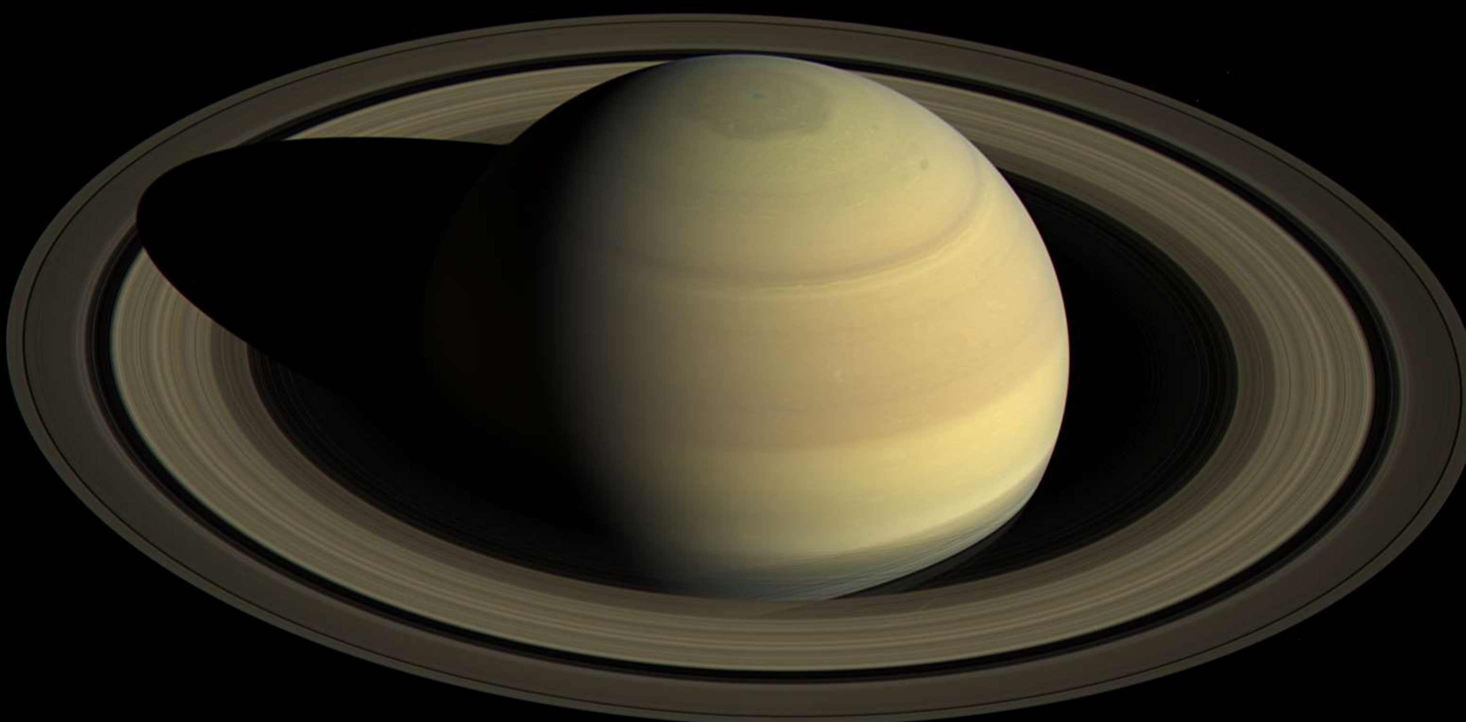
AST 2002
Introduction to Astronomy



A Few Reminders

Homework #1 is due tomorrow at midnight…
14 questions as quiz in WebCourses

Extended time for Syllabus quiz until 31st Jan

Sent round e-mails to people having issues with iClickers…

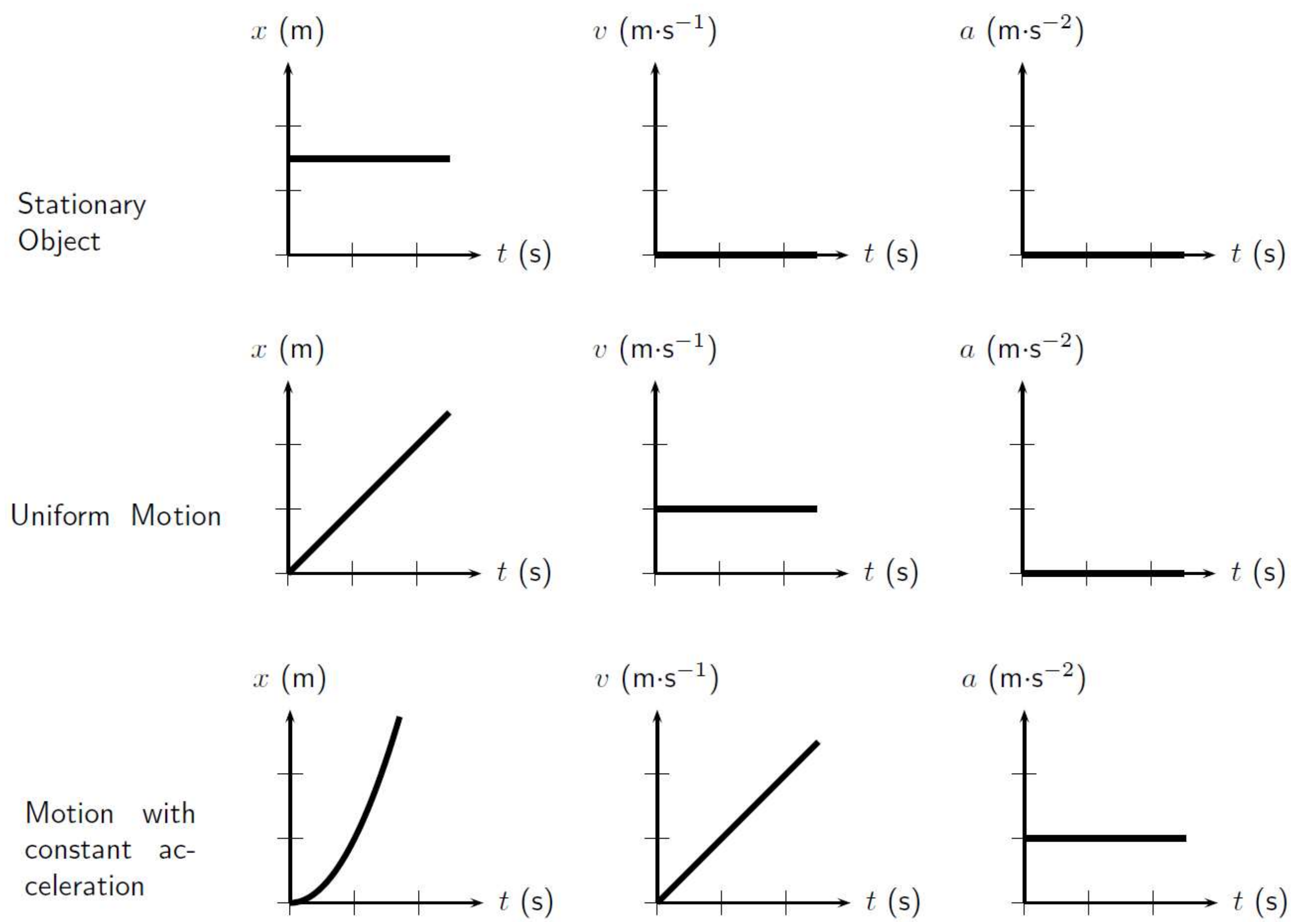
Knights Under the Stars event at Robinson Observatory:
Wed 31st Jan, 7:00 – 8:30 pm.

Newton's Laws of Motion

- **1st Law:** An object in motion will not alter its course unless another force acts upon on (inertia)
  - ***An object will move in a straight line unless acted on by another force…***
- **2nd Law:** Net forces cause a change in the motion of an object (acceleration, where F=ma)
  - ***If an object's motion is changing, a force must be acting on it…***
- **3rd Law:** Forces are paired and are equal in strength but act in the opposite direction (action-reaction pairs)
  - ***The forces must be equal and opposite…***

Position, Speed *vs.* Velocity, Acceleration (and Jerk)

Position, x | Velocity, v | acceleration, a



What is the Difference between Speed and Velocity?

Thought Question:

- Is it possible for a car to take a corner at a constant speed?

