downward on the free end of the rope with a force of 358 N. Neglect any friction between the rope and the branch, and determine the man's upward acceleration. (Cutnell 4.75) **0.14 m/s²**
7. A 95.0-kg person stands on a scale in an elevator. What is the apparent weight when the elevator is (a) accelerating upward with an acceleration of 1.80 m/s², (b) moving upward at a constant speed, and (c) accelerating downward with an acceleration of 1.30 m/s²? (Cutnell 4.94) **1100 N, 931 N, 808 N**
8. A 15-g bullet is fired from a rifle. It takes 2.50×10^{-3} s for the bullet to travel the length of the barrel, and it exits the barrel with a speed of 715 m/s. Assuming that the acceleration of the bullet is constant, find the average net force exerted on the bullet. (Finding the acceleration is review.) (Cutnell 4.95) **4290 N**
9. Suppose a 60.0-kg gymnast climbs a rope. (a) What is the tension in the rope if he climbs at a constant speed? (b) What is the tension in the rope if he accelerates upward at a rate of 1.50 m/s²? (OpenStax 4.20) **588 N, 678 N**
10. A 5.00×10^{5}-kg rocket is accelerating straight up. Its engines produce 1.250×10^{7} N of thrust, and air resistance is 4.50×10^{6} N. What is the rocket's acceleration? (OpenStax 4.23) **6.20 m/s²**
11. The wheels of a midsize car exert a force of 2100 N backward on the road to accelerate the car in the forward direction. If the force of friction including air resistance is 250 N and the acceleration of the car is 1.80 m/s², what is the mass of the car plus its occupants? (OpenStax 4.24) **1030 kg**
12. Calculate the force a 70.0-kg high jumper must exert on the ground to produce an upward acceleration 4.00 times the acceleration due to gravity. (OpenStax 4.25) **3430 N**
13. A nurse pushes a cart by exerting a force on the handle at a downward angle 35.0° below the horizontal. The loaded cart has a mass of 28.0 kg, and the force of friction is 60.0 N. (a) Draw a free-body diagram for the system of interest. (b) What force must the nurse exert to move at a constant velocity? (OpenStax 4.35) **73 N**

Physics 02-06 Angular Velocity and Centripetal Acceleration **Name: ___________________________**

Uniform Circular Motion

Motion in ___________ with constant ___________

Rotation Angle (Δθ)

___________ through which an object ___________

Arc Length (Δs)

- ___________ around part of a ___________

$$\Delta\theta = \frac{\Delta s}{r}$$

Angle Units

- 1 Circle = 1 revolution
- 1 Circle = 360°
- 1 Circle = 2π radians

Arc length must be in ___________

Convert 60° to radians

Convert 2 revolutions to radians

Angular Velocity (ω)

How fast an object ___________

$$\omega = \frac{\Delta\theta}{\Delta t}$$

Unit: rad/s CCW___________ CW___________

$$v = r\omega$$

A CD rotates 320 times in 2.4 s. What is its angular velocity in rad/s? What is the linear velocity of a point 5 cm from the center?

Centripetal Acceleration

$$a_c = \frac{v^2}{r} = r\omega^2$$

At any given moment

v is pointing ___________ to the circle

a_c is pointing towards the ___________ of the circle

If the object suddenly broke from circular motion would travel in ___________ ___________ to circle

Two identical cars are going around two corners at 30 m/s. Each car can handle up to 1 g. The radius of the first curve is 50m and the radius of the second is 100 m. Do either of the cars make the curve? (Hint: find the a_c)

Physics 02-06 Angular Velocity and Centripetal Acceleration	***Name:*** ________________________
Homework	

