Newton's Laws of Motion

Poll everywhere

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Outline

Outline

- results

Homework correction

- Changed wording on question 5 and gave more info for question 7.
- Updated on canvas and [course website](#).
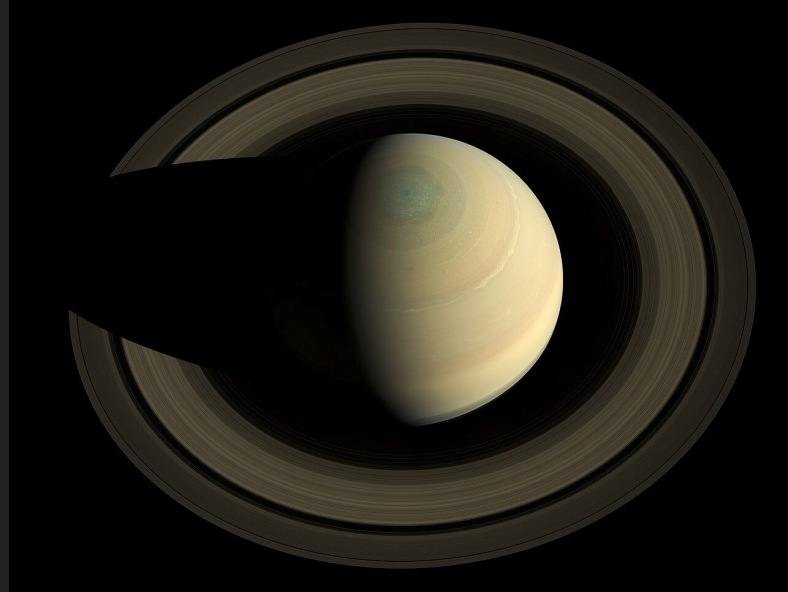
Formation of the Moon

- The Moon is thought to have formed through an impact early in Earth's history.
- Mars-sized object (Theia) collided with Earth, scattering debris in orbit around Earth — Giant impact hypothesis.
- Debris from collision eventually formed the Moon.

