**Force & Motion**

1. **Force**:

1. What is a force?
2. Give examples of different kinds of forces: (*opposite, combined, upholding, pressure, work, centripetal*)
3. What produces forces? (*energy*)

* A **force** is a push or pull. A force may give energy to an object, setting the object in motion, stopping it, or changing its direction. Force & motion are in the same direction.
* Forces in the same direction combine by addition.

Demo: Have 3 students come to front (have 2 students weigh what the third student weighs)

* + 2 students push against the same object in the same direction

Net Forces

equals

130 lbs 120 lbs 250 lbs

* Forces in opposite directions combine by subtraction.
  + 1 student faces off against another 2 students

CANCEL each other

130 lbs 120 lbs 250 lbs

Tug O War

**Unbalanced forces** cause a change in motion. When forces are balanced, there is no change in motion. Produces a “Net force” which is the sum of all the vector forces (magnitudes and directions).

**Balanced forces** are opposite in direction and equal in size. Net force = 0. Motion can be sustained by balanced forces, called constant motion.

1. **Forces that OPPOSE MOTION**

* **Forces in opposite directions**
* **Gravity**
* **Friction** is a force that opposes motion.
  + The three kinds of friction:
    - Sliding (scuff feet on the floor) - lubrication
    - Rolling (roller blades, bicycles, cars) – ball bearings
    - Fluid friction (oil in crankcase, fish in water) – lubricants, streamlining
    - Static (standing or sitting without sliding)

1. The Nature of Forces **Activity** (coins)
2. Relative Motion
3. Motion is always relative to POSITION
4. The most basic motion (speed) is described as “position versus time” or “displacement”
5. Every position has a “Reference Point”
6. A point against which position is measured
7. All motion is relative – motion depends on the reference point that is used.

[**http://somup.com/cFXhD1n144**](http://somup.com/cFXhD1n144) **Relative Motion (0:32) Car in a snow storm**

[**http://somup.com/cFXhDQn14A**](http://somup.com/cFXhDQn14A) **Relative Motion (0:55) Boy on Train platform**

<http://somup.com/cFXhoMn14r> Relative Motion Bugs and Daffy (fun) (6:53)



Use the images to the right 🡪

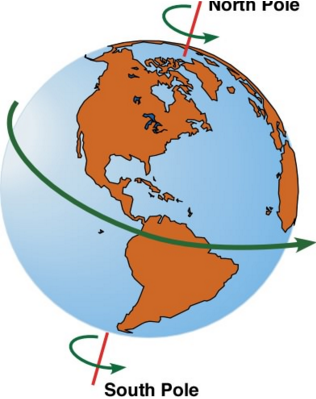
You are sitting in a car … how fast are you moving?

in relation to the car: 0 mph



How fast is the car moving?

