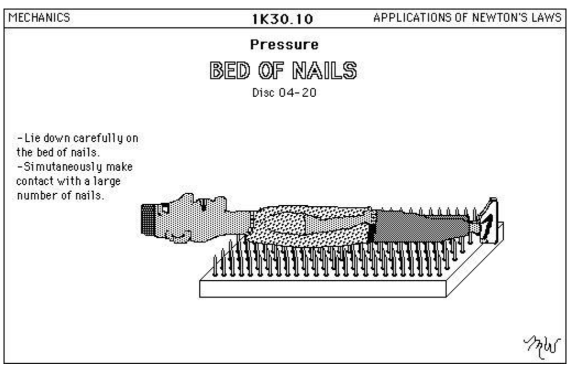
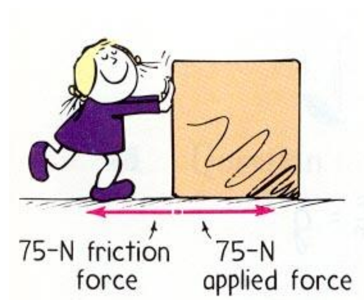
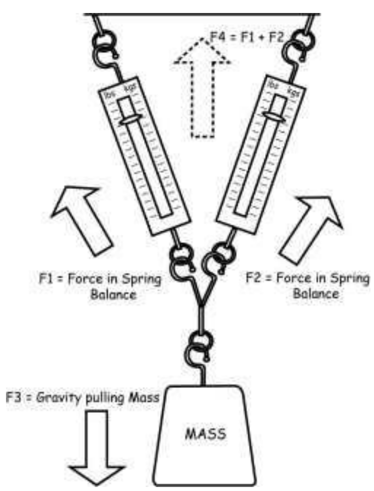
Unit 3

Newton's Laws

Unit Packet Contents







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Unit Objectives: Newton's Laws

1. Define force and name several different types of forces.
2. Explain Newton's first law of motion.
3. Define inertia and explain how it is related to Newton's first law.
4. Compare and contrast systems that are in dynamic and static equilibrium.
5. Explain Newton's second law of motion.
6. Use F=ma to solve problems related to Newton's second law of motion.
7. Define the weight force and explain how it is different from mass.
8. Explain what the Normal force is and give an example showing how it is related to weight.
9. Explain what friction and tension forces are and give examples where they apply.
10. State Newton's third law of motion and give examples of it being applied.
11. Explain the difference between static and kinetic frictional forces.
12. Define the term frictional force and solve simple problems involving kinetic friction.
13. Explain why a frictional force calculated using $F_f = \mu F_N$ is described as a maximum frictional force.
14. Demonstrate proper use of scientific notation and perform calculations involving numbers in scientific notation.
15. Explain Newton's Law of Universal Gravitation and discuss situations where it applies.
16. Use Newton's LUG to calculate gravitational forces.
17. Explain how Hook's law describes the effects of compressing or stretching a spring.
18. Use the Hook's law equation to solve various types of problems.

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Notes: Newton's Laws Intro

Objectives:
1. Define force and name several different types of forces.
2. Explain Newton's first law of motion.
3. Define inertia and explain how it is related to Newton's first law.
4. Compare and contrast systems that are in dynamic and static equilibrium.
5. Explain Newton's second law of motion.
6. Use F=ma to solve problems related to Newton's second law of motion.

The Force:

- A force is a __push pull or drag__
- A force is a __vector__ and therefore acts in a specific direction
- If forces combine they must be added by __vector addition__.
- Units of __Newtons__ is derived from __Kg m/s^2__

Newton's First Law:

- An object in __motion__ will remain in __motion__ and an object __at rest__ will remain __at rest__ unless it is acted upon by an __unbalanced outside force__

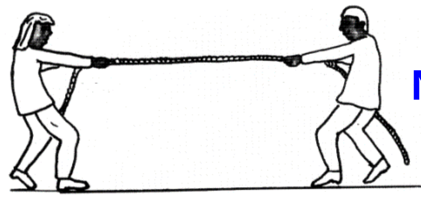
Inertia:

- The tendancy of an object to __resist a change in motion__
- __velocity__ (speed and direction) tends to __remain constant__
- An object's inertia is directly proportional to its __mass__

Concurrent Forces:

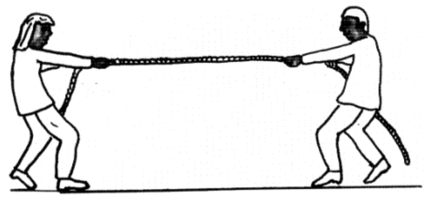
- Two or more forces acting on the __same object__ at the __same time__
- Example: Little girl pulling a wagon while her brother pushes.

- To find the result of any combination of **2 or more** forces acting on an object, **vector addition** must be used
- Suppose Jane and Jared are each exerting a force on a rope.
  - First they both pull with a force of 100 N tug-o-war style.



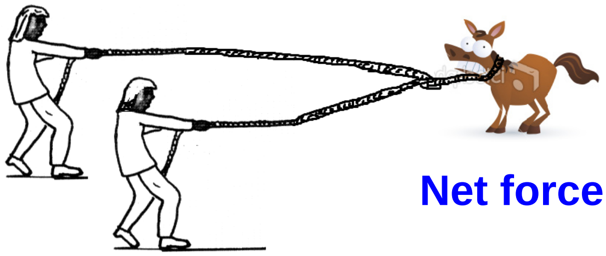
Net force is ____________________

  - This time Jane pulls with a force of 100 N but Jared is getting tired and pulls with 80 N.



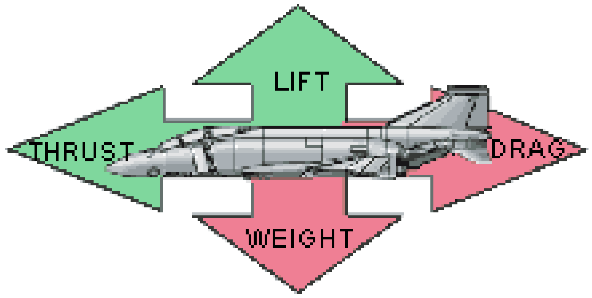
Net force is ____________________

  - Now they both are pulling on one end while a stubborn donkey is on the opposite end. Jane and Jared's forces are still 100 N and 80 N respectively. The donkey's force is 150 N.

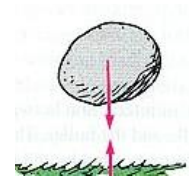


Net force is ____________________

Balanced vs. Unbalanced forces:



- ***Balanced*** -- Forces acting on an object are balanced if the **vector sum is zero**.
- If forces on an object are balanced than the object cannot be **accelerating**.
  - For example a jet flying in **level flight** at **constant velocity**



- ***Unbalanced*** -- Forces acting on an object are unbalanced if the____vector___ ____sum is not zero_______
  - For example a rock in ____free fall_______ without wind resistance
- If the forces on an object are not balanced than the object must be ___accelerating___

Classify the following situations as involving balanced or unbalanced forces.

1. A car is traveling at 20 m/s and the driver steps on the brake.

2. A bicyclist pedals to maintain a constant speed of 3.5 m/s

3. A chair is dragged across a floor at constant velocity.

4. A plane makes a turn at constant speed

5. An object is dropped vertically toward the ground.

Equilibrium

Remember Newton's 1st law.

- If no unbalanced force acts on an object its motion __doesn't change______
- An object with no _unbalanced force_ acting on it is in _equilibrium_____.

Static equilibrium

- An object __at rest__ with no unbalanced forces acting on it
- For example a book __resting__ on a table __stays at rest__

Dynamic Equilibrium

- An object __moving at constant speed__ with no unbalanced forces acting on it.
- E.g. a car traveling constant 55 mph

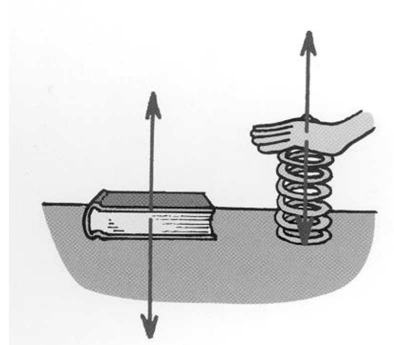


Figure 4.11 ▲
(Left) The table pushes up on the book with a force equal to the downward weight of the book. (Right) The spring pushes up on your hand with the same force you use to push down on the spring.

Newton's Second law of Motion:

- If an __unbalanced force__ acts on an object, the object will experience an __acceleration__ in the direction of the __force__.

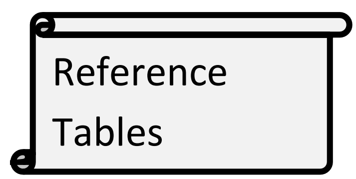
The magnitude of the force, the magnitude of the acceleration and the mass of the object are related by the formula:

$$a = \frac{F_{net}}{m}$$

$F_{net} = Net\ \ force$

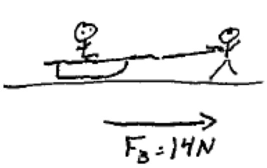
$m = mass$

$a = acceleration$



Problem 1: A boy exerts a 14 Newton force on his little sister who is in a sled. The sister and sled combined have a mass of 25 Kg. At what rate did they accelerate?

