Tonight's Agenda

1) Quick review of last week

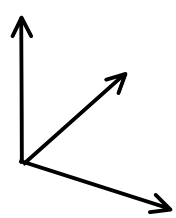
2) Lesson on Force and Motion

3) Experiments on Force and Motion

4) More discussion on Post Project

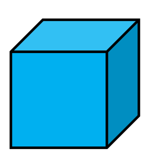
5) Volunteers for Holiday Party

Basic Quantities - Independent

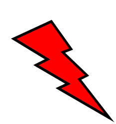


Space - Length

Time



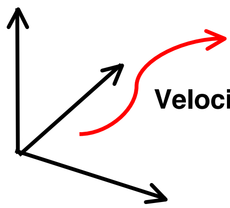
Matter - Mass



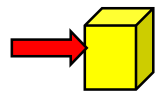
Charge - Electro-magnetics

Derived Quantities

Combinations of Basics

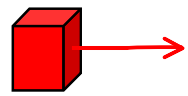


Velocity $= \dfrac{\text{Length}}{\text{Time}}$

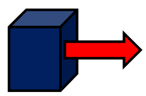


Force $= \dfrac{\text{Mass Length}}{\text{Time}^2}$

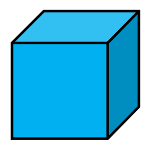
Dimensionality And Units



Momentum $= \dfrac{\text{Mass Length}}{\text{Time}}$



Energy $= \dfrac{\text{Mass Length}^2}{\text{Time}^2}$



Density $= \dfrac{\text{Mass}}{\text{Length}^3}$

Derived Quantities

Used in Aerodynamics

Density $= \dfrac{\text{Mass}}{\text{Length}^3}$

Force $= \dfrac{\text{Mass Length}}{\text{Time}^2}$

Velocity $= \dfrac{\text{Length}}{\text{Time}}$

Momentum $= \dfrac{\text{Mass Length}}{\text{Time}}$

Pressure $= \dfrac{\text{Force}}{\text{Area}} = \dfrac{\text{Mass}}{\text{Length Time}^2}$

Energy $= \dfrac{\text{Mass Length}^2}{\text{Time}^2}$

Torque $= \dfrac{\text{Mass Length}^2}{\text{Time}^2}$

Mass Flow $= \dfrac{\text{Mass}}{\text{Time}}$

Dimensionality

Temperature – Basic or Derived ?

Kinetic Theory of Gases

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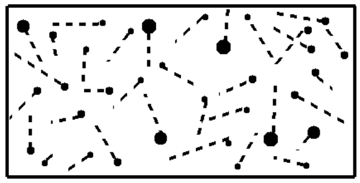

Molecular Model:

Small molecules relative to distance apart.

Molecules in constant random motion.

Frequent collisions between molecules.

Ordered motion superimposed on random motion.

Density -> mass and volume

Pressure -> momentum (mass x velocity)

Temperature -> kinetic energy (mass x velocity^2)

Laws of Physics ?

Observations of the Relations between Derived Quantities

Newton's Laws of Motion

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"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."

"Force is equal to the change in momentum (mV) per change in time. For a constant mass, force equals mass times acceleration."

F=m a

"For every action, there is an equal and opposite re-action."

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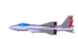
Forces and Motion