in relation to the road: 64 mph



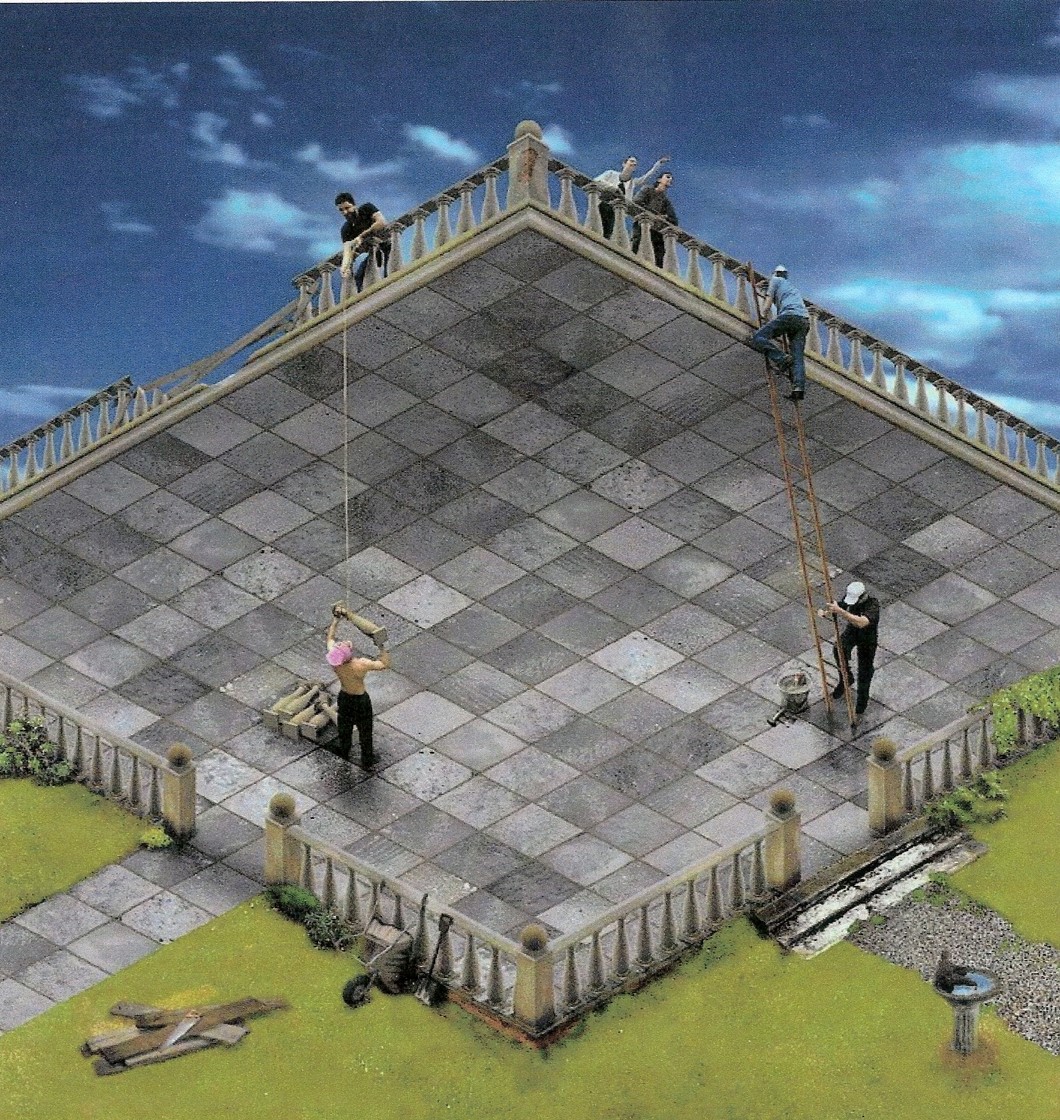
But what about from outer space?

in relation to outer space:

Going West: ~936 mph

Going East: ~1064 mph

Relative Motion / Position (depends on your reference point)



1. Position versus Time  displacement

+

0

+

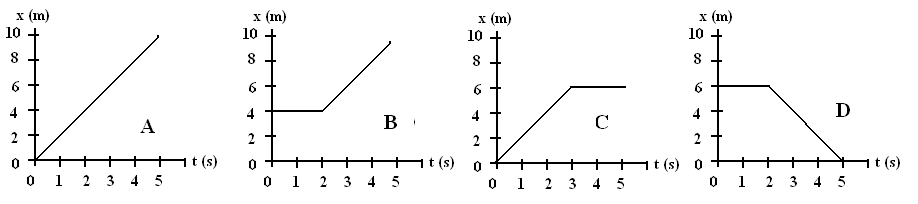
0

0

-

+

A  moving in a positive direction for 5 seconds



B  stopped for two seconds, then moving in a positive direction for 3 seconds

C  moving in a positive direction for 3 seconds, then stopped for 2 seconds

D  stopped for two seconds, then moving in a negative direction for 3 seconds



-

0

E  moving in a negative direction for 3 seconds, then stopped for 2 seconds

Position-Time Worksheet

1. **SPEED (force produces motion and this relates to speed)**

**a. SKATEBOARD**ING

* A student stands on the skateboard without moving. (*What kind of force?)*
* Have another student push the skateboarder. (*What kind of force?)*
* Will the student move indefinitely? (*Why or why not?)*

V

d

t

b. Speed = distance / time

c. Velocity = displacement / time (*speed + direction = velocity)*

Distinguish between

* INSTANTANEOUS speed  speed at a given moment or time
* CONSTANT speed  speed does not change over time
* AVERAGE speed  total distance / total time

d. Calculate speed using the toy car **ACTIVITY**

* Use a stop watch and the video: <http://somup.com/crhIq4FLYP> (1:09)
* Given distance or time, record time or distance travelled.
* Calculate the speed for each case.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Given Distance | | | Avg v | Given Time | | | | Avg v |
| Distance (m) | *1 m* | *2 m* | *3 m* | 6 m |  |  |  |  |  |
| Time (s) |  |  |  |  | *1 s* | *2 s* | *3 s* | *4 s* |  |
| Speed (d/t) |  |  |  |  |  |  |  |  |  |

Calculate average speed when given distance and when given time.