$M_s = 25\,kg$ $a = ?$



$a = \frac{F_{net}}{m}$

$a = \frac{14N}{25kg}$

$a = 0.56\ m/s^2$

Problem 2: A 2 kg hockey puck is accelerated by a slap shot force at a rate of 28.9 m/s^2. What force is exerted with the stick?

exerted with the stick?

$F = ?$

$m = 2\ kg$

$a = 28.9\ m/s^2$

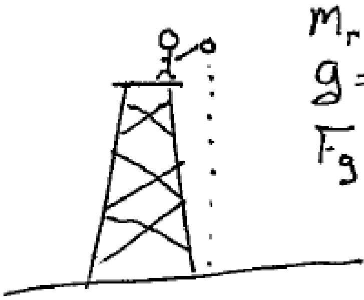
$a = \frac{F_{net}}{m}$

$F_{net} = ma$

$F_{net} = (2\ kg)(28.9\ m/s^2)$

$F_{net} = 57.8\ N$

Problem 3: A boy drops a 6.5 kg rock from the top of a tower. What was the magnitude of the gravitational force that accelerated the rock toward the ground?



$m_r = 6.5\ kg$

$g = 9.8\ m/s^2$

$F_g = ?$

$F_g = ma = mg$

$F_g = (6.5\ kg)(9.8\ m/s^2)$

$F_g = 63.7\ N$

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Guided Practice: Newton's Laws Intro

Concept-Development Practice Page **4-1**

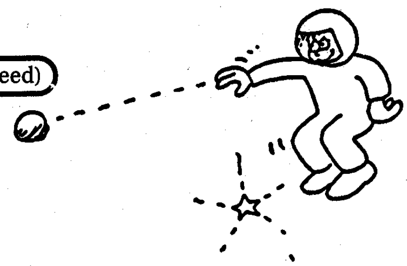
1. (*Circle the correct answer.*) An astronaut in outer space away from gravitational or frictional forces throws a rock. The rock will

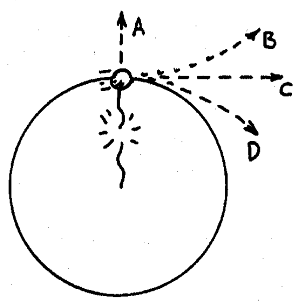
   (gradually slow to a stop)

   (continue moving in a straight line at constant speed)

   The rock's tendency to do this is called

   (inertia) (weight) (acceleration)

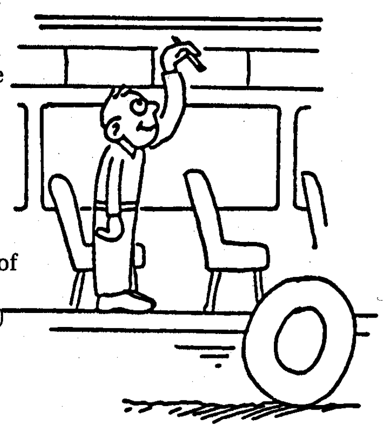


2. 

   The sketch shows a top view of a rock being whirled at the end of a string (clockwise). If the string breaks, the path of the rock is

   (A) (B) (C) (D)

3. Suspose you are standing in the aisle of a bus that travels along a straight road at 100 km/h, and you hold a pencil still above your head. Then relative to the bus, the velocity of the pencil is 0 km/h, and relative to the road, the pencil has a horizontal velocity of



   (less than 100 km/h) (100 km/h) (more than 100 km/h)

   Suppose you release the pencil. While it is dropping, and relative to the road, the pencil still has a horizontal velocity of

   (less than 100 km/h) (100 km/h) (more than 100 km/h)

   This means that the pencil will strike the floor at a place directly

   (behind you) (at your feet below your hand) (in front of you)

   Relative to you, the way the pencil drops

   (is the same as if the bus were at rest)

   (depends on the velocity of the bus)

   How does this example illustrate the law of inertia?

   A body in motion tends to remain in motion as long as no net force is exerted on the body in the direction of motion. Since there is no horizontal force on the pencil, its horizontal motion doesn't change.

Concept-Development Practice Page 5-2

Force and Acceleration

1. Skelly the skater, total mass 25 kg, is propelled by rocket power.

   a. Complete Table I (neglect resistance)

   a = F/25 kg

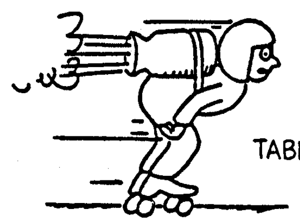


TABLE I

FORCE	ACCELERATION
100 N	4 m/s²
200 N	8 m/s²
250 N	10 m/s²

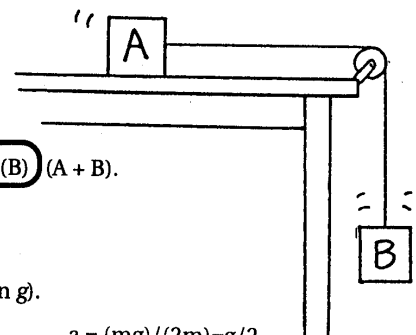
   b. Complete Table II for a constant 50-N resistance.

   a = (F - 50 N)/25 kg

TABLE II

FORCE	ACCELERATION
50 N	0 m/s²
100 N	2 m/s²
200 N	6 m/s²

2. Block A on a horizontal friction-free table is accelerated by a force from a string attached to Block B. B falls vertically and drags A horizontally. Both blocks have the same mass *m*. (Neglect the string's mass.)



(Circle the correct answers)

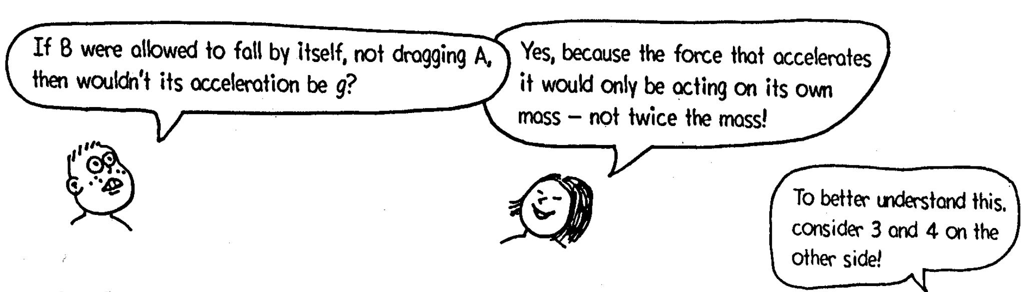
   a. The *mass* of the system [A + B] is (*m*) **(2 *m*)**.

   b. The *force* that accelerates [A + B] is the weight of (A) **(B)** (A + B).

   c. The weight of B is (*mg*/2) **(*mg*)** (2 *mg*).

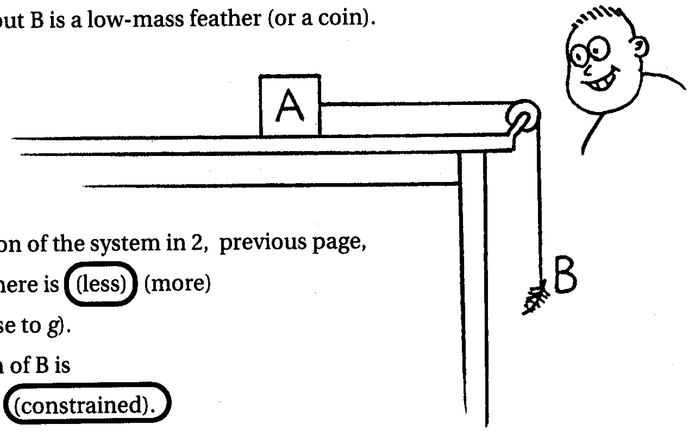
   d. Acceleration of [A + B] is **(less than *g*)** (*g*) (more than *g*).

   e. Use *a* = to show the acceleration of [A + B] as a fraction of *g*. a = (mg)/(2m)=g/2



Force and Acceleration continued

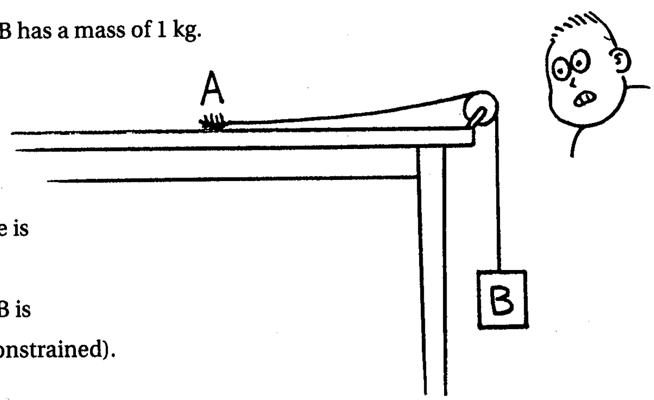
3. Suppose A is still a 1-kg block, but B is a low-mass feather (or a coin).



a. Compared to the acceleration of the system in 2, previous page, the acceleration of [A + B] here is **(less)** (more) and is **(close to zero)** (close to *g*).

b. In this case the acceleration of B is (practically that of free fall) **(constrained).**

4. Suppose A is a feather or coin, and B has a mass of 1 kg.



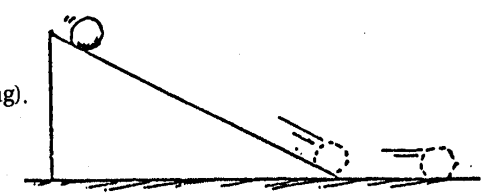
a. The acceleration of [A + B] here is (close to zero) **(close to *g*).**

b. In this case the acceleration of B is **(practically that of free fall)** (constrained).