Tom Benson
Thomas.J.Benson@nasa.gov

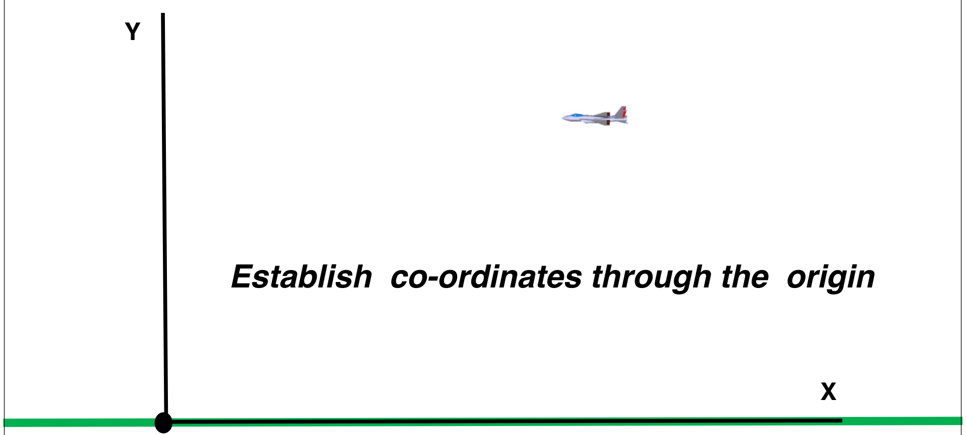
How do I describe the location of an object ?

How do I describe the location of an object ?

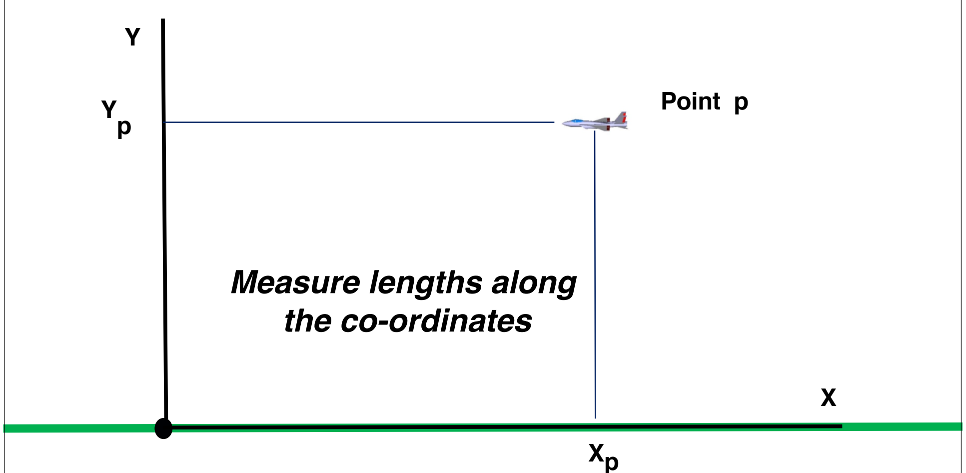


Select an Origin - point of reference

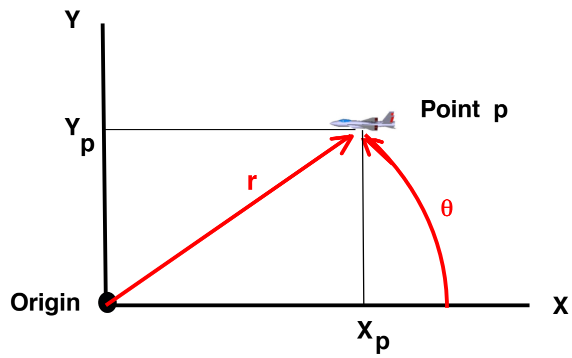
How do I describe the location of an object ?



How do I describe the location of an object ?



Rectangular and Polar Coordinates



Point p can be located relative to the origin by Rectangular Coordinates (X_p, Y_p) or by Polar Coordinates (r, θ)