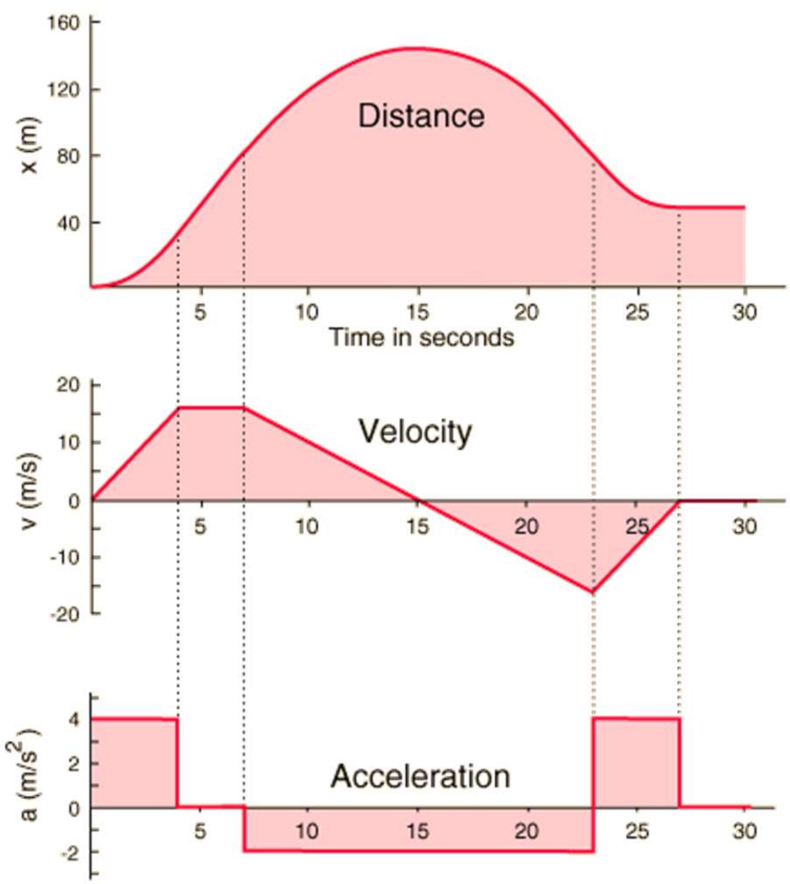
Yes, speed is a <u>scalar</u> quantity – only the order of magnitude matters

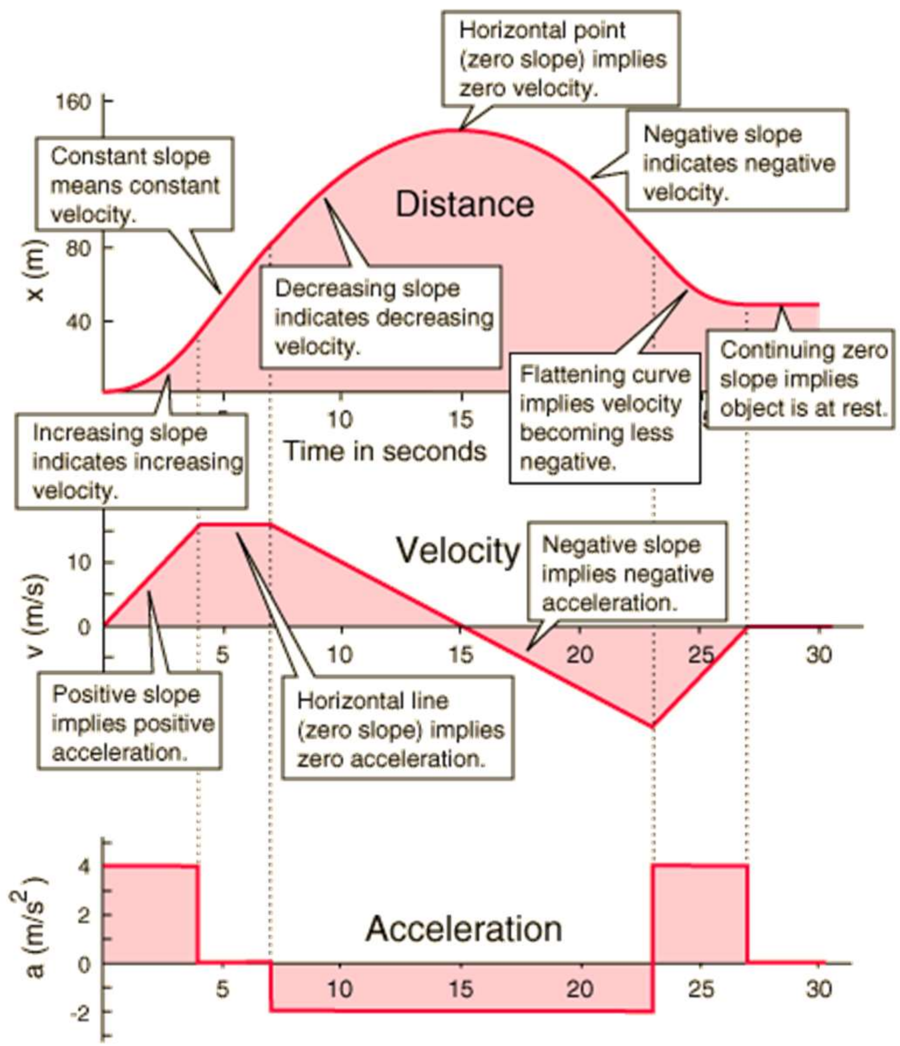
- How about at constant velocity?

No, velocity is a <u>vector</u> quantity – direction matters, and it's changing here!

You can feel a force acting here

Position-, Velocity-, and Acceleration-Time Graphs

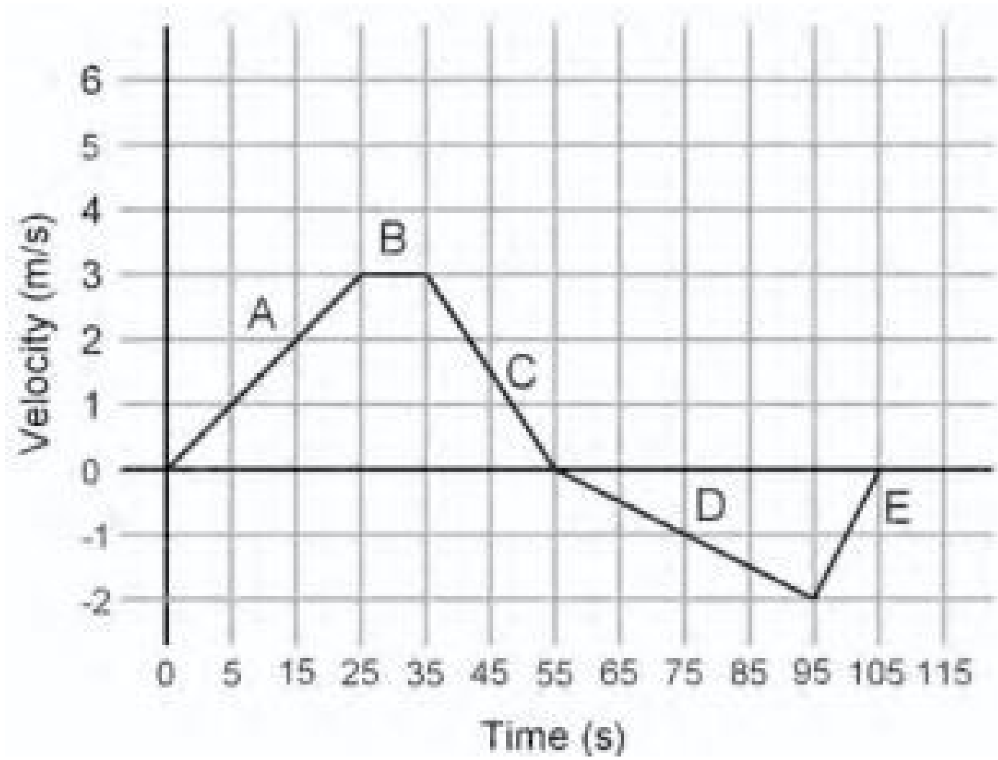




http://hyperphysics.phy-astr.gsu.edu/hbase/Mechanics/motgraph.html

iClicker Question

The graph below shows a velocity-time graph for an object in motion. Which of the five lines (A-E) represents the point where the object is experiencing the lowest magnitude of acceleration (or deceleration)?