5. Summarizing 2, 3, and 4, where the weight of one object causes the acceleration of two objects, we see the range of possible accelerations is

(between zero and *g*) (between zero and infinity) (between *g* and infinity).

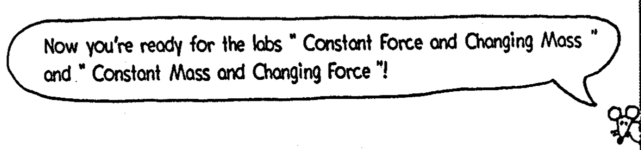
6. A ball rolls down a uniform-slope ramp.



a. Acceleration is (decreasing) **(constant)** (increasing).

b. If the ramp were steeper, acceleration would be **(more)** (the same) (less).

c. When the ball reaches the bottom and rolls along the smooth level surface it (continues to accelerate) **(does not accelerate).**



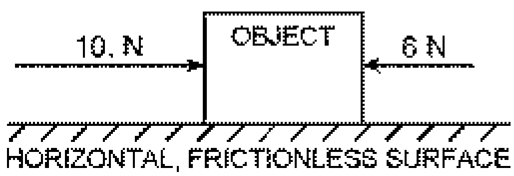
TTQ *(Typical Test Questions)*

Documented Thinking

1) Which of the following bodies is in equilibrium?

A) a projectile at the highest point in its trajectory
B) a satellite orbiting Earth in a circular orbit
C) a car moving with a constant speed along a straight, level road
D) a ball falling freely toward the surface of Earth

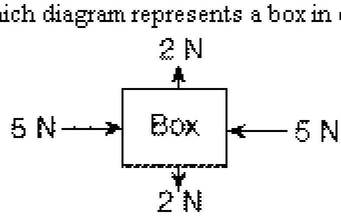
2) Two forces act concurrently on an object on a horizontal, frictionless surface, as shown in the diagram below.

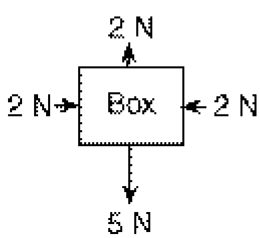


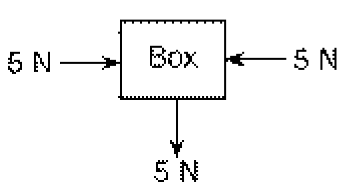
What additional force, when applied to the object, will establish equilibrium?

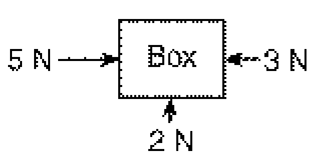
A) 16 N toward the right
B) 4 N toward the right
C) 16 N toward the left
D) 4 N toward the left

3) Which diagram represents a box in equilibrium?

A) 

B) 

C) 

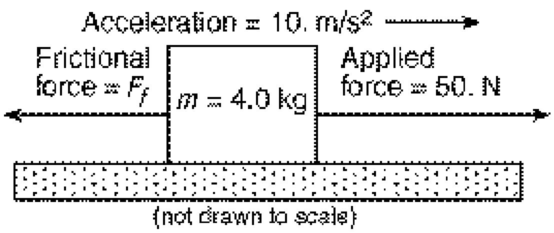
D) 

Documented Thinking

4) A force of 25 newtons east and a force of 25 newtons west act concurrently on a 5.0-kilogram cart. What is the acceleration of the cart?

A) 1.0 m/s^2 west
C) 0 m/s^2
B) 0.20 m/s^2 east
D) 5.0 m/s^2 east

5) The diagram below shows a 4.0-kilogram object accelerating at 10. meters per second^2 on a rough horizontal surface.



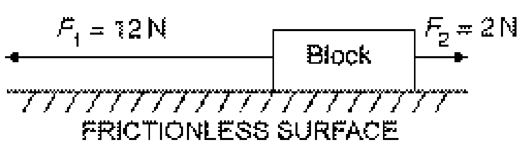
What is the magnitude of the frictional force F_f acting on the object?

A) 20. N
C) 40. N
B) 10. N
D) 5.0 N

6) A student is standing in an elevator that is accelerating downward. The force that the student exerts on the floor of the elevator must be

A) less than the force of the floor on the student
B) less than the weight of the student when at rest
C) greater than the force of the floor on the student
D) greater than the weight of the student when at rest

7) Two forces, F_1 and F_2, are applied to a block on a frictionless, horizontal surface as shown below.



If the magnitude of the block's acceleration is 2.0 meters per second^2, what is the mass of the block?

A) 6 kg
C) 1 kg
B) 7 kg
D) 5 kg

8) A 25-newton horizontal force northward and a 35-newton horizontal force southward act concurrently on a 15-kilogram object on a frictionless surface. What is the magnitude of the object's acceleration?

A) 4.0 m/s^2
C) 1.7 m/s^2
B) 0.67 m/s^2
D) 2.3 m/s^2

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Notes: Types of Forces

Objectives:
1. Define the weight force and explain how it is different from mass.
2. Explain what the Normal force is and give an example showing how it is related to weight.
3. Explain what friction and tension forces are and give examples where they apply.

1. *The Weight Force*

Mass, Weight and Volume . . . What's the difference???

- Mass is a measure of the quantity of __**matter**__ that an object possesses.
- Your mass on earth will be __**the same**__ as it would be on the moon because you still have the same amount of matter making up your body.
- The more mass an object has the more it resists having its motion change so the more __**inertia**__ it has.
- Volume is the amount of __**space**__ that an object occupies.
- Weight is a force between any object with mass and the __**earth's surface**__
- Always points toward the __**center of the earth**__
- Newton's 2nd law applies

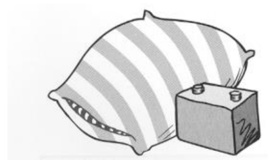


Figure 4.7 ▲ The pillow has a larger size (volume) but a smaller mass than the battery.

$$g = \frac{F_g}{m}$$

$$g = accel\ due\ to\ gravity$$
$$F_g = Weight\ or\ Force\ of\ gravity$$

Figure 4.8 ▲ It's just as difficult to shake a stone in its weightless state in space as it is in its weighted state on Earth.

Also commonly written:

$$F_g = mg$$

Reference Tables

Problem 1: What is the weight of a man that has a mass of 70 Kg.

$M = 70\ kg$
$g = 9.8\ m/s^2$
$F_g = ?$

$F_g = mg$
$F_g = (70\ kg)(9.8\ m/s^2)$
$F_g = 686\ N$

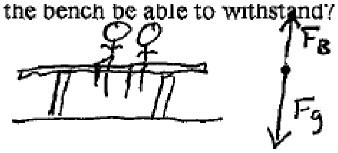
Problem 2: A man is building a bench that he wants to be able to support a person with a mass of 150 Kg. What force must the bench be able to withstand?

Kg. What force must the bench be able to withstand?

$M = 150\ kg$

$g = 9.8\ m/s^2$

$F_g = ?$



F_B must balance F_g

so...

$F_g = mg$

$F_g = (150kg)(9.8\ m/s^2)$

$F_g = 1470\ N$

Problem 3: The man in problem 1 traveled to another planet. His weight on this planet was 310 newtons. What is the acceleration due to gravity on this planet?