$X_p = r \cos(\theta)$ $\quad\quad$ $r = \mathrm{sqrt}(X_p^2 + Y_p^2)$

$Y_p = r \sin(\theta)$ $\quad\quad$ $\theta = \tan^{-1}(Y_p / X_p)$

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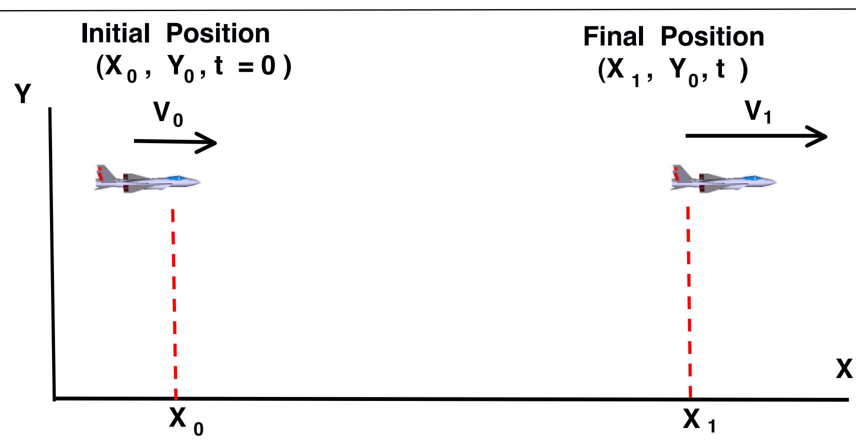
Suppose the Object Moves?



How do we describe the motion ?

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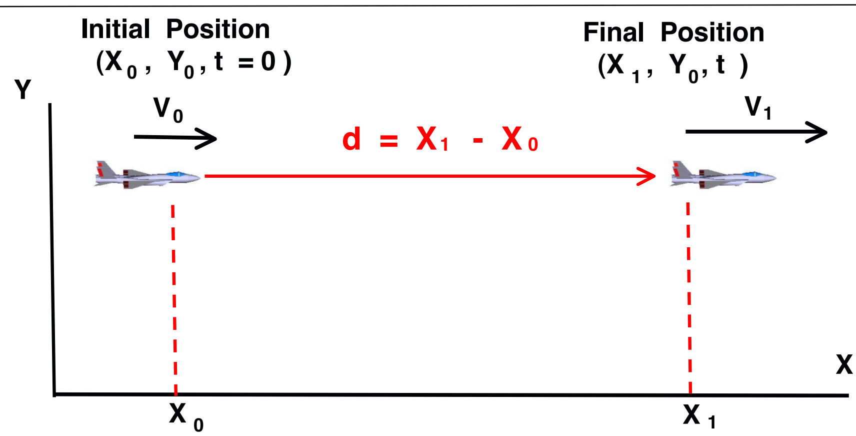
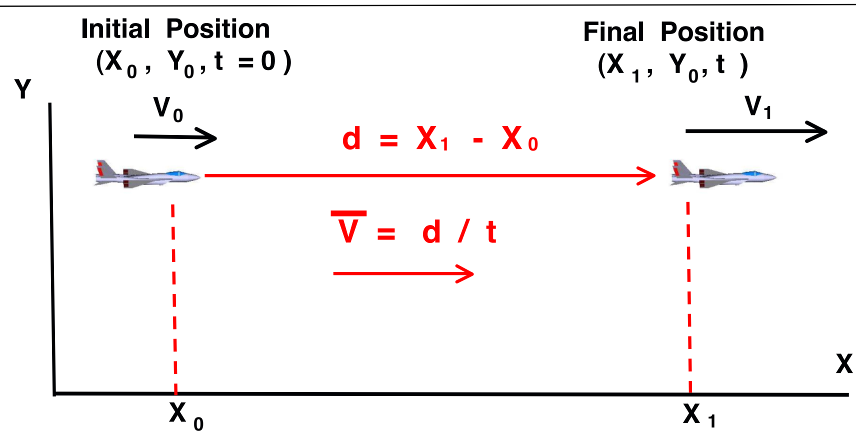
How do we describe motion?