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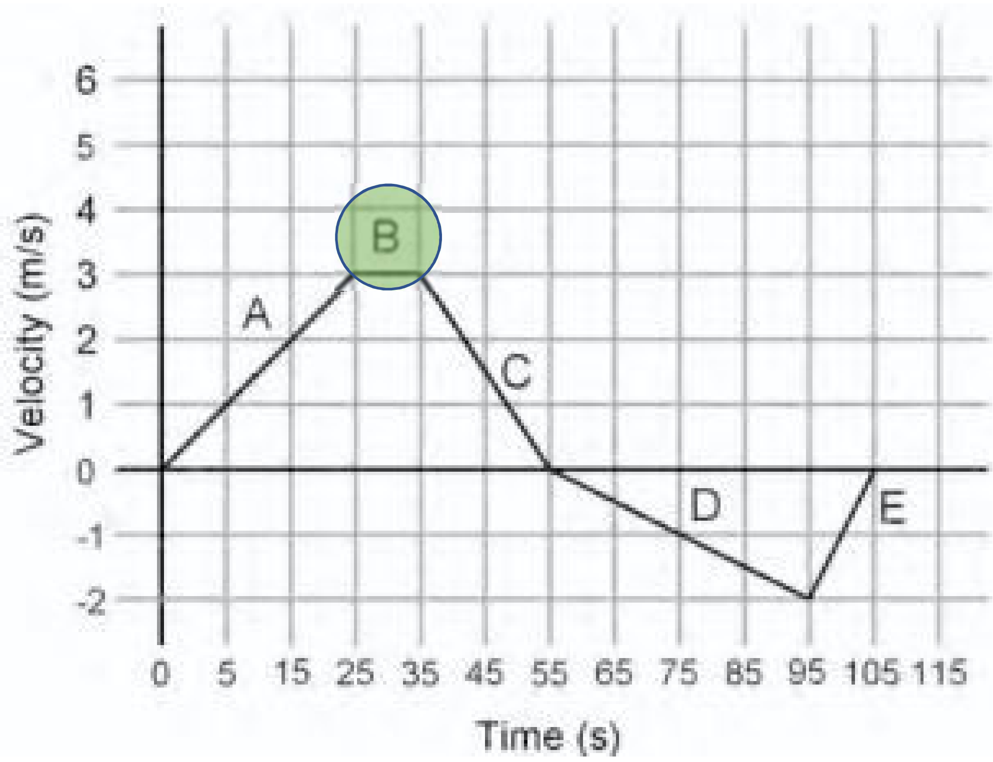


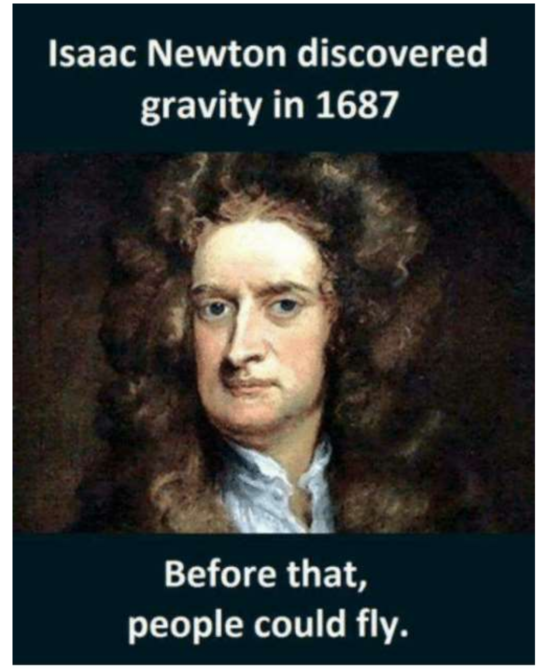
Least acceleration
= horizontal line (B)

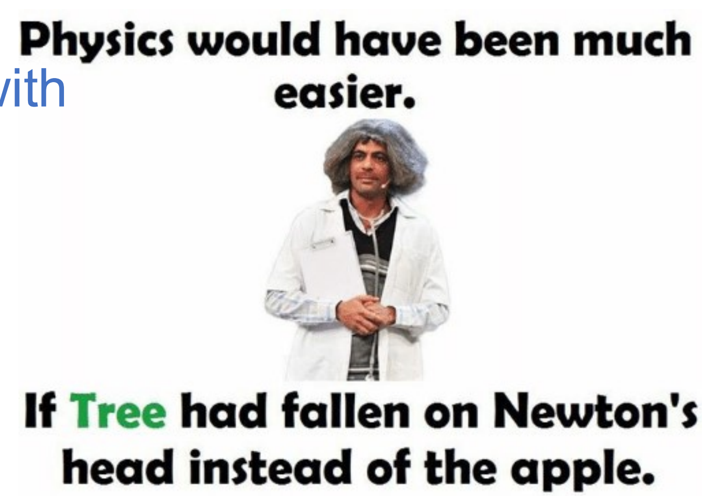
Most acceleration
= steepest line (E)

Isaac Newton

1643 - 1727

- Newton's Laws of Motion and Law of Gravity explains why planets orbit the Sun, following Kepler's observationally derived Law.
- 'Average student until 1663 ~ age 20)
- Read entirety of known mathematics in 2 yrs.
- The plague closed the University between 1665-1667, sending Newton back home to a bit of enforced reflection.
- It was during this period that he came up with most of his major contributions…
  - Invention of calculus
  - Theory of gravity
  - The Laws of Motion
  - The inverse square law
- Had his flaws too… (breakdowns, Leibniz)