$M = 70kg$

$F_g = 310N$

$g = ?$

$g = \frac{F_g}{M}$

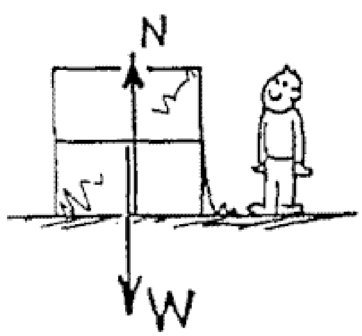
$g = \frac{310N}{70kg}$

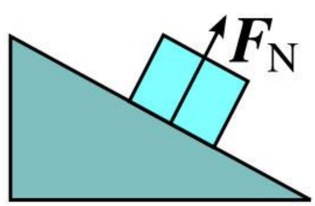
$g = 4.4\ m/s^2$

units: $\frac{N}{kg} = \frac{(kg\ m/s^2)}{kg} = m/s^2$

2. *NormalForce*

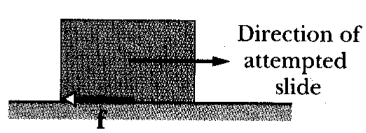
- When a body exerts a force on a surface the body experiences a _**normal force**_ which is by definition __**perpendicular**_ to the surface.
- If the body is resting on a horizontal surface, the normal force is the force that **balances**____ the weight force.





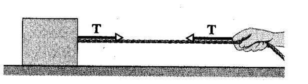
3. *Friction*

- The resistance of a body __**sliding**___ over a surface is referred to as a _**frictional force**____
- The frictional force runs _**parallel**_____to the surface _**opposite**____ the direction of motion or attempted motion.
- We'll learn more about friction in t

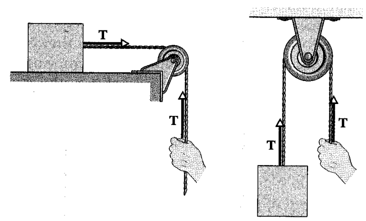


4. *Tension*

- When a cord or rope or even possible a rigid body is pulled taut, it is said to be under tension or experiencing a tension force.
- The cord is considered as only a connection between the bodies and serves only to transfer the force.



(a)

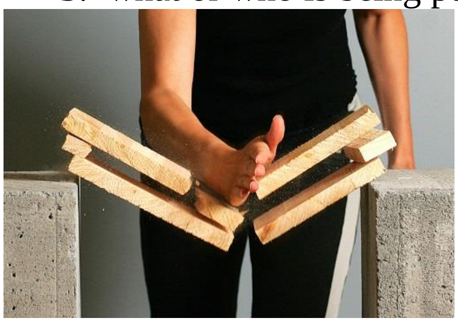


(b)

Guided Practice: Types of Forces Writearound

For each of the following pictures name a force that is acting and write a description of how the force is acting. Specifically state:

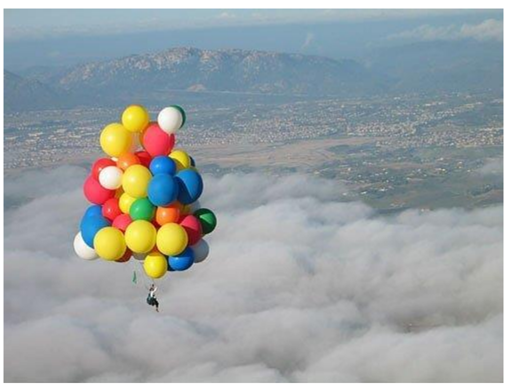
1. What type of force is acting
2. what or who is pushing
3. what or who is being pushed



Type of force

Pushing

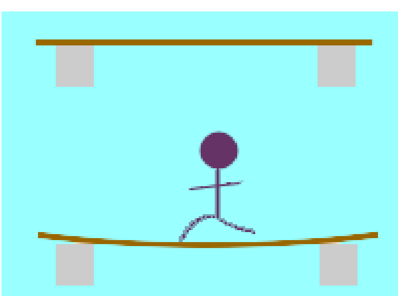
Being pushed



Type of force

Pushing

Being pushed



Type of force

Pushing

Being pushed

Type of force

Pushing

Being pushed

Type of force

Pushing

Being pushed

Type of force

Pushing

Being pushed

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Notes: Newton's 3rd and Frictional Forces

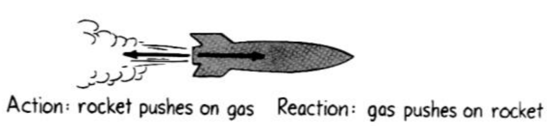
Objectives:
1. State Newton's third law of motion and give examples of it being applied.
2. Explain the difference between static and kinetic frictional forces.
3. Define the term frictional force and solve simple problems involving kinetic friction.
4. Explain why a frictional force calculated using $F_f = \mu F_N$ is described as a maximum frictional force.

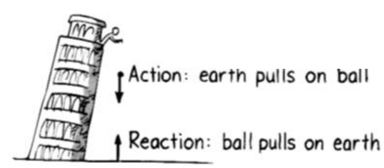
Wish I Were a Fly on the Wall
By Robert D. Cowan
There once was a fly on the wall
I wonder why didn't it fall
Because its feet stuck
Or was it just luck
Or does gravity miss things so small?

Newton's third law of motion

- When one object exerts a force on another object, the second object exerts an __equal force__ on the first in the __opposite direction__
- Forces always act in __action – reaction__.
- Action – Reaction pairs are two forces acting on __two different__ objects.

Common examples:

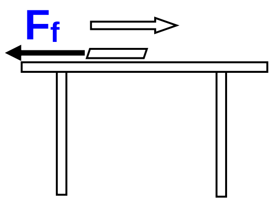




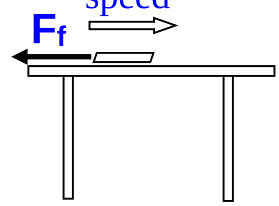
Ever present Friction

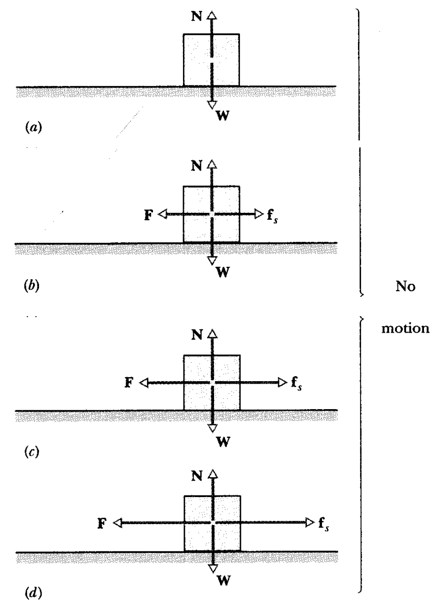
- Consider a book __sliding__ across a tabletop.
- There is a frictional force that causes the book to eventually __come to rest__
- In order to keep the book moving across the table at __constant speed__ it would be necessary to exert a force to __exactly balance__ the friction force.

Sliding but slowing down

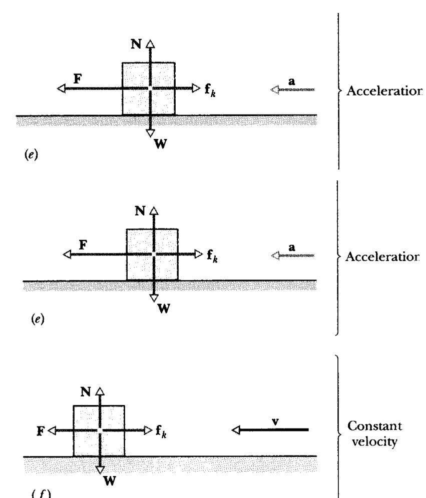


Sliding at constant speed





- Now consider a heavy crate __resting__ on the floor.
- The weight force is __balanced__ by an upward _________ force. *[diagram (a)]*
- Now imagine that you exert an __effort force__ on the crate designated __F__ which is not large enough to move the crate. *[diagram (b)]*
- The horizontal forces are __balanced__ here as well because the friction force responded to __resist__ the effort force.
- This friction force is know as the __static friction__ force because it is acting with no resulting __motion__
- Now increase the magnitude of the effort force *[diagram (c) & (d)]* and note that the crate still __does not move__
- In both of these, the friction force __f_s__ is larger than in diagram (b) but is still just large enough to __balance__ the effort force.
- Once again the magnitude of the effort force is increased, [diagram (e)] this time to the point where the crate does __move__.
- Here the effort force is __larger__ than the friction force so there is a __non-zero__ net force on the crate and it is _______________
- Once the crate starts moving, the friction force resisting its motion is referred to as the __kinetic friction__ force.
- For most surfaces the kinetic friction force is __smaller__ than the maximum value of the __static friction__ force
- To have the crate move at constant speed you would have to __decrease__ your effort force immediately after it starts sliding. *[diagram (f)]*
- Notice that the force vector in diagram (f) is __smaller__ than that in diagrams (b-d) even though in diagram (f) the crate is moving.



Properties of Friction

- There are three important properties of a frictional force.
  - If the body does not move than the **static friction force** and the component of the effort force F that is **parallel** to the surface are **equal** in magnitude.