1. The speedometer of your car shows you are traveling at a constant speed of 35 m/s. Is it possible that your car is accelerating? If so, explain how this could happen.
2. The equations of kinematics describe the motion of an object that has a constant acceleration. These equations cannot be applied to uniform circular motion. Why not?
3. Is it possible for an object to have an acceleration when the velocity of the object is constant? When the speed of the object is constant? In each case, give your reasoning.
4. There is an analogy between rotational and linear physical quantities. What rotational quantities are analogous to distance and velocity?
5. Can centripetal acceleration change the speed of circular motion? Explain.
6. Microwave ovens rotate at a rate of about 6 rev/min. What is this in revolutions per second? What is the angular velocity in radians per second? (OpenStax 6.2) **0.1 rev/s, 0.63 rad/s**
7. (a) What is the period of rotation of Earth in seconds? (b) What is the angular velocity of Earth? (c) Given that Earth has a radius of 6.4×10^6 m at its equator, what is the linear velocity at Earth's surface? (OpenStax 6.4) **86400 s, $\mathbf{7.3 \times 10^{-5}}$ rad/s, 470 m/s**
8. A baseball pitcher brings his arm forward during a pitch, rotating the forearm about the elbow. If the velocity of the ball in the pitcher's hand is 35.0 m/s and the ball is 0.300 m from the elbow joint, what is the angular velocity of the forearm? (OpenStax 6.5) **117 rad/s**
9. In lacrosse, a ball is thrown from a net on the end of a stick by rotating the stick and forearm about the elbow. If the angular velocity of the ball about the elbow joint is 30.0 rad/s and the ball is 1.30 m from the elbow joint, what is the velocity of the ball? (OpenStax 6.6) **39.0 m/s**
10. A car travels at a constant speed around a circular track whose radius is 2.6 km. The car goes once around the track in 360 s. What is the magnitude of the centripetal acceleration of the car? (Cutnell 5.2) **0.79 m/s²**
11. Computer-controlled display screens provide drivers in the Indianapolis 500 with a variety of information about how their cars are performing. For instance, as a car is going through a turn, a speed of 221 mi/h (98.8 m/s) and a centripetal acceleration of 3.00g (three times the acceleration due to gravity) are displayed. Determine the radius of the turn (in meters). (Cutnell 5.5) **332 m**
12. There is a clever kitchen gadget for drying lettuce leaves after you wash them. It consists of a cylindrical container mounted so that it can be rotated about its axis by turning a hand crank. The outer wall of the cylinder is perforated with small holes. You put the wet leaves in the container and turn the crank to spin off the water. The radius of the container is 12 cm. When the cylinder is rotating at 2.0 rev/s, what is the magnitude of the centripetal acceleration at the outer wall. (Cutnell 5.6) **19 m/s²**
13. Each of the space shuttle's main engines is fed liquid hydrogen by a high-pressure pump. Turbine blades inside the pump rotate at 617 rev/s. A point on one of the blades traces out a circle with a radius of 0.020 m as the blade rotates. (a) What is the magnitude of the centripetal acceleration that the blade must sustain at this point? (b) Express this acceleration as a multiple of g. (Cutnell 5.8) **$\mathbf{3.0 \times 10^5}$ m/s², $\mathbf{3.1 \times 10^4}$ g**
14. A fairground ride spins its occupants inside a flying saucer-shaped container. If the horizontal circular path the riders follow has an 8.00 m radius, at how many revolutions per minute will the riders be subjected to a centripetal acceleration 1.50 times that due to gravity? (OpenStax 6.10) **12.9 rev/min**
15. The propeller of a World War II fighter plane is 2.30 m in diameter. (a) What is its angular velocity in radians per second if it spins at 1200 rev/min? (b) What is the linear speed of its tip at this angular velocity if the plane is stationary on the tarmac? (c) What is the centripetal acceleration of the propeller tip under these conditions? Calculate it in meters per second squared and convert to multiples of g. (OpenStax 6.13) **126 rad/s, 145 m/s, $\mathbf{1.82 \times 10^4}$ m/s, $\mathbf{1.85 \times 10^3}$ g**
16. Olympic ice skaters are able to spin at about 5 rev/s. (a) What is their angular velocity in radians per second? (b) What is the centripetal acceleration of the skater's nose if it is 0.120 m from the axis of rotation? (c) An exceptional skater named Dick Button was able to spin much faster in the 1950s than anyone since—at about 9 rev/s. What was the centripetal acceleration of the tip of his nose, assuming it is at 0.120 m radius? (d) Comment on the magnitudes of the accelerations found. It is reputed that Button ruptured small blood vessels during his spins. (OpenStax 6.16) **31.4 rad/s, 118 m/s², 384 m/s²**
17. A rotating space station is said to create "artificial gravity"—a loosely-defined term used for an acceleration that would be crudely similar to gravity. The outer wall of the rotating space station would become a floor for the astronauts, and centripetal acceleration supplied by the floor would allow astronauts to exercise and maintain muscle and bone strength more naturally than in non-rotating space environments. If the space station is 200 m in diameter, what angular velocity would produce an "artificial gravity" of 9.80m/s² at the rim? (OpenStax 6.19) **0.313 rad/s**