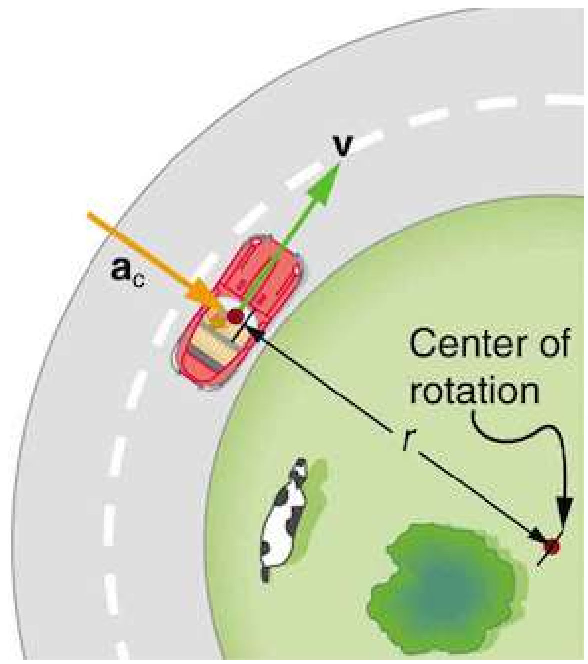




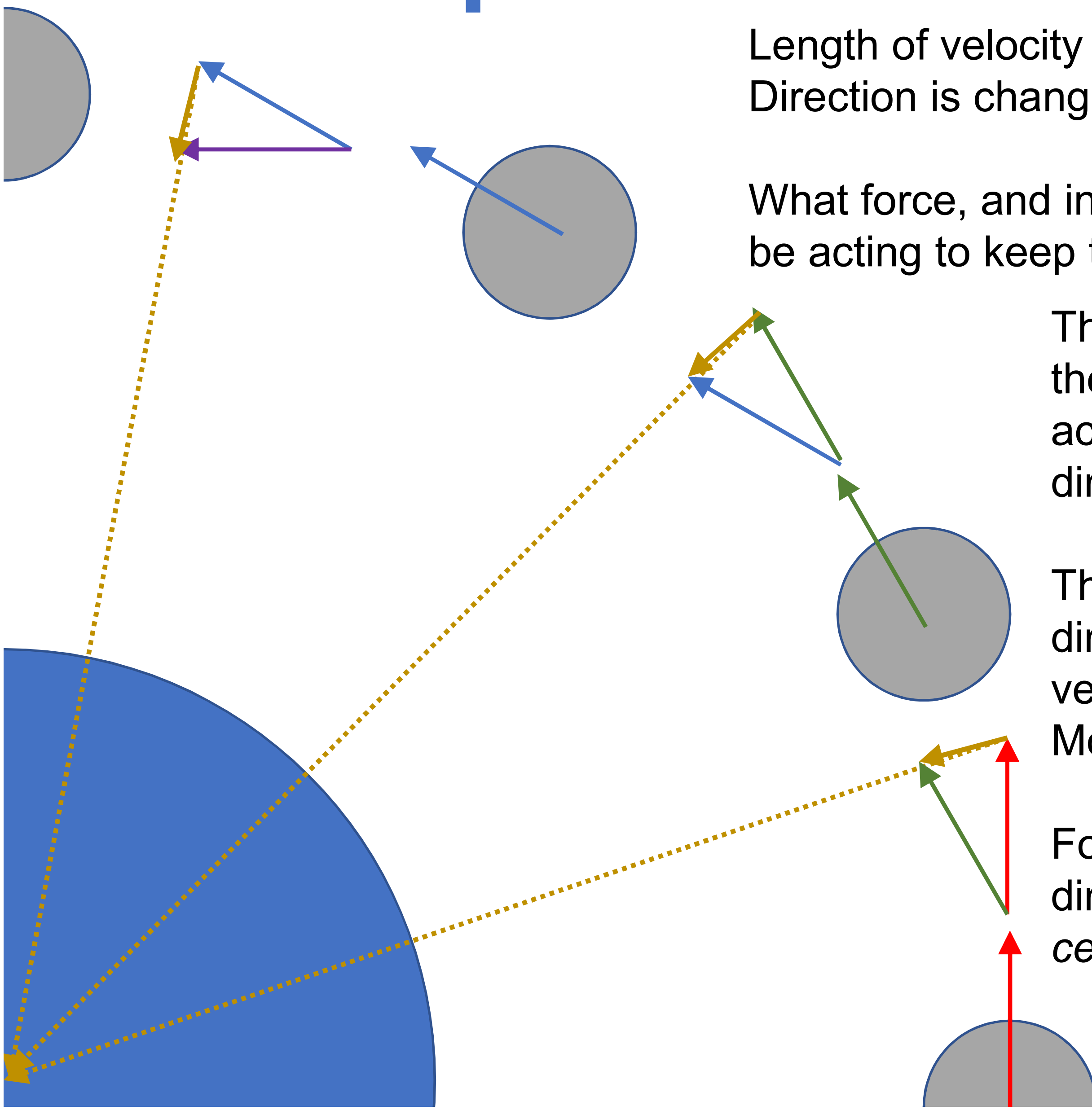
Discovering the Force of Gravity

- Newton watched the Moon orbiting the Earth.
  - It is in orbit
  - it is moving in (essentially) a circle
  - Therefore…. <u>force HAS TO BE acting</u> on it to deflect it from a straight line. (1^{st} law, Galileo)

- When you move in a circle at constant speed, there is a force acting on you, there is an acceleration changing your direction.
- This is known as a centripetal force.



Centripetal Forces *(Also see Khan Academy)*



Length of velocity vector → is constant.
Direction is changing… but speed is constant.

What force, and in what direction does it need to be acting to keep the Moon in orbit here?

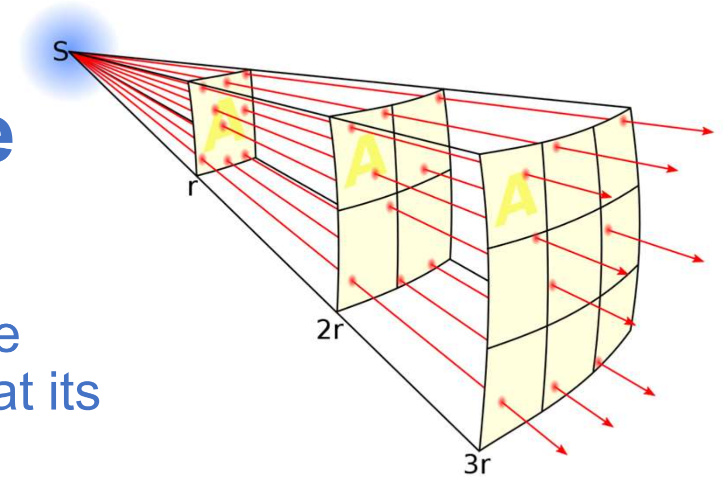
The yellow arrows ← represent the Δv (change in velocity), or acceleration vector. This is the direction that the force is acting.

The net force is acting in the direction of the acceleration vector… a Force is pulling on the Moon from Earth…

Force is acting perpendicular to the direction of motion (*centripetal* = *center seeking*)

$$F_{centripetal} = m\frac{v^2}{r}$$

Newton's Derivation of the Inverse Square Law



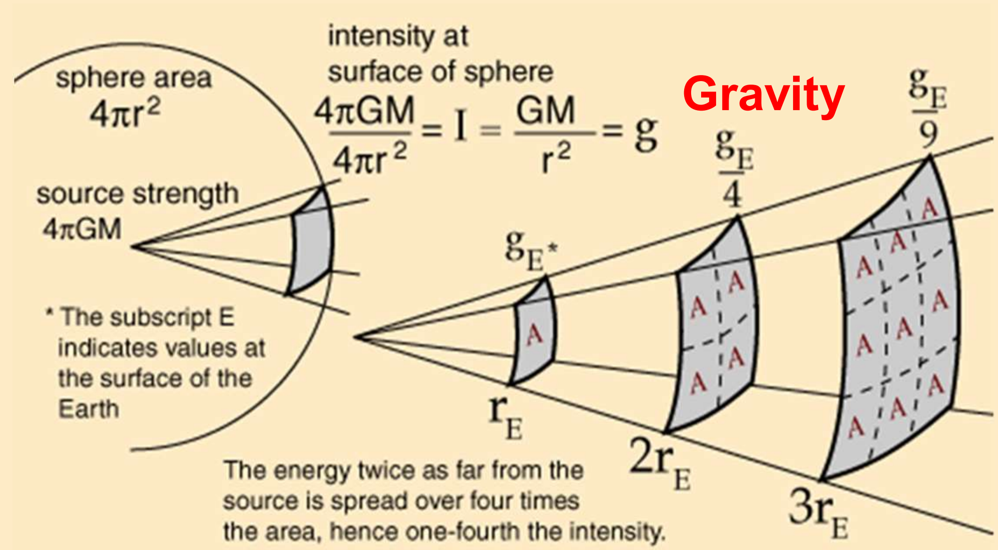
- If you know there must exist a force between the Earth and the moon, then you can calculate what its strength has to be….
  - Newton concluded the force acting on the Moon must be **~1/3600** of the force of gravity on the Earth's surface.
  - **Other fact:** Moon was about **60 times farther** from the CENTER OF THE EARTH than the Earth's surface

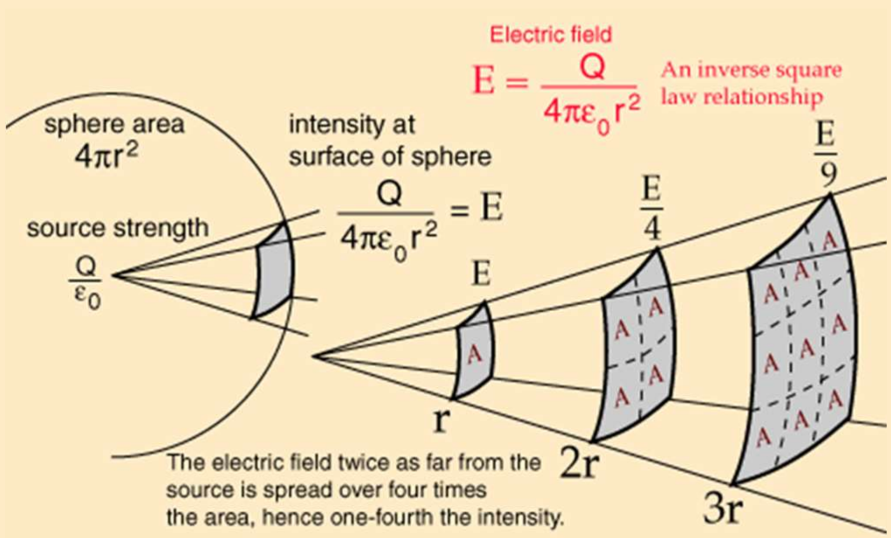
- So the force on the Moon was **1/3600** as strong as the force acting on you at the surface of the Earth…..
  - He concluded that the force of the Earth's gravity decreases by $1/r^2$. The inverse square of distance
  - That is how gravity (and other fundamental forces) work, <u>their intensity decreases by the inverse square of distance.</u>

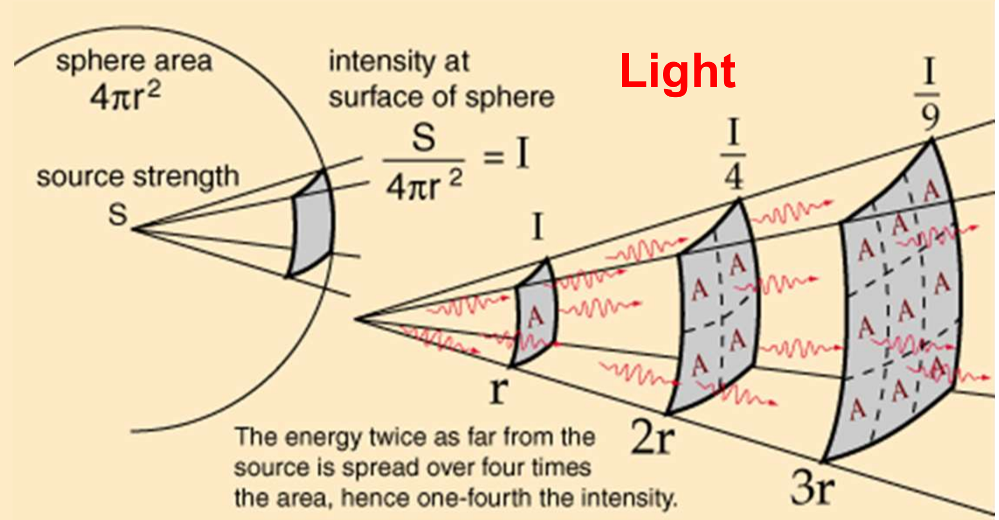
The fundamental cause for this can be understood as geometric dilution corresponding to point-source radiation into three-dimensional space