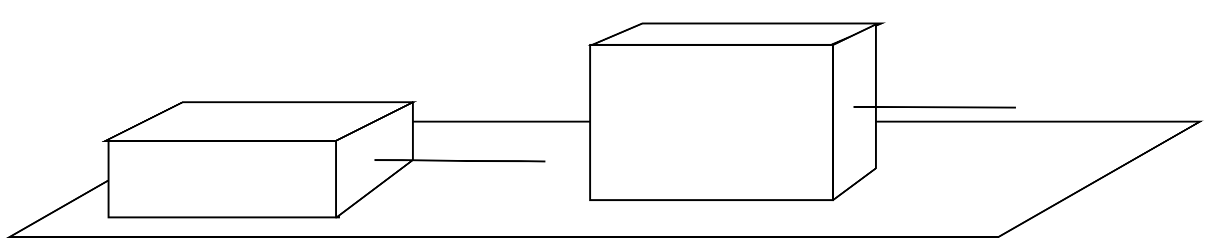
  Examples:

  - The magnitude of f_s has a maximum value $f_{s,max}$ that is given by:

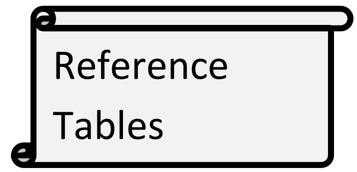
$$F_f = \mu F_n$$

Reference Tables

    - μ is the **coefficient of friction** which is characteristic of the surfaces in contact.
    - F_n is the magnitude of the **normal force**.
  - What do we mean by saying F_f a **maximum value**
    - If an effort force exceeds $f_{s,max}$ then the forces will be **unbalanced** and the body will begin to **slide**.
    - An effort force may have any value between zero and the **maximum F_f** and the friction force will be just large enough to **balance** the effort force.
  - Kinetic friction vs. Static friction or **moving** vs. **stationary**
    - For a body sliding on a surface the friction force usually **decreases**
    - To account for this a separate set of coefficients of friction are used for **moving** surfaces.
    - These are called the **kinetic** coefficients of friction.
- Friction force is independent of the **area of contact**.



Reference Tables



- The front page of your reference tables has a table of "Approximate Coefficients of Friction"
- The equation for friction forces are also on your reference tables in the mechanics section.

Example problem 1: A force of 50 Newton's is used to drag a 10 kilogram block across a horizontal table. A frictional force of 15 newtons is present on the block.

a. Sketch a diagram of the block showing the direction and magnitude of the force vectors.

b. Find the unbalanced force on the object.

c. Find the acceleration of the object.

Example problem 2: A student drags an object across a laboratory table at constant velocity using an applied force of 12 Newton's. What is the frictional force present on the object?

Example problem 3: A 5.0 kilogram block slides across a horizontal surface at constant velocity. If a 5.0 Newton frictional force is present, calculate the coefficient of kinetic friction between the two surfaces.

Example 4: A wood block with a mass of 1.5 kg is being pulled at constant speed by a string across a wood table.

a. Draw a force diagram showing all of the forces acting on the block.
b. Calculate the weight of the block.
c. What is the normal force acting on the block by the table?
d. Calculate the friction force acting on the block.
e. What is the magnitude of the force applied by the string?

Guided Practice: Forces and Newton's Laws

Forces Concept Mapping

Newton's Laws of

First Law

Known as the law of . . .

Inertia

An object in motion stays in constant speed straight line

. . . An object at rest stays at rest.

UNLESS acted upon by an unbalanced force.

If Unbalanced Force . . . go to 2nd Law

Second Law

A = F/m

A large force results in a large acceleration

A large mass results in a small acceleration

Third Law

Known as the law of . . .

If an object exerts a force on a second object . . .

Then the second object exerts an equal force on the

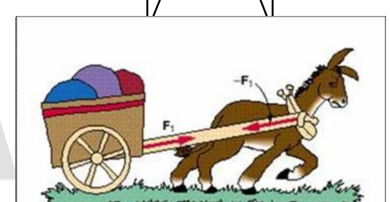


Figure 4.13 A mule and a cart. Does Newton's third law prevent the mule from moving the cart?

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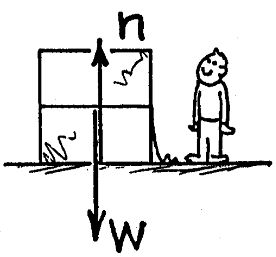
Guided Practice: Friction and Acceleration

Concept-Development Practice Page **5-1**

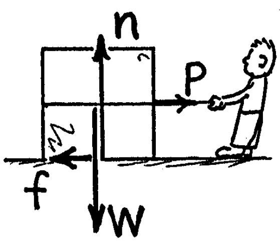
Friction



1. A crate filled with delicious junk food rests on a horizontal floor. Only gravity and the support force of the floor act on it, as shown by the vectors for weight **W** and normal force **n**.

   a. The net force on the crate is (zero) (greater than zero).

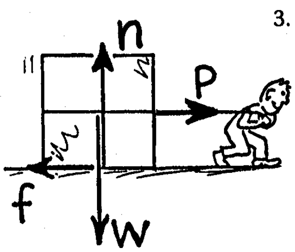
   b. Evidence for this is no acceleration.



2. A slight pull **P** is exerted on the crate, not enough to move it. A force of friction **f** now acts,

   a. which is (less than) (equal to) (greater than) **P**.

   b. Net force on the crate is (zero) (greater than zero).

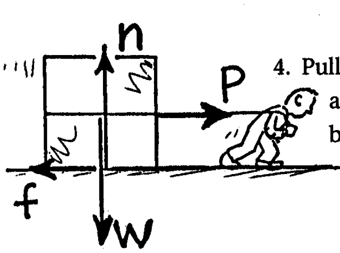


3. Pull **P** is increased until the crate begins to move. It is pulled so that it moves with constant velocity across the floor.

   a. Friction **f** is (less than) (equal to) (greater than) **P**.

   b. Constant velocity means acceration is (zero) (greater than zero).

   c. Net force on the crate is (less than) (equal to) (greater than) zero.



4. Pull **P** is further increased and is now greater than friction **f**.

   a. Net force on the crate is (less than) (equal to) (greater than) zero.

   b. The net force acts toward the right, so acceleration acts toward the (left) (right)

5. If the pulling force **P** is 150 N and the crate doesn't move, what is the magnitude of **f**? 150N

6. If the pulling force **P** is 200 N and the crate doesn't move, what is the magnitude of **f**? 200N

7. If the force of sliding friction is 250 N, what force is necessary to keep the crate sliding at constant velocity? 250N

8. If the mass of the crate is 50 kg and sliding friction is 250 N, what is the acceleration of the crate when the pulling force is 250 N? $0\ m/s^2$ 300 N? $1 m/s^2$ 500 N? $5m/s^2$

1. Unbeknownst to the students, every time the school floors are waxed, Mr. Ruston likes to slide down the hallway in his socks. Mr. Ruston weighs 665 Newtons and the coefficient of sliding friction between his socks and the floor is 0.120. what is the force of friction that opposes Mr. Ruston's motion down the hall?

2. While redecorating her apartment, Kitty slowly pushes an 82-kg stuffed panda across the wooden dining room floor, which resists the motion with a force of friction of 320 N. What is the coefficient of sliding friction between the stuffed panda and the floor?

3. A 125 kg crate falls off of the back of a truck and lands on the road. The crate slides along the road and decelerates due to a friction force of 25 Newtons acting on the crate.
   a. Draw a free body diagram showing all forces acting on the crate.

   b. Calculate the coefficient of friction between the crate and the pavement

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Independent Practice: Friction w/ Acceleration

1. A student drags a block across a table pulling it with a spring scale. While pulling the block at constant speed the spring scale reads 2.75 Newtons. The mass of the block is 500 grams. What is the coefficient of friction between the block and the table?

2. As Alan is taking a shower, the soap falls out of the soap dish and Alan steps on it with a force of 500N. If Alan slides forward and the frictional force between the soap and the tub is 50N, what is the coefficient of friction between these two surfaces?

3. Howard, the soda jerk at Bea's diner, slides a 0.60 kg root beer from the end of the counter to a thirsty customer. A force of friction of 1.2 N brings the drink to a stop right in front of the customer
   a. What is the coefficient of sliding friction between the glass and the counter?
   b. If the glass encounters a sticky patch on the counter, will this spot have a higher or lower coefficient of friction?

4. Heluise is performing a physics lab and exerts a constant force on a cart of 2.65 Newtons. The cart accelerates at a rate of 3.92 m/s^2. The mass of the cart being accelerated is 0.500 kg. DO NOT assume the cart is frictionless.
   a. Draw a free body diagram showing all of the forces acting on the cart.
   b. Calculate the magnitude of the net force acting on the cart.
   c. Calculate the magnitude of the friction force acting on the cart.
   d. Calculate the weight force and the normal force.
   e. Calculate the coefficient of friction for the cart on the lab table.

TTQ ***(Typical Test Questions)***

1) What is the magnitude of the force needed to keep a 60.-newton rubber block moving across level, dry asphalt in a straight line at a constant speed of 2.0 meters per second?

A) 40. N
B) 120 N
C) 60. N
D) 51 N

2) An 80-kilogram skier slides on waxed skis along a horizontal surface of snow at constant velocity while pushing with his poles. What is the horizontal component of the force pushing him forward?