Using the information give in the data table, calculated the average speed.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | Average Speed |
| Distance (m) | *5.0 m* | *10.0 m* | *20.0 m* |  |
| Time (s) | *1.3 s* | *2.5 s* | *5.1 s* |  |
| Speed (d/t) |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Given Distance | | | Avg v | Given Time | | | | Avg v |
| Distance (m) | *1 m* | *2 m* | *3 m* |  | 0.62 m | 1.20 m | 2.02 m | 3.00 m | 6.84 m |
| Time (s) | 2.3 s | 4.8 s | 6.6 s | 13.7 s | *1 s* | *2 s* | *3 s* | *4 s* | 10 s |
| Speed (d/t) | 0.41 m/s | 0.42 m/s | 0.45 m/s | 0.44 m/s | 0.62 m/s | 0.60 m/s | 0.67 m/s | 0.75 m/s | 0.68 m/s |

**Notice: average speed = total distance / total time**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | Average Speed |
| Distance (m) | *5.0 m* | *10.0 m* | *20.0 m* | 35 m (total distance) |
| Time (s) | *1.3 s* | *2.5 s* | *5.1 s* | 8.9 s (total time) |
| Speed (d/t) | 3.8 m/s | 4.0 m/s | 3.9 m/s | 3.9 m/s |

8.8 mph [*4 m/s x 60 s/min x 60 min/hr x 1 km/1000m x 1 mile/1.6 km*]

20. Use the position-time graph to find:

a. How far the object travels between t = 0 s and t = 40 s?



b. How far does the object travel between the 40 s and 70 s interval?



c. How far does the object travel between the 90 s and 100 s interval?



21. Plot a velocity-time graph using the information in this Table:



ANSWER:



a. What are the independent and dependent variables on the graph?

*Velocity is the dependent variable and time is the independent variable.*

b. What happens at the 5 s point?

*Reverses direction*

c. Describe the motion from t = 0 to 4 s in terms of velocity & acceleration.

*The velocity increases the entire time. From t = 0 s to t = 2 s, the acceleration is constant, but the acceleration decreases at t = 3 s to a new constant acceleration until t = 4 s.*

d. Describe the motion from t = 4 to 5 s in terms of velocity & acceleration.?

*The velocity remains constant from t = 4 s to t = 5 s. Therefore, there is no acceleration. However, there was a change in speed before the 4 s point to the 5 s point (which is a deceleration).*

e. Describe the motion from t = 5 to 12 s in terms of velocity & acceleration.?

*The velocity is now decreases the entire time. From t = 5 s to t = 7 s, the acceleration is constant, but the acceleration decreases at t = 7 s to a new constant acceleration until t = 12 s.*

f. Speed problems (basic) and Speed **Problem Set**

g. **LAB** on speed

h. Velocity-Time Worksheet

Handling equations:

Friends STANDING Friends

mis

“ A little misunderstanding between friends”

1. **ACCELERATION**

An unbalanced force produces acceleration (*change in motion*). Force and motion are in the same direction, but acceleration and motion (velocity) do not have to be.

a) A change in speed over time  rate of change of motion

1. slowing down or speeding up
2. keeping the same speed but changing direction

* circular / rotational motion (centripetal force)

e.g. *going around a corner on a roller coaster*

**DEMO**: roll a Hula hoop down the hall with reverse acceleration

*Reverse spin a Hula hoop, meaning its velocity is in one direction while its acceleration is in a different direction. The circular motion, of the Hula hoop also causes an “inward” acceleration due to centripetal force.*

velocity

acceleration

centripetal force

velocity

<http://somup.com/cFXh0in1ky> Motion in Two Directions ctr (0:25)

b) a = ∆v/t … m/s / s = **m/s2**

a

∆v

t

 ∆v = a t

 t = ∆v/a

c) a = vf – vi vf =final velocity  vi = initial velocity

t

d) Acceleration **ACTIVITY**!

[*go outdoors, to gym, or in hallway*]

e) **Centripetal Motion** (a type of acceleration)

a) Centripetal force produces an inward pull towards a center

b) When centripetal force is gone, objects will travel in a tangent to the circular motion (i.e softball fast pitch)

*With circular motion, a car can be heading in one direction (while going in a circle) and its centripetal force will cause the car to accelerate towards the center of the circular motion.*

*Also with circular motion, a hockey puck rotates (towards the center) while heading north. This is rotational motion.*

f) Constant Acceleration Lab (Parts 1 & 2)

Acceleration is the rate of speed over time, meaning that speed changes over time. Previously we worked with average velocity (*speed plus direction*), finding displacement over time (**v = d/t**). Therefore, we can find displacements, times and speed changes for experiments or real life situations. For instance, if you are travelling 70 mph and travel for 2 minutes, how far have you traveled? If you are running at a constant speed and run a known distance, how long did it take you?