Inverse Square Law is Everywhere

- **ALL matter produces a gravitation force!**
- **Why???**
- *The fundamental cause for this can be understood as geometric dilution corresponding to point-source radiation into three-dimensional space*
- **The force changes by $1/r^2$**
- **The inverse square law applies to ALL Forces…. gravity, magnetism, electrical fields, light….!**







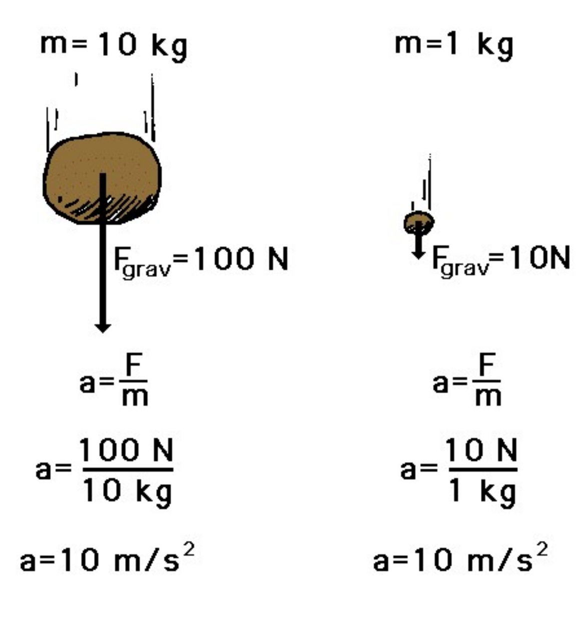
Most people use Mass & Weight interchangeably

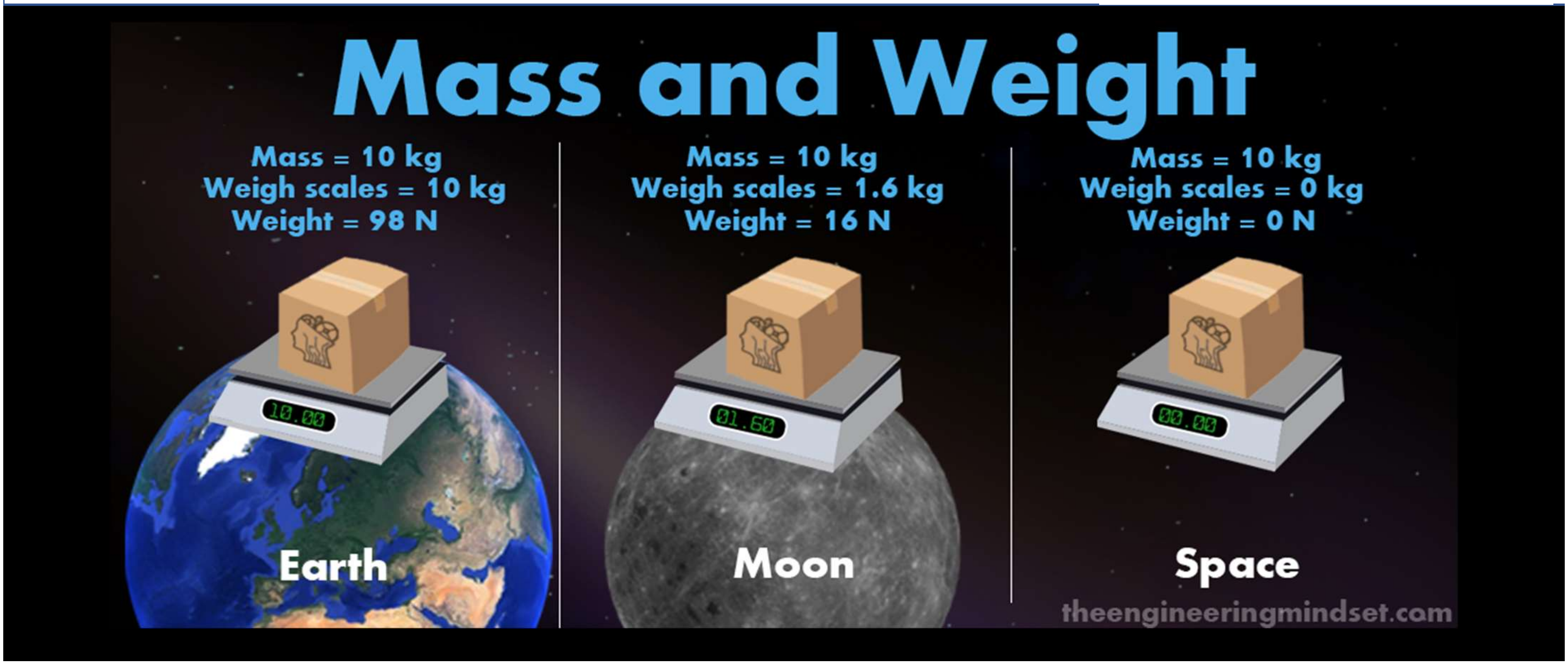
Technically, weight is a force, measured in Newtons (N)
Mass is given in kilograms (kg)

Weight = Mass x g (acceleration due to gravity, 9.81 m/s^2)

Force = Mass x Acceleration (F=ma, Newton's 2nd law)

Gravity on the Moon is ~1/6th the value on Earth





The Lunar Olympics?

Mass and weight

	Earth	Moon	Mercury	Venus	Mars	Pluto
Surface Gravity (compared to Earth)	1	0.17	0.38	0.90	0.38	0.06
How much you can lift	10 kg	60 kg	30 kg	10 kg	30 kg	170 kg
How high you can jump	20 cm	120 cm	53 cm	22 cm	53 cm	340 cm
How long it takes to fall back to the ground	0.4 s	2.4 s	1.1 s	0.4 s	1.1 s	6.8 s
How far you can kick a ball	20 m	120 m	53 m	22m	53 m	340 m

Gravity, Weight & Weightlessness

Can feel weightlessness in many different environments

- Is gravity really that different?

Remember gravity is measured from the center of an object

- We are 6378 km from the center of the Earth
- Space shuttle astronauts in space are only 200 km farther away…..
- In inverse square terms that is 1.03 times

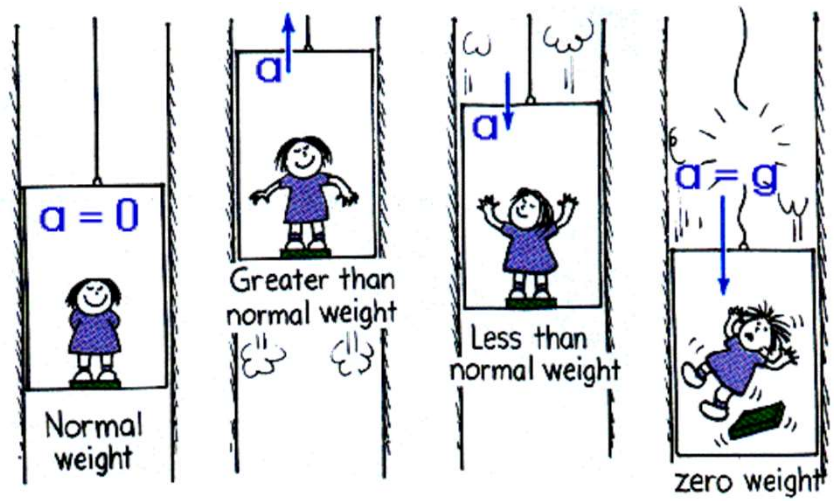
Is Gravity Less in Orbit? Work it out

- If the distance is 1.03 times the distance at the Earth's surface….
- $R^2 = 1.06$
- $1/R^2 \times G = 9.2\ m/s^2$
- The force of gravity is only 6% less in low Earth orbit