A) 0.05 N
B) 40 N
C) 4 N
D) 0.4 N

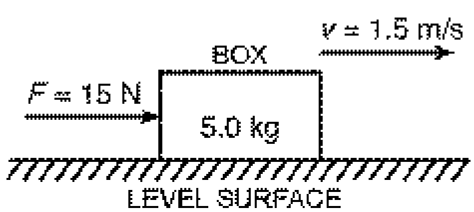
3) A car's performance is tested on various horizontal road surfaces. The brakes are applied, causing the rubber tires of the car to slide along the road without rolling. The tires encounter the *greatest* force of friction to stop the car on

A) dry asphalt
B) wet asphalt
C) dry concrete
D) wet concrete

4) A carpenter hits a nail with a hammer. Compared to the magnitude of the force the hammer exerts on the nail, the magnitude of the force the nail exerts on the hammer during contact is

A) greater
B) less
C) the same

5) As shown in the diagram below, an open box and its contents have a combined mass of 5.0 kilograms.



A horizontal force of 15 newtons is required to push the box at a constant speed of 1.5 meters per second across a level surface. The inertia of the box and its contents increases if there is an increase in the

A) mass of the contents of the box
B) speed of the box
C) magnitude of the horizontal force applied to the box
D) coefficient of kinetic friction between the box and the level surface

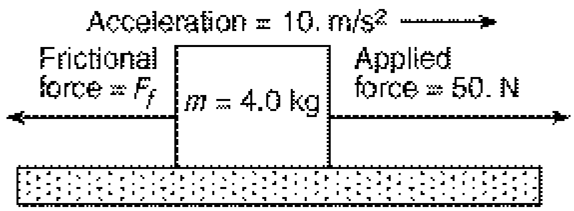
6) Which of the following objects has the *greatest* inertia?

A) a 20.-kg object at rest
B) a 5.0-kg object moving at a speed of 5.0 m/s
C) a 15-kg object moving at a speed of 1.0 m/s
D) a 10.-kg object moving at a speed of 3.0 m/s

TTQ ***(Typical Test Questions)***

Documented Thinking

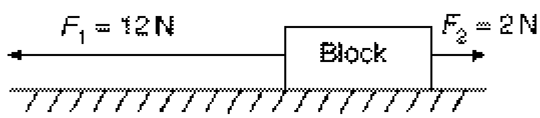
7) The diagram below shows a 4.0-kilogram object accelerating at 10. meters per second^2 on a rough horizontal surface.



What is the magnitude of the frictional force F_f acting on the object?

A) 40. N C) 20. N
B) 5.0 N D) 10. N

8) Two forces, F_1 and F_2, are applied to a block on a frictionless, horizontal surface as shown below.



If the magnitude of the block's acceleration is 2.0 meters per second^2, what is the mass of the block?

A) 7 kg C) 5 kg
B) 1 kg D) 6 kg

9) A 0.50-kilogram frog is at rest on the bank surrounding a pond of water. As the frog leaps from the bank, the magnitude of the acceleration of the frog is 3.0 meters per second^2. Calculate the magnitude of the net force exerted on the frog as it leaps. [*Show all work, including the equation and substitution with units.*]

10) A student and the waxed skis he is wearing have a combined weight of 850 newtons. The skier travels down a snow-covered hill and then glides to the east across a snow-covered, horizontal surface.

(a) Determine the magnitude of the normal force exerted by the snow on the skis as the skier glides across the horizontal surface.

(b) Calculate the magnitude of the force of friction acting on the skis as the skier glides across the snow-covered, horizontal surface. [*Show all work, including the equation and substitution with units.*]

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Notes: Scientific Notation

- To express very large or small numbers which are common in physics we often represent them in **scientific notation**, for example:
  - 3,560,000,000 m = **3.56×10^{9} m**
  - 0.000 000 492 s = **4.92×10^{-7}s**
- To convert numbers to scientific notation perform the following steps.
  1. If the number does not have a decimal point place one on it after the **last digit**.
  2. Move the decimal point one digit at a time, **counting digits** until there is one digit to the left of the decimal.
  3. Report the number as D.DD x 10^{n} where n is the number of digits moved.
  4. For large numbers (greater than 1) n will be **positive** and for small numbers n will be **negative**

Exercise 1: Convert the following numbers to scientific notation.

1) 275,000,000 miles

2.75×10^{8} miles

2) 44,000 kilograms

4.4×10^{4} kg

3) 0.000 000 000 037 9 seconds

3.79×10^{-11} seconds

4) 0.983 cm

9.83×10^{-1} cm

Guided Practice

Convert the following numbers to scientific notation:

1) 123 000 000 000 **1.23×10^{11}**

2) 0.000 000 003 234 **3.234×10^{-9}**

3) 46 500 000 **4.65×10^{7}**

8.34×10^{5}

4) 834 000

4.27×10^{4}

5) 42 700

2.832×10^{-2}

6) 0.028 32

Convert the following numbers to standard notation

1) $6.23 \text{ X } 10^{14}$

623 000 000 000 000

2) $9.2367 \text{ X } 10^{-8}$

0.000000092367

3) $6.54 \text{ X } 10^{3}$

6 540

4) $7.342 \text{ X } 10^{-3}$

0.007342

5) $3.32 \text{ X } 10^{6}$

3 320 000

6) $8.432 \text{ X } 10^{-1}$

0.8432

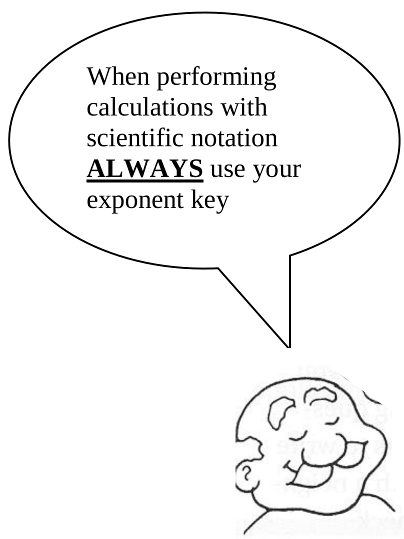
Exercise 2: For each of the following operations, estimate the exponent of the answer represented in scientific notation then perform the following operations using your calculator.

a. $2.45 \text{ x } 10^{-12} \text{ x } 7.543 \text{ x } 10^{10}$ **$1.84 \text{ x } 10^{-1}$**

b. $8.83 \text{ x } 10^{34} \text{ x } 3.290 \text{ x } 10^{-10}$ **$2.91 \text{ x } 10^{25}$**

c. $\frac{6.34x10^{22}}{5.22x10^{-4}}$ **$1.21 \text{ x } 10^{26}$**

d. $\frac{6.237x10^{12}}{8.56x10^{36}} + \frac{4.294x10^{15}}{5.894x10^{38}}$ **$8.014x10^{-24}$**



- Often when dealing with measurements that are very small or large numbers the prefixes in the following table are used.

Reference Tables

Prefixes for Powers of 10

Prefix	Symbol	Notation
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Measuring big stuff (↑)

Measuring small stuff (↓)

When going backwards on the table just change the sign of the exponent

1 picogram = 10^{-12} grams

OR

1 gram = 10^{+12} picograms

- It will be helpful to remember that measurements using prefixes with **positive** exponents are for measuring **large** things.
  - e.g. Distance from New York to L.A. is **3932 kilometers**
  - Mass of the Earth is **5.9 billion Teratons**
- Measurements using prefixes with **negative** exponents are for measuring **small** things
  - e.g. A paramecium has a length of approximately **5000 nanometers**
  - A single human hair has a mass of approximately **600 micrograms**
- Consider the following examples to illustrate use of these metric units.
  - Each line from the above table can be used to produce two different equalities.

1 meter = 100 cm or 1 cm = 0.01 meters or 10^{-2} meters

1 kilogram = **10^{3}** grams or 1 gram = **10^{-3}** kg

1 hertz = **10^{-6}** megahertz or **1 MHz = 10^{6} Hz**

1 liter = **10^{3}** milliliters or **1 mL = 10^{-3} L**

1 second = **10^{9}** nanoseconds or **1 ns = 10^{-9} s**

Converting metric units

- When given a measurement with a prefix, it can easily be converted to **the base unit** using the table of metric prefixes from the reference tables.
  - Examples:
  - How many meters is equal to 35 kilometers?

    35 km = 35 x 10^3 m
    or 3.5 x 10^4 m

  - How many grams is equal to 250 nanograms?

    250 ng = 250 x 10^{-9} g
    or
    2.50 x 10^{-7} g

  - How many millimeters are equal to 0.025 meters?