Formation of the Moon

Saturn's rings are debris from a destroyed moon

Formation of the Moon

THEIA

EARTH

1 About 4.5bn years ago the Earth is struck by Theia, an object the size of Mars.

2 Intense heat is created by the impact and huge amounts of debris from both Theia and the Earth are thrown into space

3 The debris coalesces as it orbits the earth

4 The moon is formed from this debris
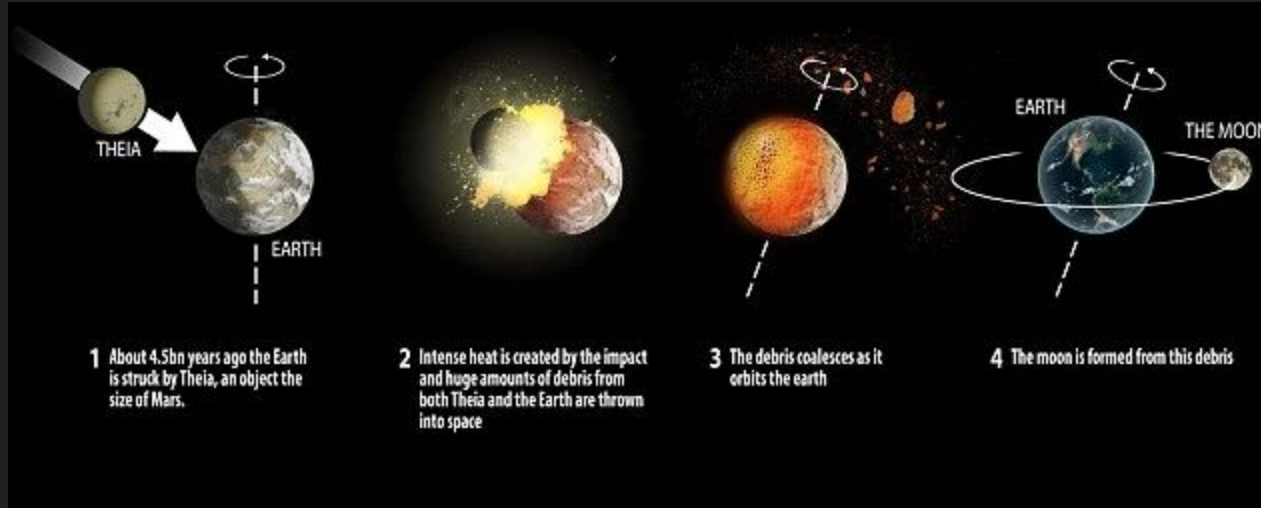
EARTH

THE MOON

Impact is why the Earth's rotational axis is misaligned with is orbital axis around the Sun
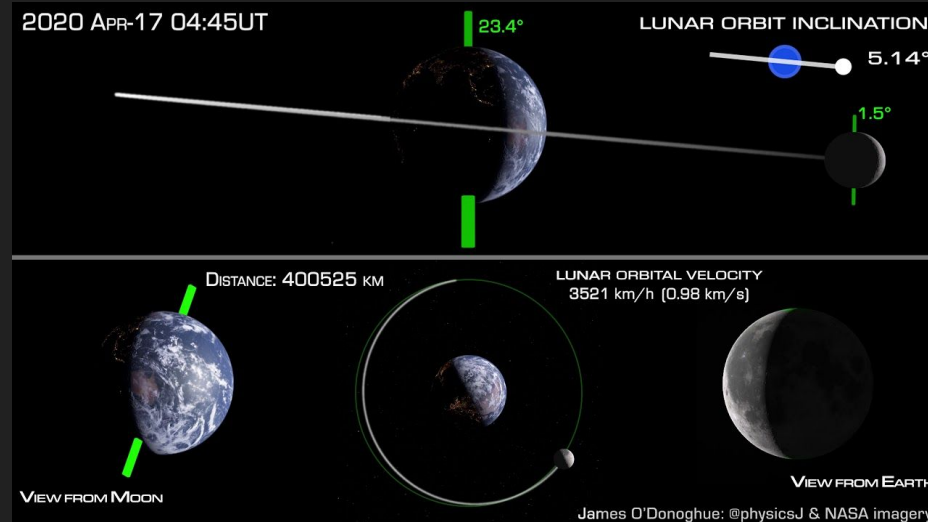
Formation of the Moon

Moon's orbit is tilted and eccentric (less circular).

Formation of the Moon
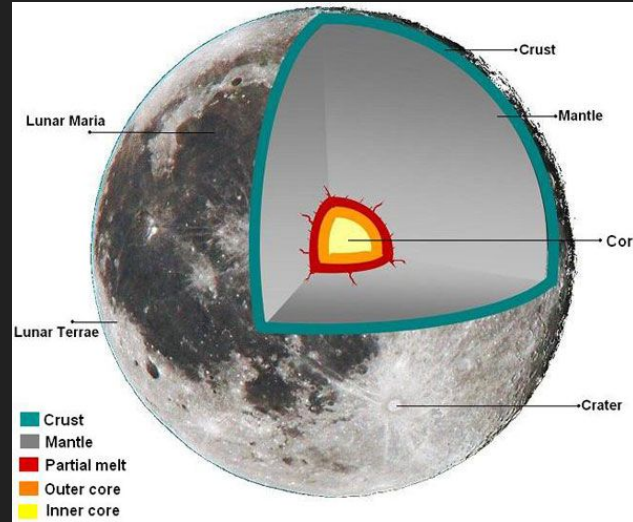
- Moon mostly made of silicate rock (depleted of iron)
- Low iron means not enough material to form dynamo in its core —> no substantial magnetic field.

Formation of the Moon
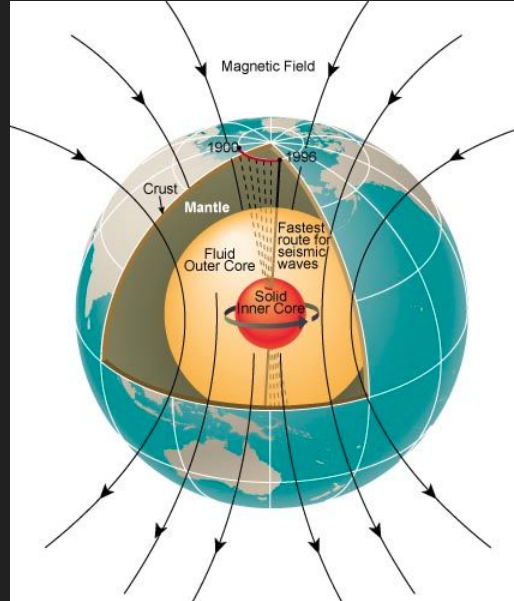
- Liquid metal core creates convective dynamo, —> Earth has a magnetic field.

Newton's Laws of Motion

- Kepler's Laws of planetary motion provided satisfying models of planetary motion that explained data well.
- Kepler developed his laws without calculus and without physics.
- It would take 78 years until Kepler's Laws explained using Newton's Laws of Motion and gravity.