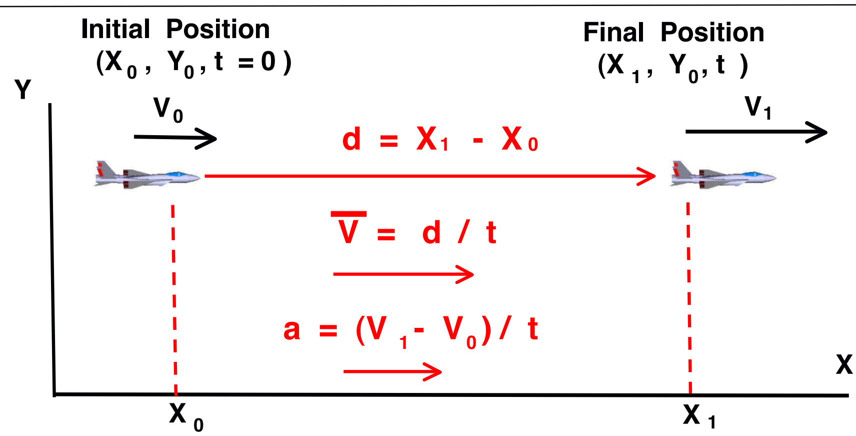
Displacement

How do we describe motion?



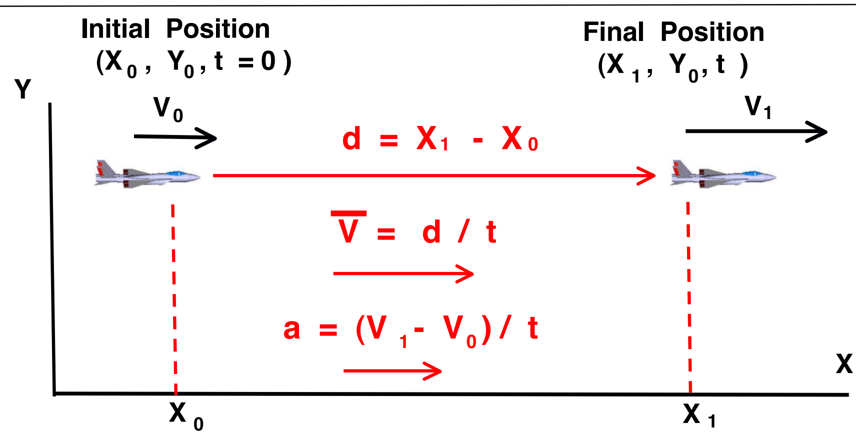
Average Velocity

How do we describe motion?