Vertical Acceleration and Gravity

A person of mass 65 kg stands on a scale in a lift. What would the reading on the scale (in Newtons) be when:

a) The lift is stationary
b) The lift accelerates upwards at 2 m/s^2
c) The lift decelerates upon reaching the top floor at -2 m/s^2
d) The lift is moving downwards at 4.5 m/s
e) The lift is in free fall…



a) W = mg
W = 65 x 9.81 **= 637.65 N**

b) F = ma, therefore F = 65 x 2 = 130 N
F total = W + F = 637.65 + 130
F total = **767.65 N** (more than normal weight)

c) F=ma, therefore F = 65 x -2 = -130 N
F total = W + F = 637.65 – 130 N
F total = **507.65 N** (less than normal weight)

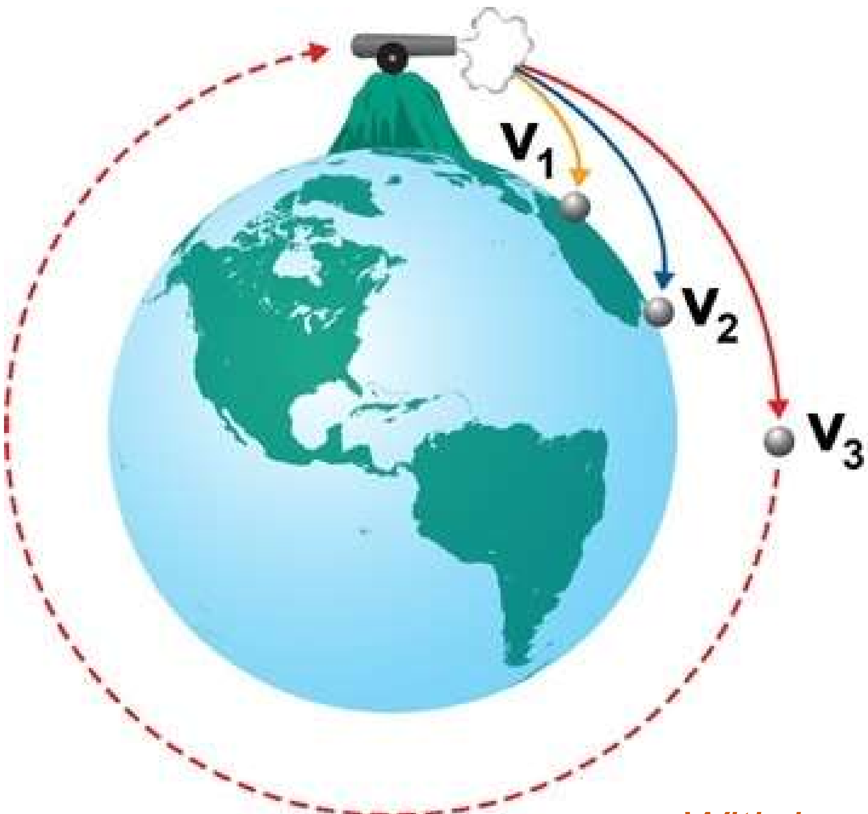
d) F = ma, but a = 0 so F = W = **637.65 N**

e) F = ma, F = 65 x -9.81 = -637.65 N
Total F = 637.65 – 637.65 N
Total F = 0 (weightlessness)

Note we defined the coordinate system to act in the same direction as gravity

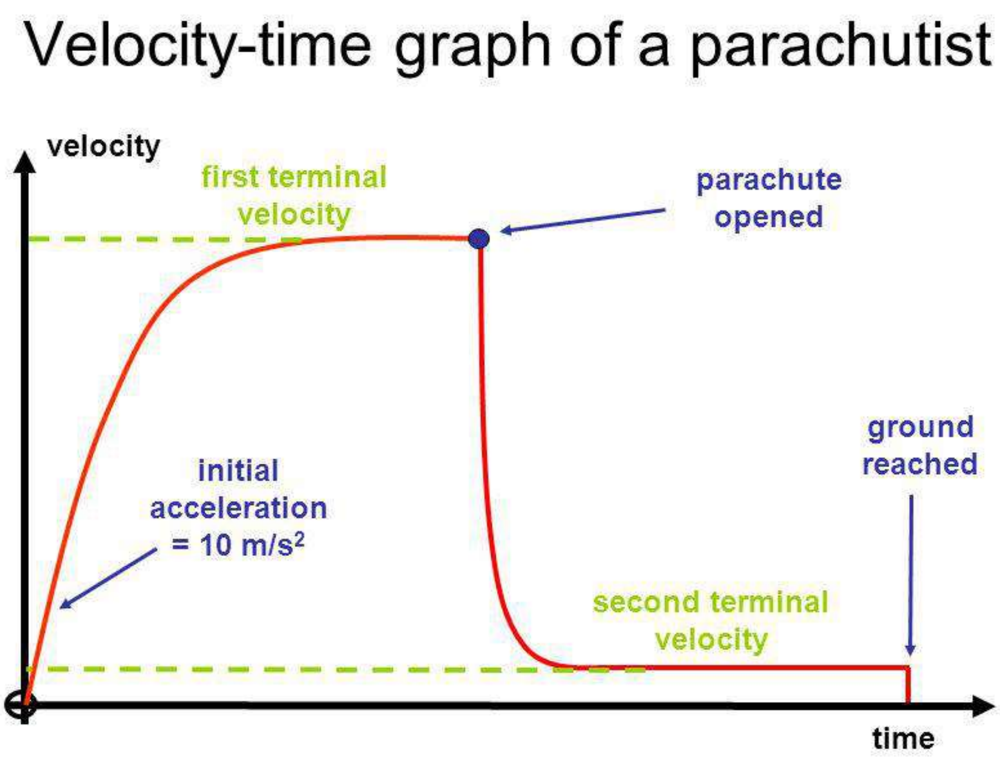
Thought Experiment – Gravity in Orbit

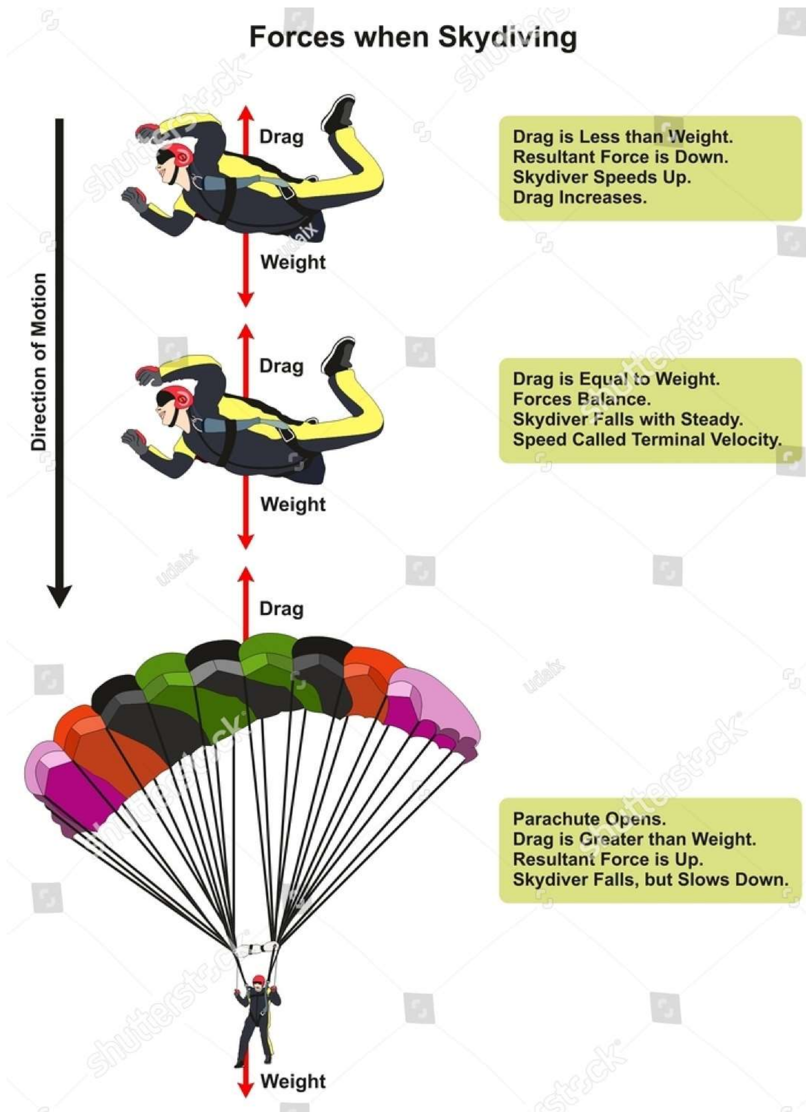
- continuously falling, but missing the Earth…



With increasing velocities, would generate orbits of higher eccentricity until eventually the velocity exceeds the escape velocity of the Earth…

Free-fall during Skydiving





What are Momentum & Inertia?