    0.025 m = 0.025 x 10^{-3} mm
    or
    2.5 x 10^{-5} mm

Guided Practice

Convert the following measured values as directed.

a. a wildcat football player with a mass of 325 kilograms = **325 x 10^3** grams
or
3.25 x 10^5

b. A sub-atomic particle with a diameter of 1350 picometers = **1350 x 10^{-12}** meters
or
1.35 x 10^{-9}

c. A cat with an electrostatic charge of 4.25 microcoulombs = **4.25 x 10^{-6}** coulombs

d. An asteroid with a mass of 47 megatons = **47 x 10^6** tons
4.7 x 10^7

Estimating Measurements

- The ability to make reasonable **estimates** of the size of things is a valuable tool.
- If you were traveling in a car that someone was driving 100 miles per hour you would probably be able to estimate that the speed was much greater than the **speed limit** without looking at the speedometer.
- A tool that is commonly used for estimating is called **order of magnitude**.
- When you describe the order of magnitude for something you are stating the **exponent** of ten for that measurement if the number were represented in.scientific notation
  - For example suppose a truck is 400 cm long:
    - 400 cm is equal to **4.00×10^2 cm** in scientific notation
    - So the order of magnitude is **10^2** or **2**
  - A pencil is 8.2 cm long
    - 8.2 cm is equal to **8.2×10^0** in scientific notation

So the order of magnitude is ____________ or **10^0** **0**

http://htwins.net/scale2/

Select the correct size of the following estimates. Use the sheet of unit conversions to assist you.

1) The length of a human finger is closest to:
   a) 10^1 cm
   b) 10^2cm
   c) 10^{-2} cm
   d) 10^{-3} cm
2) The volume of your locker is closest to
   a) 10^{-1} liters
   b) 10^0 liters
   c) 10^1 liters
   d) 10^3 liters
3) The height of a tree is closest to
   a) 10^{-2} meters
   b) 10^0 meters
   c) 10^1 meters
   d) 10^2 meters
4) The mass of a high school football player is closest to:
   a) 10^0 kg
   b) 10^1 kg
   c) 10^2 kg
   d) 10^3 kg
5) Which of the following is the approximate thickness of a sheet of paper:
   a) 10^0 cm
   b) 10^{-1} cm
   c) 10^{-2} cm
   d) 10^{-3} cm
6) Your height is closest to:
   a) 10^{-1} m
   b) 10^0 m
   c) 10^1 m
   d) 10^2 m

Notes: Newton's Gravitation & Hooke's Law

Objectives:

1. Demonstrate proper use of scientific notation and perform calculations involving numbers in scientific notation.
2. Explain Newton's Law of Universal Gravitation and discuss situations where it applies.
3. Use Newton's LUG to calculate gravitational forces.
4. Explain how Hook's law describes the effects of compressing or stretching a spring
5. Use the Hook's law equation to solve various types of problems.

Newton's Law of Universal Gravitation

- Remember we described the force that the Earth exerts on objects as the __**weight**__ force.
- This force was studied by __**Isaac Newton**__.
- From his work Newton discovered that a force __**gravitation**__ exists between any two objects that have __**mass**__.
- This force applies to many common examples:
    - __**force attracting anything to the Earth's surface**__
    - __**force holding planets in the solar system**__
    - __**force holding satellites in orbit of the Earth**__

- Newton discovered that this force is related to the __masses__ of the objects and the __distance__ separating the objects.

$$F_g = \frac{G m_1 m_2}{r^2}$$

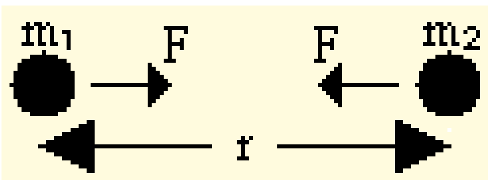
F_g = Gravitational force (weight)

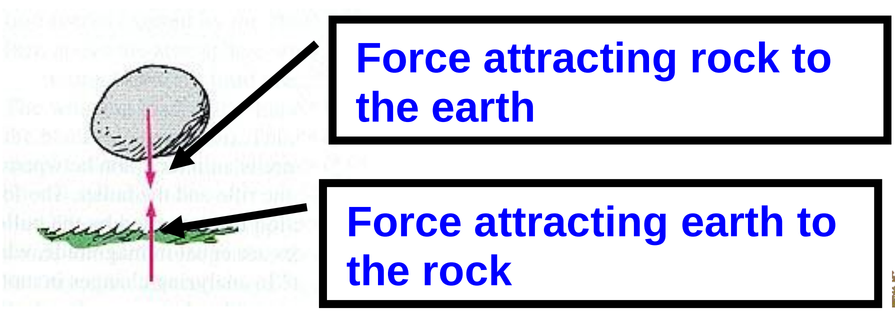
G = Universal Gravitation Const. ($6.67 x 10^{-11} N \bullet m^2 / kg^2$)

m_1 = mass of first body

m_2 = mass of second body

r = dist. separating bodies





Sample Problem 1: Edna and Efram are sitting in physics class separated by a distance of 7.1 meters. Edna has a mass of 60.0 kg and Efram (a heavyweight on the wrestling team) has a mass of 125 kg. Calculate the gravitational force of attraction that exists between Edna and Efram as they sit in class.

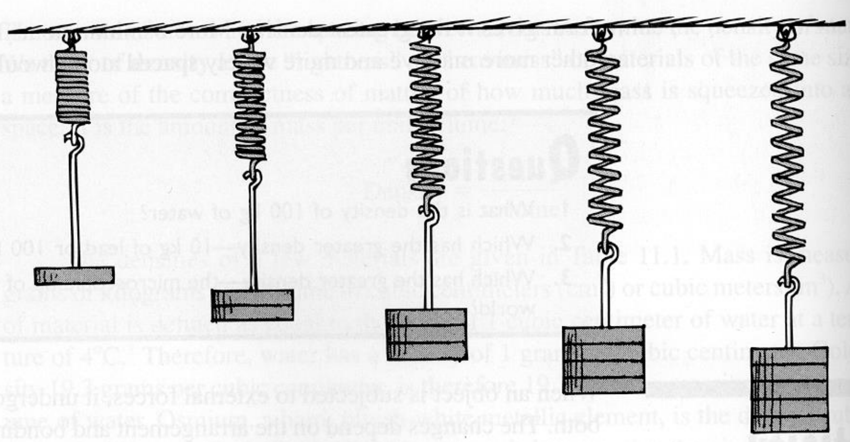
Sample Problem 2: Calculate the weight force between Efram and the Earth's surface using 2 methods.

a. Use $F_f = mg$
b. Use Newton's universal Law of Gravitation.

Hooke's Law

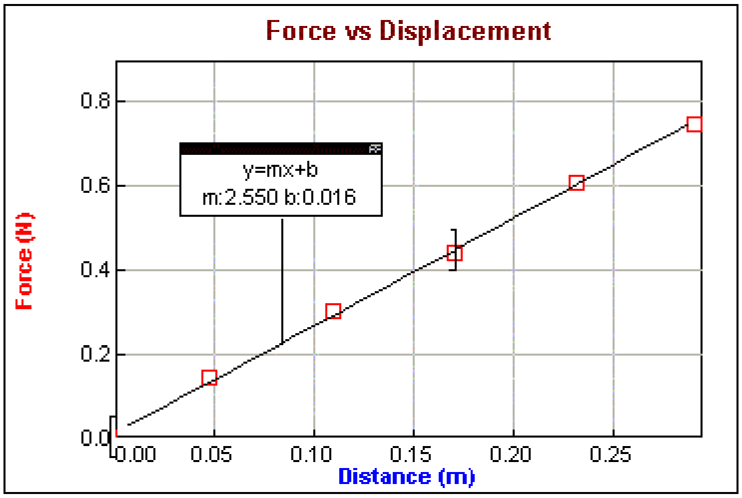
- For perfectly elastic systems there is a constant value that describes the proportion between a force being exerted on a system and the deformation of the system from its non-stressed state.
- Perfectly elastic means that the force results in no __**permenant deformation**__
- Force may result in a __**stretching or compressing**__ deformation.
- The slope of a plot from __**force**__ vs. __**displacement from equilibrium**__ will be the force constant.

FIGURE 11.6 The stretch of the spring is directly proportional to the applied force. If the weight is doubled, the spring stretches twice as much.



F = k x

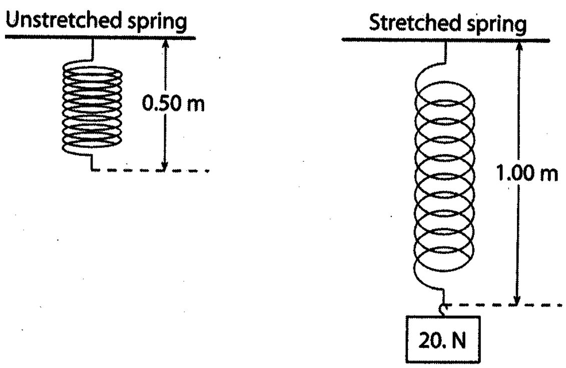
F = force magnitude
k = force constant (N/m)
x = displacement of spring from non-stressed position.



Sample Exercise:

a. On the above graph sketch a line that would represent data collected from a spring of greater stiffness and label that line A
b. Sketch a line that would represent data collected from a spring of greater flexibility and label that line B.