Acceleration

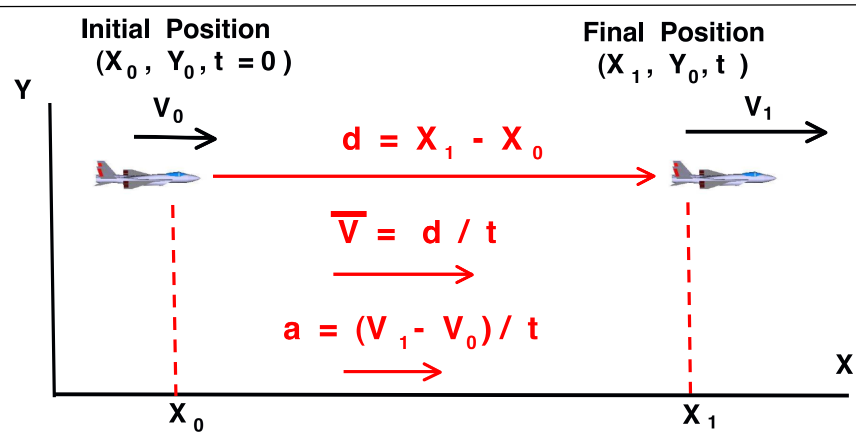
Displacement, Velocity, Acceleration



If velocity is constant - acceleration is zero

If acceleration is zero - velocity is constant

Displacement, Velocity, Acceleration

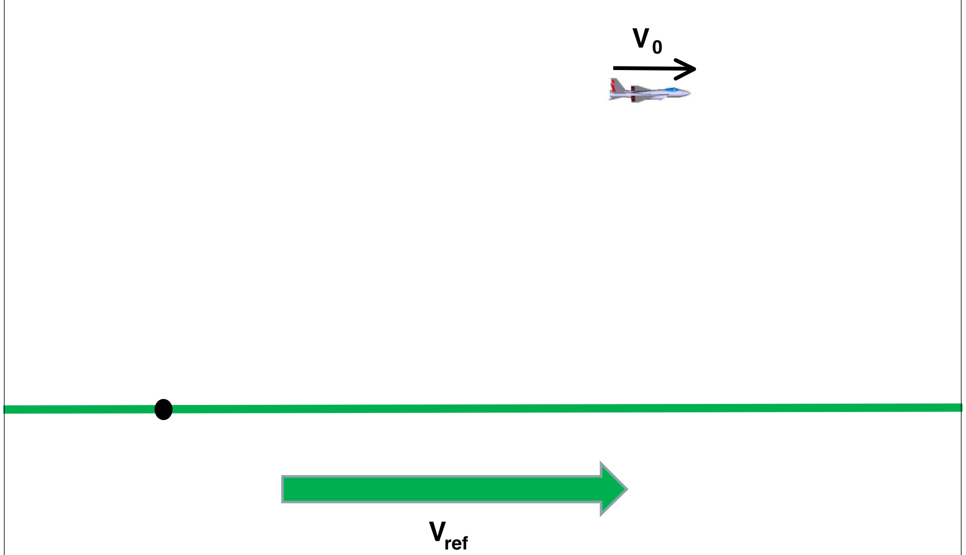


If the acceleration is a constant - $V_1 = V_0 + a\,t$

$$\bar{V} = ½\,(V_1 + V_0) = ½\,(V_0 + a\,t + V_0) = V_0 + ½\,a\,t$$

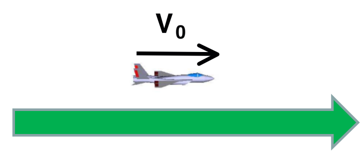
$$d = t\,\bar{V} = V_0\,t + ½\,a\,t^2$$

Suppose the Origin is Moving ?



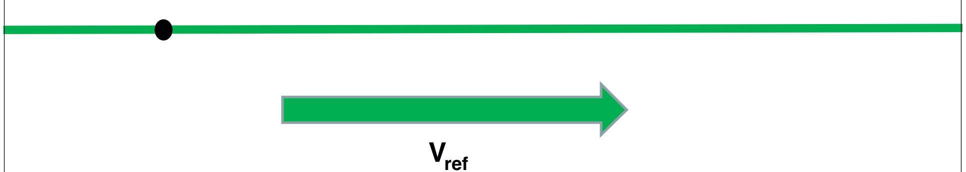
Suppose the Origin is Moving ?

Actual velocity of aircraft is
$V_0 + V_{ref}$



If the reference velocity is constant – no problem

" Newtonian reference plane"



FORCE ?

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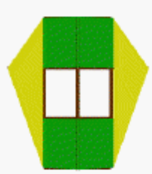
What is it?

Why is it important?
What does it do ?

How does it work?



Examples ?

Forces

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Objects generate forces.
(objects are solid, liquid, or gas)

Forces cause motion.

Forces produce acceleration.

An object's mass resists motion.
(for the same force, heavier object accelerates less)

Forces come in pairs.