Physics 02-07 Centripetal Force and Banked Curves	*Name: ________________*

Centripetal Force

Newton's Second Law

$$F = ma$$

$$F_C = \frac{mv^2}{r} = mr\omega^2$$

Some other ____________ creates ____________ force

- Swinging something from a string →____________
- Satellite in orbit →____________
- Car going around curve →____________

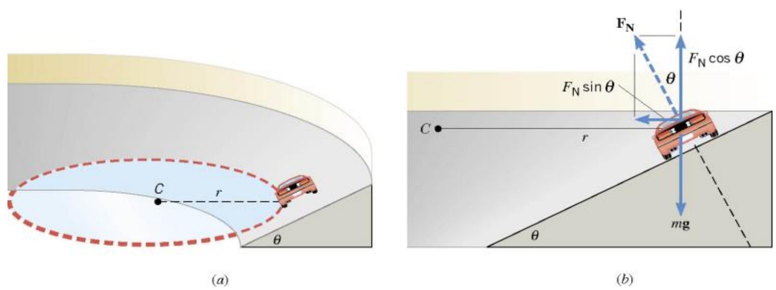
A 1.25-kg toy airplane is attached to a string and swung in a circle with radius = 0.50 m. What was the centripetal force for a speed of 20 m/s? What provides the F_C?

What affects Fc more: a change in mass, a change in radius, or a change in speed?

Banked Curves

When a car travels around an ____________ curve, ________________________ provides the centripetal force. By banking a curve, this reliance on friction can be ________________ for a given speed. The ____________ force will provide the centripetal force.

$$\tan(\theta) = \frac{v^2}{rg}$$



In the Daytona International Speedway, the corner is banked at 31° and r = 316 m. What is the speed that this corner was designed for?

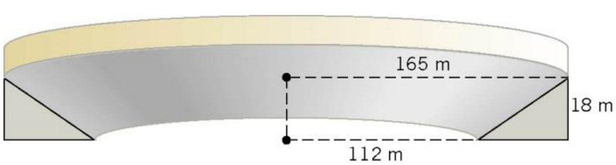
Cars go 195 mph around the curve. How?

Why do objects seem to fly away from circular motion?

How does the spin cycle in a washing machine work?

Physics 02-07 Centripetal Force and Banked Curves	***Name: ________________***
Homework	

1. A bug lands on a windshield wiper. Explain why the bug is more likely to be dislodged when the wipers are turned on at the high rather than the low setting.
2. A penny is placed on a rotating turntable. Where on the turntable does the penny require the largest centripetal force to remain in place? Explain.
3. Define centripetal force. Can any type of force (for example, tension, gravitational force, friction, and so on) be a centripetal force? Can any combination of forces be a centripetal force?
4. If centripetal force is directed toward the center, why do you feel that you are 'thrown' away from the center as a car goes around a curve? Explain.
5. Do you feel yourself thrown to either side when you negotiate a curve that is ideally banked for your car's speed? What is the direction of the force exerted on you by the car seat?
6. A 0.015-kg ball is shot from the plunger of a pinball machine. Because of a centripetal force of 0.028 N, the ball follows a circular arc whose radius is 0.25 m. What is the speed of the ball? (Cutnell 5.11) **0.68 m/s**
7. In a skating stunt known as "crack-the-whip," a number of skaters hold hands and form a straight line. They try to skate so that the line rotates about the skater at one end, who acts as the pivot. The skater farthest out has a mass of 80.0 kg and is 6.10 m from the pivot. He is skating at a speed of 6.80 m/s. Determine the magnitude of the centripetal force that acts on him. (Cutnell 5.12) **606 N**
8. At an amusement park there is a ride in which cylindrically shaped chambers spin around a central axis. People sit in seats facing the axis, their backs against the outer wall. At one instant the outer wall moves at a speed of 3.2 m/s, and an 83-kg person feels a 560-N force pressing against his back. what is the radius of a chamber? (Cutnell 5.14) **1.5 m**
9. (a) A 22.0 kg child is riding a playground merry-go-round that is rotating at 40.0 rev/min. What centripetal force must she exert to stay on if she is 1.25 m from its center? (b) What centripetal force does she need to stay on an amusement park merry-go-round that rotates at 3.00 rev/min if she is 8.00 m from its center? (OpenStax 6.23) **483 N, 17.4 N**
10. Calculate the centripetal force on the end of a 100 m (radius) wind turbine blade that is rotating at 0.5 rev/s. Assume the mass is 4 kg. (OpenStax 6.24) $\mathbf{4 \times 10^3\ N}$
11. What is the ideal banking angle for a gentle turn of 1.20 km radius on a highway with a 105 km/h speed limit (about 65 mi/h), assuming everyone travels at the limit? (OpenStax 6.25) **4.14°**
12. What is the ideal speed to take a 100 m radius curve banked at a 20.0° angle? (OpenStax 6.26) **18.9 m/s**
13. (a) What is the radius of a bobsled turn banked at 75.0° and taken at 30.0 m/s, assuming it is ideally banked? (b) Calculate the centripetal acceleration. (c) Does this acceleration seem large to you? (OpenStax 6.27) **24.6 m, 36.6 m/s^2, 3.73 g**
14. At what angle should a curve of radius 150 m be banked, so cars can travel safely at 25 m/s without relying on friction? (Cutnell 5.20) **23°**
15. On a banked race track, the smallest circular path on which cars can move has a radius of 112 m, while the largest has a radius of 165 m, as the drawing illustrates. The height of the outer wall is 18 m. Find the (a) the smallest and (b) the largest speed at which cars can move on this track without relying on friction. (Cutnell 5.22) **19 m/s, 23 m/s**