We can also find variables related to acceleration in much the same way. We can work with displacements, times and velocities because these are variables of acceleration as described by [ **a = (vf – vi) / t** ]. If we know certain variables, we can calculate other variables because they are all mathematically related. For instance, if we want to calculate the final velocity of an object, we can rearrange the equation as follows:

**vf = vi + a t**

The simplest way to investigate this is to use **constant acceleration**. We know that average velocity is displacement over time (**v = d/t**). We can also find average velocity by adding velocities and dividing by the total number of velocities [ **v = (vf + vi) / 2** ]. If we place the first average velocity equation into the second, we get the following: **d/t = (vf + vi) / 2**. Solving for displacement, we get:

**d = ½ (vf + vi) t**

Based on the previous information, we can calculate displacements if we know time and acceleration. If the initial velocity, acceleration, and time interval are known, the displacement of an object can be found by combining equations already used.

Beginning with [ **a = (vf – vi) / t** ] we can solve for **vf** as get: **vf = vi + at** . Then, we can substitute this equation in the displacement equation, **d = ½ (vf + vi) t** … d = ½ (vi + at + vi) t which is rewritten: d = ½ (2vi + at) t and get:

**d = vi t + ½ at2**

There are two terms in this equation. The first term, **vi t** , corresponds to the displacement of an object if it were moving with constant velocity, **vi** . The second term, **½ at2**, gives the displacement of an object starting from rest and moving with uniform acceleration.

The sum of these two terms, **vi t** and **½ at2**, gives the displacement of an object that starts with an initial velocity and accelerates uniformly. For an object that starts from rest, the equation reduces to: **d =** **½ at2**.

g) Acceleration Problem Set

1. **Inertia** is the tendency of matter to **resist** a change in motion.
2. **Newton’s Laws of Motion**

**Newton's first law of motion** states that an object at rest will remain at rest and an object in motion will remain in motion at constant velocity unless acted upon by an unbalanced force.

**Newton's second law of motion** describes how force, acceleration, and mass are related. Force equals mass times acceleration.

**Newton's third law of motion** states that forces always occur in pairs. Every action has an equal and opposite reaction.

1. **Gravity**

a. The acceleration due to the force of attraction that exists between all objects in the universe.

1) The size of the force of gravity depends on the masses of the two objects and the distance between them.

2) The acceleration due to gravity at the surface of the Earth is 9.8 m/sec/sec.

3) **Weight**  is a measure of the pull of gravity on a given mass. Mass is a measure of the amount of matter in an object. Mass is constant; weight can change.

W = mg

b. Weight and mass are different quantities.

1. **Free Fall**

a. When an object is only influenced by the **acceleration due to gravity**, it is said to be in Free fall.

1. Based on derivations of velocity and acceleration, the distance an object falls can be calculated as follows:

**d = vi t + ½ at2**



2. If the object starts at rest, the equation reduces because

**vi = 0 🡪**

For a freely falling object dropped from rest, how far will it fall after five seconds? How far will it fall after 10 seconds?

d = ½ gt2 = ½ (9.8 m/s2)(5 s)2 = 122.5 m

d = ½ gt2 = ½ (9.8 m/s2)(10 s)2 = 490 m

b. Instantaneous velocity of impact

At the moment a freely falling object impacts the ground, the instantaneous velocity can be calculated by multiplying gravity by time:

Vi = gt

Imagine the person in the image above drops a quarter from the cliff and it takes 3 seconds to hit the water. What is the speed of the quarter upon impact?

Vi = gt

Vi = (9.8 m/s2) (3 s) = 29.4 m/s

**Example**: A paratrooper jumps from a plane flying 10,000 m above the earth. Describe the velocity of the paratrooper (vertical component only).

Gravity is 9.8 m/s2. This means that the paratrooper’s velocity will INCREASE by 9.8 m/s EVERY second. Therefore, v1s = 9.8 m/s; v2s = 19.6 m/s; v3s = 29.4 m/s; etc.

Will the paratrooper increase in velocity (vertical component only) indefinitely?

c. Air Resistance or drag (a form of fluid friction) opposes free fall

d. Terminal Velocity

When objects free fall they continually gain speed because of the influence of acceleration due to gravity. HOWEVER, air resistance also comes into play. Eventually, a free-falling object will reach its terminal velocity:

<http://somup.com/cFXh3Mn1k0> Terminal Velocity ctr (0:59)

<http://somup.com/cFXh38n1kO> Terminal Velocity (1:22)

e. Free Fall Lab

f. Free Fall Problem Set