Newton's Laws of Motion

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Sir Isaac Newton

Newton's First Law

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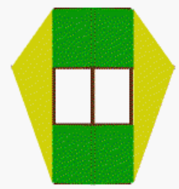
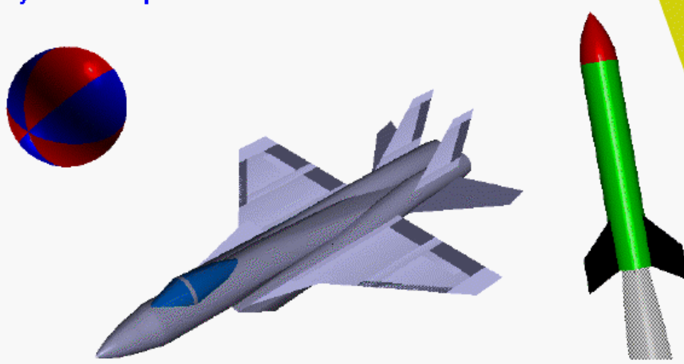
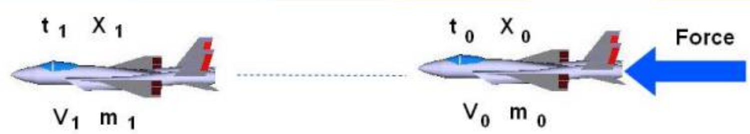
"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."





National Aeronautics and Space Administration

Newton's Second Law



Force = Change of Momentum with Change of Time

Difference form: $$F = \frac{m_1 V_1 - m_0 V_0}{t_1 - t_0}$$

With constant mass: $$F = m \frac{V_1 - V_0}{t_1 - t_0}$$

t = time
X = location
m = mass
V = Velocity

$$F = m\ a$$

Force = mass x acceleration

Velocity, acceleration, momentum and force are vector quantities

Newton's Third Law
Applied to Aerodynamics

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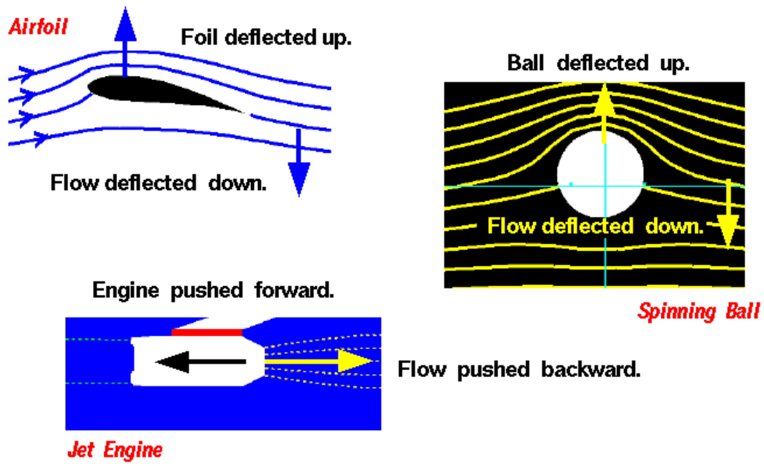
For every action, there is an equal and opposite re-action.



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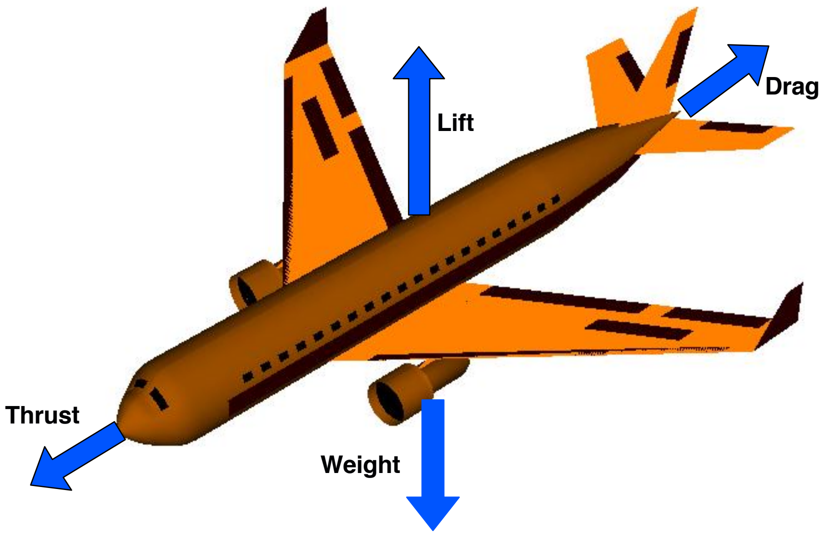
Four Forces on an Airplane