Physics 02-08 Satellites **Names: __________________**

- Any object __________ another object only under the influence of __________
- Gravity provides the __________ force

There is only __________ speed that a satellite can have if the satellite is to remain in an orbit with a __________ radius.

$$v = \sqrt{\frac{GM}{r}}$$

- r is measured from __________ of the Earth
- As r __________, v__________
- __________ of the satellite is not in equation

Calculate the speed of a satellite 500 km above the earth's surface.

Find the mass of a black hole where the matter orbiting it at r = 2.0×10^{20} m move at speed of 7,520,000 m/s.

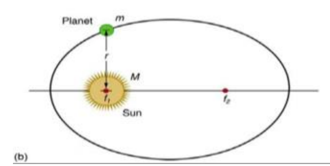
Since satellites are moving only under the influence of __________, and the acceleration points towards __________, satellites are in __________.

Kepler's Laws of Planetary Motion

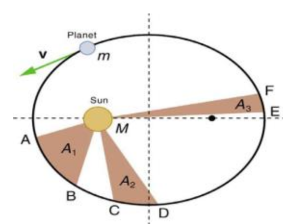
After studying motion of planets, __________ came up with his laws of planetary motion __________ then proved them all using his Universal Law of Gravitation

Assumptions:

- A __________ mass, *m*, orbits much __________ mass, *M*, so we can use *M* as an approximate inertia reference frame
- The system is __________



1. The __________ of each planet about the Sun is an __________ with the sun at one __________.
2. Each __________ moves so that an __________ line drawn from the __________ to the __________ sweeps out equal __________ in equal __________.
3. The __________ of the __________ of the __________ of any two planets about the sun is equal to their __________ of the __________ of their average __________ from the sun.



$$\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$$

For circular orbits

$$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$$

Physics 02-08 Satellites	***Names:*** ___________________

Use the data of Mars to find the mass of the sun assuming a circular orbit. ($r = 2.279 \times 10^8$ km, $T = 1.881$ yr)