- A 20.-newton weight is attached to a spring causing it to stretch, as shown in the following diagram.



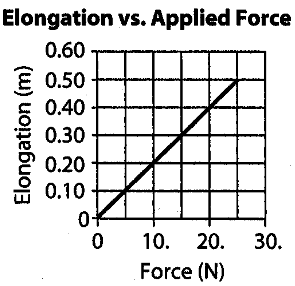
What is the spring constant of this spring?

F = k x

k = F/x
k = 20N / 0.50 m

k = 40 N/m

The graph that follows shows the relationship between the elongation of a spring and the force applied to the spring causing it to stretch.

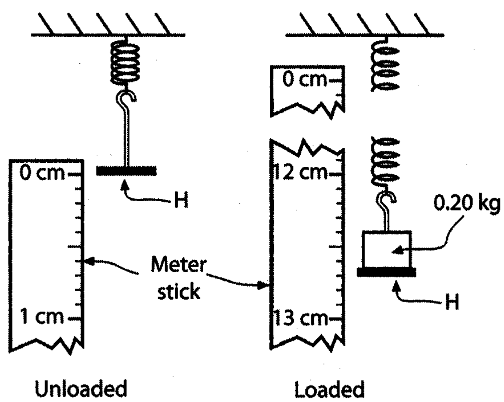


F = k x

k = F/x
k = 10N / 0.20 m

k = 50 N/m

- A mass hanger is attached to a spring, as shown in the following diagrams.



What is the magnitude of the displacement of the mass hanger H after a 0.20-kilogram mass is loaded on it? (Assume the hanger is at rest in both positions.)

Also find the spring constant

X = 12.71 cm

But lets also find the spring constant

F is $F_g = mg$
$F = (0.20\ kg)\ (9.8\ m/s^2)$
F = 19.6 N

k = F/x

k = 19.6 N / 12.71 cm

1.54 N/cm

Name ______________________ Regents / Honors Physics

Date ____________

Guided Practice: Newton's LUG

Practice Page

Force and Weight

1. An apple that has a mass of 0.1 kilogram has the same mass wherever it is. The amount of matter that makes up the apple

   (depends upon) (does not depend upon)

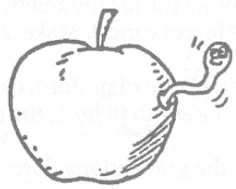
   the location of the apple. It has the same resistance to acceleration wherever it is — its inertia everywhere is

   (the same) (different).

   The weight of the apple is a different story. It may weigh exactly 1 N in San Francisco and slightly less in mile-high Denver, Colorado. On the surface of the moon the apple would weigh 1/6 N, and far out in outer space it may have almost no weight at all. The quantity that doesn't change with location is

   (mass) (weight),

   and the quantity that may change with location is its

   (mass) (weight).

   That's because

   (mass) (weight)

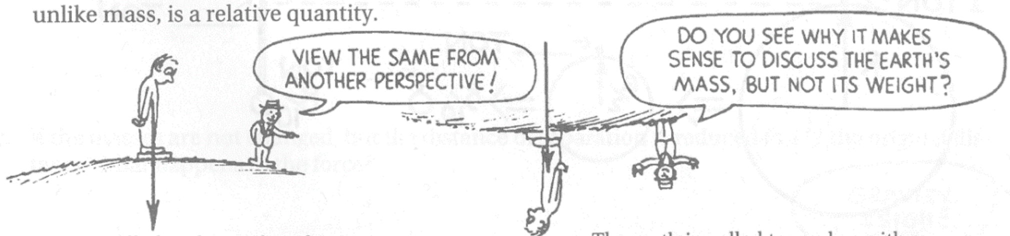
   is the force due to gravity on a body, and this force varies with distance. So weight is the force of gravity between two bodies, usually some small object in contact with the earth. When we refer to the

   (mass) (weight)

   of an object we are usually speaking of the gravitational force that attracts it to the earth.

Fill in the blanks:

2. If we stand on a weighing scale and find that we are pulled toward the earth with a force of 500 N, then we weigh ________ N. Strictly speaking, we weigh ________ N relative to the earth. How much does the earth weigh? If we tip the scale upside down and repeat the weighing process, we can say that we and the earth are still pulled together with a force of ________ N, and therefore, relative to us, the whole 6 000 000 000 000 000 000 000 000-kg earth weighs ________ N! Weight, unlike mass, is a relative quantity.



We are pulled to the earth with a force of 500 N, so we weigh 500 N.

The earth is pulled toward us with a force of 500 N, so it weighs 500 N.

Concept-Development Practice Page 13-2

Gravitational Interactions

The equation for the law of universal gravitation is

$$F = G\frac{m_1 m_2}{d^2}$$

where F is the attractive force between masses m_1 and m_2 separated by distance d. G is the universal gravitational constant (and relates G to the masses and distance as the constant π similarly relates the circumference of a circle to its diameter). By substituting changes in any of the variables into this equation, we can predict how the others change. For example, we can see how the force changes if we know how either or both of the masses change, or how the distance between their centers changes.

Suppose, for example, that one of the masses somehow is doubled. Then substituting $2m_1$ for m_1 in the equation gives

$$F_{NEW} = G\frac{2m_1 m_2}{d^2} = 2\left(G\frac{m_1 m_2}{d^2}\right) = 2F_{OLD}$$

So we see the force doubles also. Or suppose instead that the distance of separation is doubled. Then substituting $2d$ for d in the equation gives

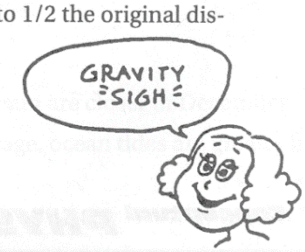
$$F_{NEW} = G\frac{m_1 m_2}{(2d)^2} = G\frac{m_1 m_2}{4d^2} = \frac{1}{4}\left(G\frac{m_1 m_2}{d^2}\right) = \frac{1}{4}F_{OLD}$$

And we see the force is only 1/4 as much.

Use this method to solve the following problems. Write the equation and make the appropriate substitutions.

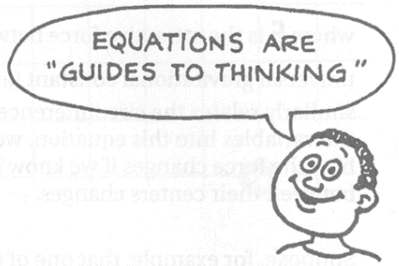
1. If both masses are doubled, what happens to the force?

2. If the masses are not changed, but the distance of separation is reduced to 1/2 the original distance, what happens to the force?



3. If the masses are not changed, but the distance of separation is reduced to 1/4 the original distance, what happens to the force?

4. If both masses are doubled, and the distance of separation is doubled, show what happens to the force.



5. If one of the masses is doubled, the other remains unchanged, and the distance of separation is tripled, show what happens to the force.

6. Consider a pair of binary stars that pull on each other with a certain force. Would the force be larger or smaller if the mass of each star were three times as great when their distance apart is three times as far? Show what the new force will be compared to the first one.

1. Using data on your reference tables determine the gravitational force acting between the sun and Earth.

2. In late 2013 a newly discovered comet will pass very close to the sun and at its closest may be as bright as the full moon. At its closest it will be 1.856×10^{6} km from the sun. The comet is estimated to have a mass of 3.1×10^{13} kg. What will be the gravitational force between the comet and the sun at its closest approach?

TTQ ***(Typical Test Questions)***

Documented Thinking

1) As an astronaut travels from the surface of Earth to a position that is four times as far away from the center of Earth, the astronaut's

A) mass remains the same
B) weight increases
C) mass decreases
D) weight remains the same

2) A 2.00-kilogram object weighs 19.6 newtons on Earth. If the acceleration due to gravity on Mars is 3.71 meters per second^2, what is the object's mass on Mars?

A) 2.64 kg
B) 2.00 kg
C) 19.6 N
D) 7.42 N

3) A 60.-kilogram physics student would weigh 1,560 newtons on the surface of planet *X*. What is the magnitude of the acceleration due to gravity on the surface of planet *X*?

A) 0.038 m/s^2
B) 6.1 m/s^2
C) 9.8 m/s^2
D) 26 m/s^2

4) The weight of a typical high school physics student is *closest* to

A) 60 N
B) 600 N
C) 1,500 N
D) 120 N

5) Io (pronounced "EYE oh") is one of Jupiter's moons discovered by Galileo. Io is slightly larger than Earth's Moon. The mass of Io is 8.93×10^{22} kilograms and the mass of Jupiter is 1.90×10^{27} kilograms. The distance between the centers of Io and Jupiter is 4.22×10^{8} meters.

(a) Calculate the magnitude of the gravitational force of attraction that Jupiter exerts on Io. [*Show all work, including the equation and substitution with units.*]

(b) Calculate the magnitude of the acceleration of Io due to the gravitational force exerted by Jupiter. [*Show all work, including the equation and substitution with units.*]