Inertia: Scalar quantity describing how massive something is, and therefore how resistant it is to changes in velocity. Something has inertia whether it is moving or not.

Momentum: Vector quantity describing how a moving mass resists changes to its velocity based on mass and velocity. Momentum = mass x velocity

	Inertia	Momentum
An object with a small mass and a small velocity	Small	Small
An object with a small mass and a large velocity	Small	Could be large (if v is large)
An object with a large mass and a small velocity	Large	Could be small (if v is small)
An object with a large mass and a large velocity	Large	Large

iClicker Question

A fly and Truck are both moving at 15 m/s. Which of these statements accurately describes the momentum and inertia of these moving bodies.

A. Both have the same inertia, the truck has more momentum

B. The truck has more momentum and more inertia

C. Both have same momentum, the fly has more inertia

D. The fly has more momentum and more inertia

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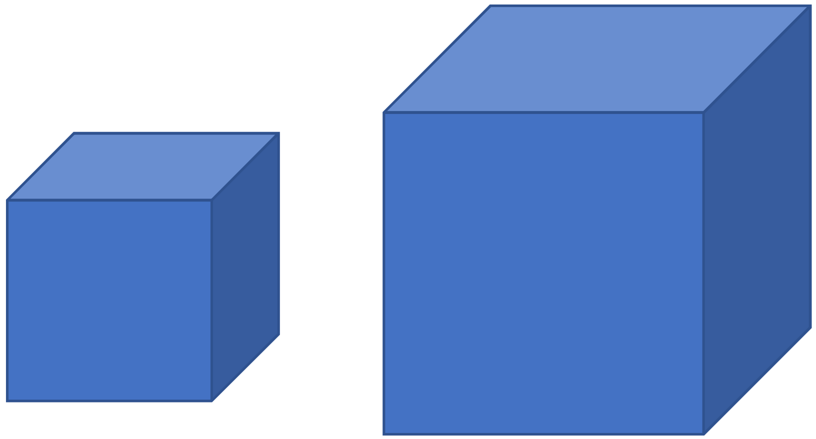
iClicker Question

A constant force is applied to an object that causes it to accelerate by 10 m/s^2. What acceleration would an object of twice the mass experience if the same force is applied to it?

A. 1 m/s^2
B. 5 m/s^2
C. 10 m/s^2
D. 20 m/s^2
E. 100 m/s^2



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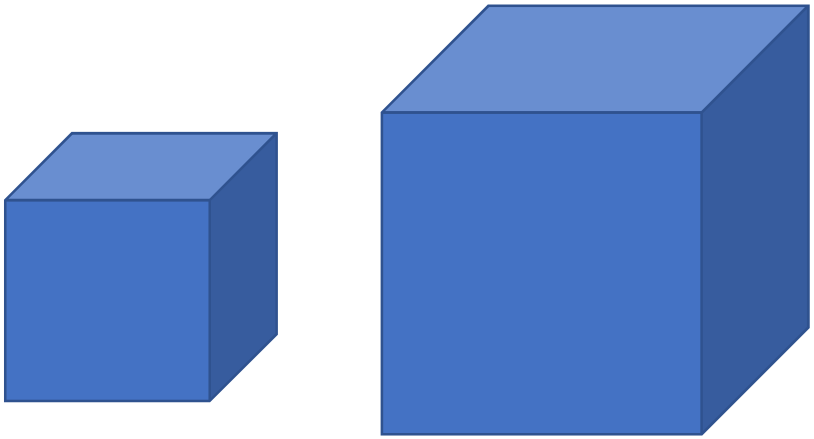
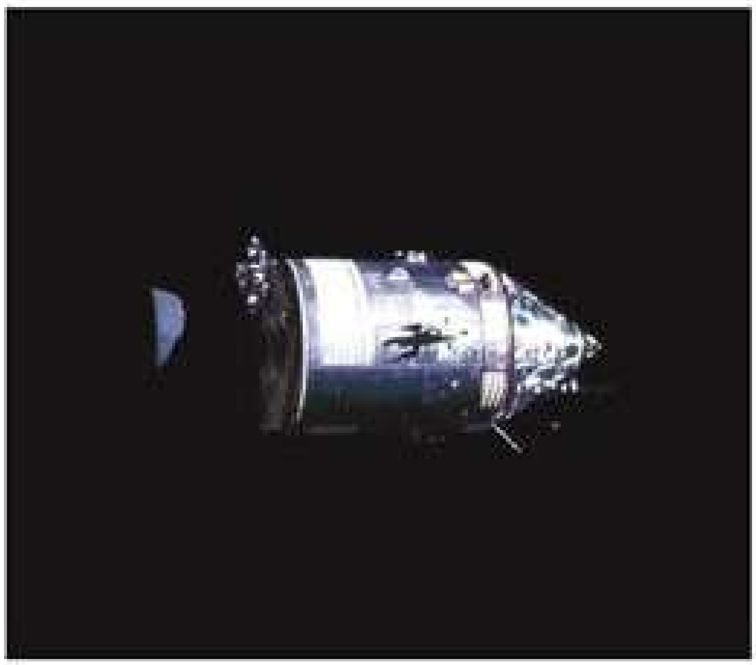


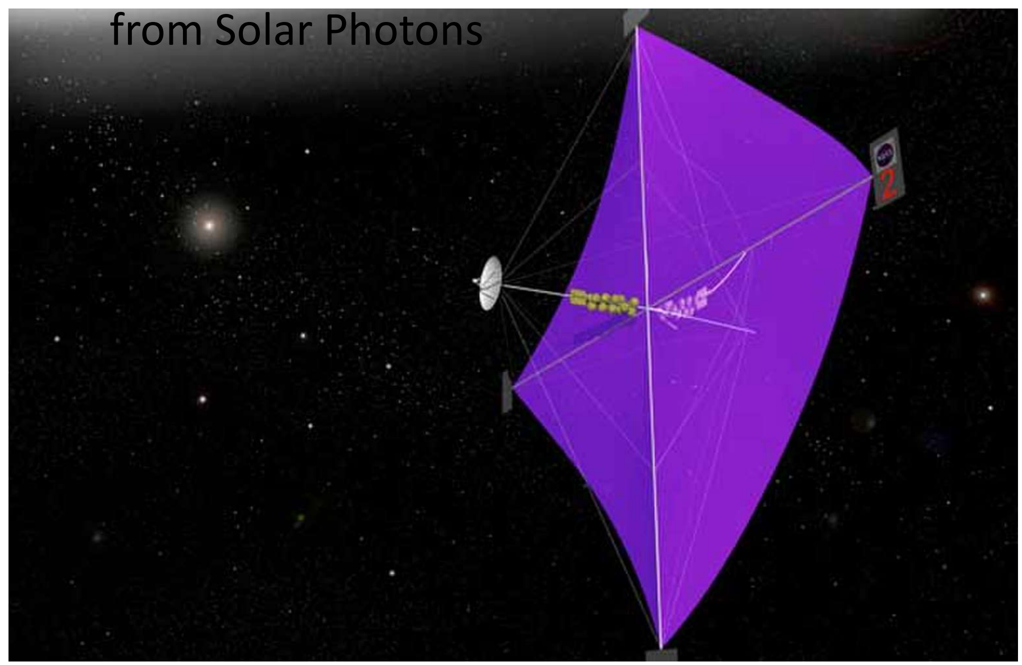
Newton’s three laws of motion

Newton’s first law of motion: An object moves at constant velocity unless a net force acts to change its speed or direction.

A spaceship needs no fuel to keep moving in space.