Mass and weight

- Mass and weight have distinct scientific definitions.
- mass— an object's resistance to a change in motion.
- All particles (that we will deal with) have mass.
- weight— The force of gravity on an object.
- The weight of an object can be zero, but the mass can never be zero.

Velocity and speed

- Velocity has a magnitude and direction.
- E.g. I am driving 40 mph north on the highway.
- Speed only describes how fast an object is moving (only magnitude of velocity).
- E.g. I was driving at 35 mph when I got pulled over.
- It is possible to have constant speed and changing velocity.

Newton's Laws of Motion

1. An object at rest remains at rest and an object in motion moves with constant speed in a straight line until it is acted upon by an external force.
2. The change in motion of a body is proportional to, and in the direction of, the force acting on it (F=ma).
3. For every action, there is an equal but opposite reaction.

Newton's Laws of Motion
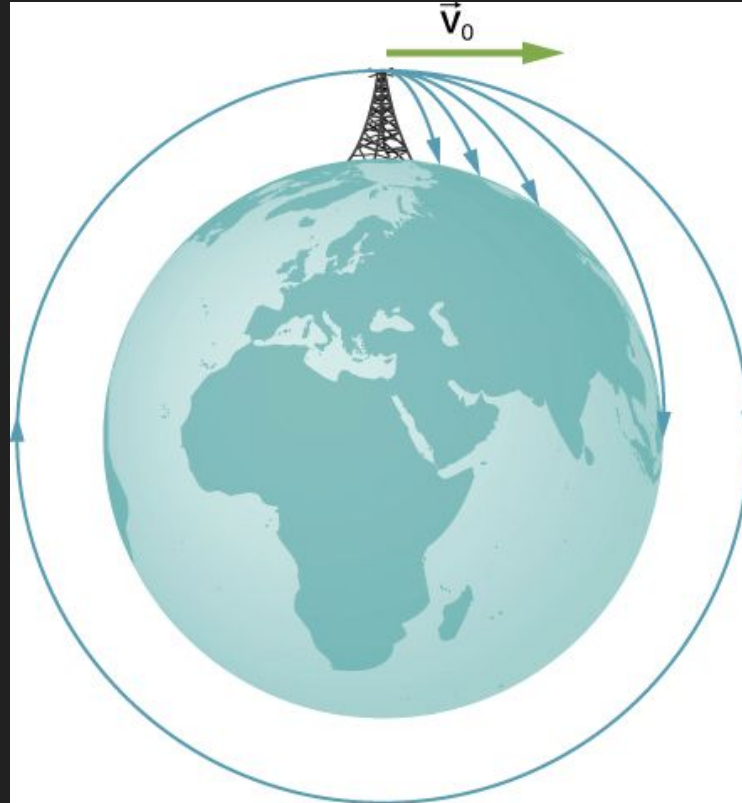
Newton's Law of Gravitation

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

$$G = 6.67 \times 10^{-11} \ \mathrm{N \ m^2 \ kg^{-2}}$$

- Force of gravity between two objects (same on both) depends on the mass of the two objects (m and M), the distance between them (r), and a constant, G.
- On the surface of a planet, the distance is the radius of the planet.

Gravity problem

1. Find the force of gravity of a 5 kg objects on the surface of Mars. Mars has mass 6.42×10^{23} kg and radius 3.39E6 m.

Acceleration due to gravity

$$g = G\frac{M}{R^2}$$

- Since acceleration due to gravity is the same for all objects, it is more common to use this.
- Acceleration due to gravity only depends on planet mass M and radius of planet R.
- For Earth, $g = 9.8$ m/s^2.

Acceleration due to gravity problem

2. Find the acceleration due to gravity on the surface of Venus if the mass of Venus is 0.815 times the mass of Earth and its radius is 0.95 the radius of the Earth. Use scaling relations.

Orbital speed from Newtonian Dynamics

- Using gravity and Newton's second law, we can derive speed of an body in a circular orbit around a larger object
- Newtonian dynamics gives the following formula:

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

Kepler's Third Law from Newtonian Dynamics

- Using the velocity equation from before, and rearranging yields Kepler's Third Law!
- Kepler's Laws are now theoretically and empirically reinforced.

$$P^2 = \frac{4\pi^2}{GM}a^3$$
$$P^2 \propto a^3$$

Announcements

- Homework pushed back to next Wednesday (24 September)
- Meet in planetarium next class

Next time

- Mars