Homework

1. Draw a free body diagram for a satellite in an elliptical orbit showing why its speed increases as it approaches its parent body and decreases as it moves away.
2. Are Kepler's laws purely descriptive, or do they contain causal information?
3. A satellite is in a circular orbit around an unknown planet. The satellite has a speed of 1.70×10^4 m/s, and the radius of the orbit is 5.25×10^6 m. A second satellite also has a circular orbit around this same planet. The orbit of this second satellite has a radius of 8.60×10^6 m. What is the speed of the second satellite? (Cutnell 5.27) $\mathbf{1.33 \times 10^4}$ **m/s**
4. A satellite is placed in orbit 6.00×10^5 m above the surface of Jupiter. Jupiter has a mass of 1.90×10^{27} kg and a radius of 7.14×10^7 m. Find the orbital speed of the satellite. (Cutnell 5.29) $\mathbf{4.20 \times 10^4}$ **m/s**
5. The moon orbits the earth at a distance of 3.85×10^8 m. Assume that this distance is between the centers of the earth and the moon and that the mass of the earth is 5.98×10^{24} kg. Find the period for the moon's motion around the earth. Express the answer in days and compare it to the length of a month. (Cutnell 5.30) **27.5 days**
6. A geosynchronous Earth satellite is one that has an orbital period of precisely 1 day. Such orbits are useful for communication and weather observation because the satellite remains above the same point on Earth (provided it orbits in the equatorial plane in the same direction as Earth's rotation). Calculate the radius of such an orbit based on the data for the moon in Table 6.2. (OpenStax 6.43) $\mathbf{4.23 \times 10^4}$ **km**
7. Calculate the mass of the Sun based on data for Earth's orbit and compare the value obtained with the Sun's actual mass. (OpenStax 6.44) $\mathbf{1.98 \times 10^{30}}$ **kg**
8. Find the mass of Jupiter based on data for the orbit of one of its moons, and compare your result with its actual mass. (OpenStax 6.45) $\mathbf{1.89 \times 10^{27}}$ **kg**
9. Astronomical observations of our Milky Way galaxy indicate that it has a mass of about 8.0×10^{11} solar masses. A star orbiting on the galaxy's periphery is about 6.0×10^4 light years from its center. (a) What should the orbital period of that star be? (b) If its period is 6.0×10^7 years instead, what is the mass of the galaxy? Such calculations are used to imply the existence of "dark matter" in the universe and have indicated, for example, the existence of very massive black holes at the centers of some galaxies. (OpenStax 6.47) $\mathbf{3 \times 10^8}$ **years,** $\mathbf{2 \times 10^{13}}$ **solar masses**

Physics

Unit 2: Forces and Uniform Circular Motion

1. *Terms like Velocity, Force, Acceleration, Equilibrium, Inertia, apparent weight, Normal force, True Weight, Gravitational Force, Applied force, Tension, Uniform Circular Motion, Period, Revolution, radius, centripetal acceleration, centripetal force, banked and unbanked curves, satellites, orbit, weightlessness, artificial gravity, Kepler's Laws of Planetary Motion*
2. *Fundamental forces*
3. *Difference between g and G*
4. *static and kinetic frictional forces*
5. *List Newton's Three Laws of Motion.*
6. *difference between mass and weight*
7. *What forces do you draw on a freebody diagram?*
8. *How is centripetal force different from all the other forces we have studied?*
9. *A 100-N force acts on a 75-kg person. What is the acceleration of the person?*
10. *A 70-kg ice skater pushes on a box on smooth ice (no friction). He applies 200 N horizontally against the 50-kg box. What are the accelerations of the ice skater and the box?*
11. *A 10-kg block rests on a frictionless plane inclined at 60°. What is the acceleration of the block as it slides down the incline?*
12. *A stoplight is suspended by two cables over a street. Weight of the light is 110 N and the cables make a 116° angle with each other. Find the tension in each cable.*
13. *A 100-kg man is standing on a bathroom scale while riding an elevator. What does the scale read when the elevator is accelerating upward at 5 m/s^2?*
14. *A 5000-kg car skids to a stop. μ_k = .5. What is the magnitude of the friction force?*
15. *Find the terminal velocity of a falling mouse in air ($A = 0.004\ m^2$, $m = 0.02\ kg$, $C = 0.5$).*
16. *Convert the angular measure of 40 degrees to radians.*
17. *A stone is in a sling and a boy whirls it around in a circle. If the centripetal acceleration is 50 m/s^2 and the radius of the circle is 10 cm, what is the speed of the stone?*
18. *Find the gravitational force of attraction between a 100-kg girl and a 200-kg boy sitting 0.5 meters apart.*
19. *What is the acceleration due to gravity at an altitude of $1 \times 10^6\ m$ above the earth's surface? **Note:** the radius of the earth is $6.36 \times 10^6\ m$.*
20. *Four people are having a tug-o-war game. Ashley pulls left with 20 N, Bert pulls left with 10 N, Charlie pulls right with 30 N, and Dannie pulls right with 5 N. What is the magnitude of the acceleration of the 5 kg rope and who wins the game?*
21. *A 10-g nut is hanging from a spring that has stretched 30 cm because a squirrel is pulling it down. If the squirrel is pulling with 300 N, what is the spring constant?*

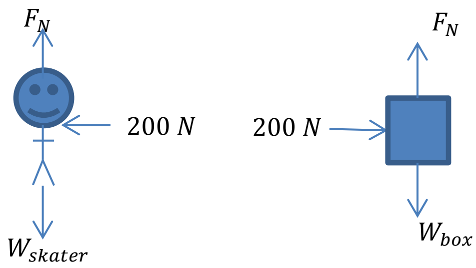
7. *Only forces acting on the object*

9. $F = ma$

$100\ N = 75\ kg\ (a)$

$a = \mathbf{1.33\frac{m}{s^2}}$

10.