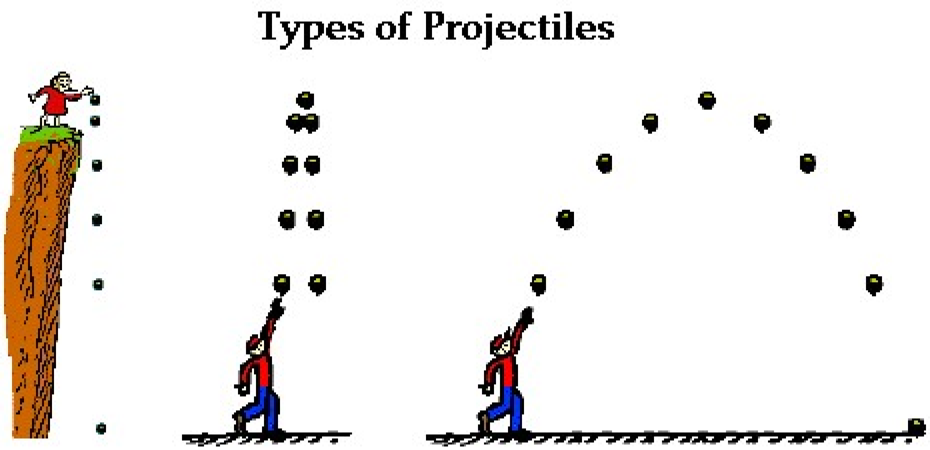
Solar Sail Concept: very small continuous acceleration is provided by momentum from Solar Photons



Newton's second law of motion:

Force = mass × acceleration

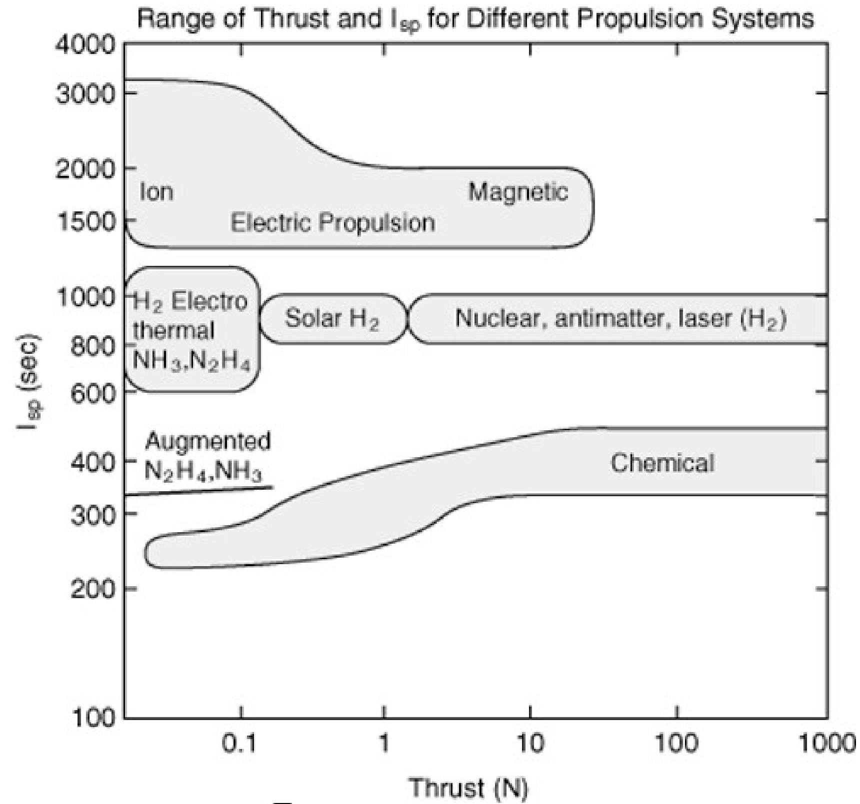
A baseball accelerates as the pitcher applies a force by moving his arm. (Once released, this force and acceleration cease, so the ball's path changes only due to gravity and effects of air resistance.)

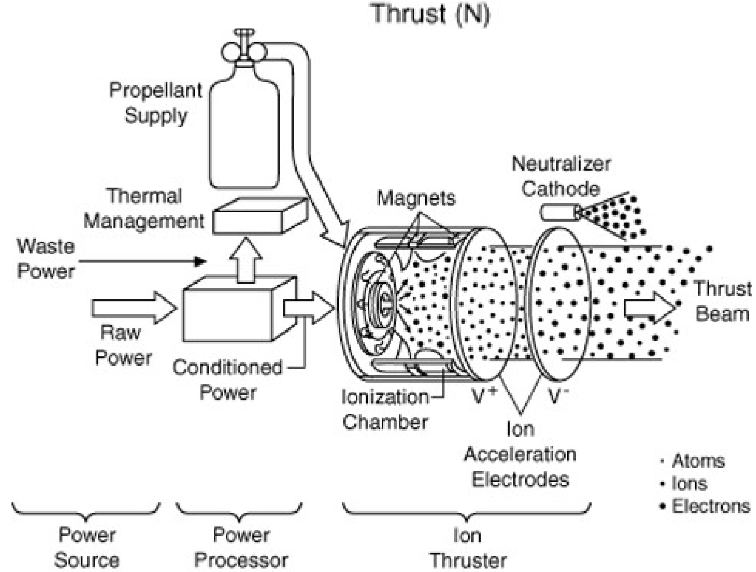


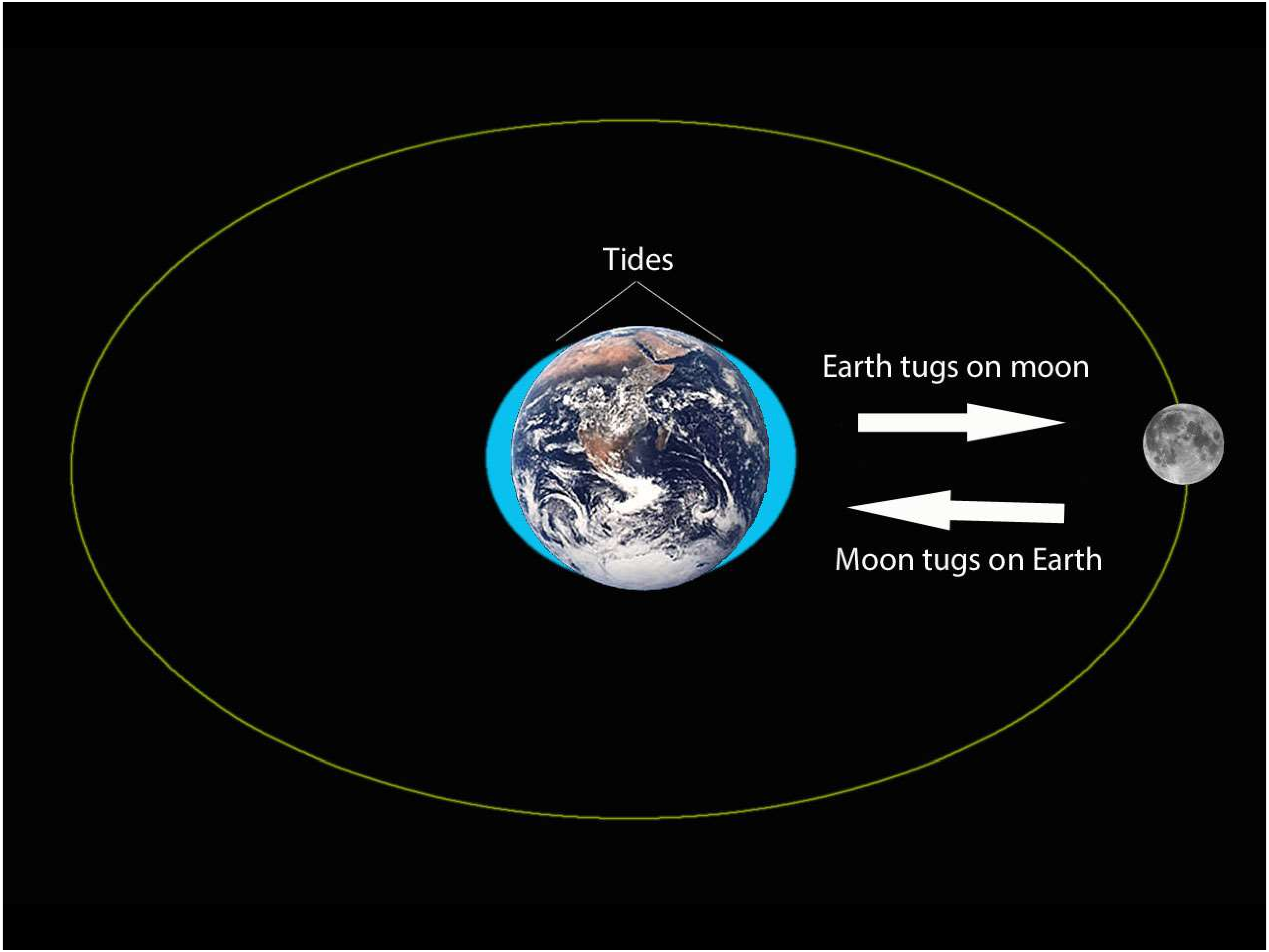
Newton's third law of motion:

For every force, there is always an *equal and opposite* reaction force.

A rocket is propelled upward by a force equal and opposite to the force with which gas is expelled out its back.






Tides
Earth tugs on moon
Moon tugs on Earth

End of Todays Lecture