The Weight Equation

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In general: $F = G \dfrac{m_1 \, m_2}{d^2}$

Force equals a gravitational constant times the product of the masses divided by the square of the distance between the masses.

$$g = G \frac{m_{earth}}{d^2_{earth}} = 9.8 \frac{meter}{sec^2} = 32.2 \frac{feet}{sec^2}$$

$$\boxed{W = m \, g}$$

Weight equals mass times gravitational acceleration.

Free Falling Objects

(no air resistance)

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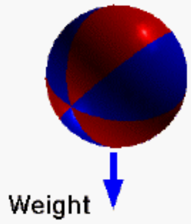
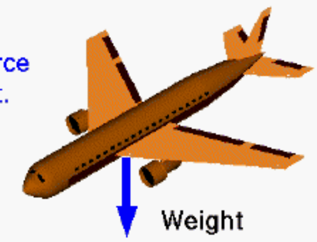


Weight is the only Force acting on the object.

$F = W = m\ g$



Motion of the object (Newton's second law).

$F = m\ a$

$$a = \frac{F}{m} = \frac{W}{m} = \frac{\cancel{m}\ g}{\cancel{m}}$$

$a = g$

Mass of the object does not affect the motion.

Shape of the object does not affect the motion.

All objects fall at the same rate in a vacuum. -- Galileo.

Motion of Free Falling Object

(no air resistance)

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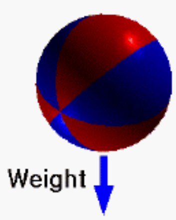


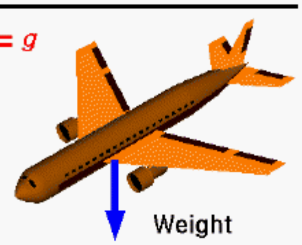
Constant Acceleration = g

V = velocity

X = distance

$a = 9.8\ m/sec^2$

$V = a\ t \qquad X = \frac{a\ t^2}{2}$



Mass and shape of object does not affect the motion.

All objects fall at the same rate in a vacuum. -- Galileo.

Time – sec.	0	1	2	3	4	5	6	7	8
Accel – m/sec^2	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Velocity – m/sec	0	9.8	19.6	29.4	39.2	49.	58.8	68.6	78.4
Dist – meters	0	4.9	19.6	44.1	78.4	122.5	176.4	240.1	313.6

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Aircraft Motion – Constant Force

X – Direction Only

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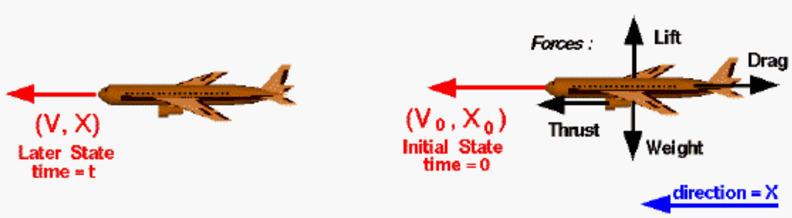

Newton's Second Law : $F = m\,a$

$a = F / m$

F = Force = Thrust – Drag

m = Mass

a = Acceleration

V = Velocity

If Force remains constant acceleration is constant:

$$V = a\,t + V_0$$

$$X = \frac{a\,t^2}{2} + V_0 t + X_0$$

On-Line Educational Resources

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Aerodynamics:

http://www.grc.nasa.gov/WWW/K-12/airplane

Wright Brothers:

http://wright.nasa.gov/

Aero Activities:

http://www.grc.nasa.gov/WWW/K-12/aerores.htm

Help:

Thomas.J.Benson@nasa.gov