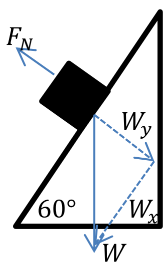


$W_{skater} = 70\ kg\left(9.8\frac{m}{s^2}\right) = 686\ N$

$W_{box} = 50\ kg\left(9.8\frac{m}{s^2}\right) = 490\ N$

x	y	x	y
$-200\ N$	F_N $W = -686\ N$	$200\ N$	F_N $W = -490\ N$
$F = ma$ $-200\ N = 70\ kg\ (a)$ $a_{skater} = \mathbf{-2.86\ m/s^2}$		$F = ma$ $200\ N = 50\ kg\ (a)$ $\boldsymbol{a_{box}} = \mathbf{4.0\ m/s^2}$	

11. $W = 10\ kg\left(9.8\frac{m}{s^2}\right) = 98\ N$



x	y
$W_x = -W\sin 60°$	F_N $W_y = -W\cos 60°$

Forces in x: $F = ma$

$-W\sin 60° = ma$

$-98\ N\sin 60° = 10\ kg\ (a)$

$a = \mathbf{-8.49\frac{m}{s^2}}$

12. F_x: $T_2\cos 32° - T_1\cos 32° = 0$

$T_2(.8480) - T_1(.8480) = 0$

$T_1 = T_2$

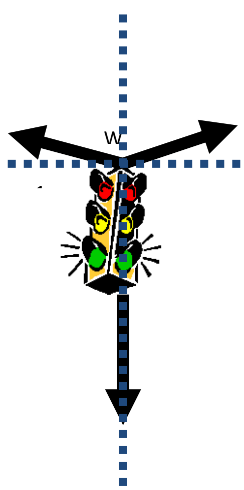
F_y: $-W + T_1\sin 32° + T_2\sin 32° = 0$

$-110\ N + T_1(.5299) + T_1(.5299) = 0$

$-110\ N + 1.0598\ T_1 = 0$

$1.0598\ T_1 = 110\ N$

$T_1 = T_2 = \mathbf{103.8\ N}$



13. $F_N - W = ma$

$F_N - (100\ kg)\left(9.8\frac{m}{s^2}\right) = (100\ kg)\left(5\frac{m}{s^2}\right)$

$F_N = \mathbf{1480\ N}$

14. F_y: $F_N - W = 0 \rightarrow F_N = W \rightarrow F_N = (5000\ kg)\left(9.8\frac{m}{s^2}\right) = 49000\ N$

F_x: $f_k = \mu_k F_N = 0.5(49000\ N) = \mathbf{24500\ N}$

15. *Mouse:* $v = \sqrt{\frac{2mg}{\rho CA}}$

$v = \sqrt{\frac{2(0.02\ kg)\left(9.8\frac{m}{s^2}\right)}{\left(1.21\frac{kg}{m^3}\right)(0.5)(0.004\ m^2)}} = \mathbf{12.7\frac{m}{s}}$

16. $40°\left(\frac{\pi}{180°}\right) = \mathbf{\frac{2\pi}{9}}$

17. $a_c = \frac{v^2}{r}$

$50\frac{m}{s^2} = \frac{v^2}{0.10\ m}$

$v^2 = 5m^2/s^2$

$v = \mathbf{2.24\ m/s}$

18. $F_g = G\frac{mM}{r^2}$

$F_g = 6.67\times10^{-11}\frac{Nm^2}{kg^2}\frac{(100\ kg)(200\ kg)}{(0.5\ m)^2} = \mathbf{5.34\times10^{-6}\ N}$

19. $g = G\frac{M}{r^2}$

$g = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(5.98\times10^{24}\ kg)}{(1\times10^6\ m + 6.36\times10^6\ m)^2} = \mathbf{7.36\ m/s^2}$

20. $F_{net} = ma$

$-20\ N - 10\ N + 30\ N + 5\ N = (5\ kg)a$

$a = 1\ m/s^2$

since this is to the right Charlie and Dannie win

21. $kx - mg - F_{sq} = ma = 0$

$k(0.3\ m) - (0.01\ kg)\left(9.8\frac{m}{s^2}\right) - 300\ N = 0$

$k = 1000$