Gravity

The Falling Apple and Moon

- Newton looked at the falling apple and knew that Galileo's idea of inertia meant that the apple would fall in a straight line.
- The moon wasn't moving in a straight line so an outside force must be acting on it.
- The moon must be falling (falling beneath the straight line path it would follow without a force)
- The moon must have a project path with a tangential velocity large enough to move around the Earth.

The Great Proportion

- Newton knew from observations on Earth that the mass of the moon and apple are insignificant.
- It was guessed that the moon should fall at a rate proportional to the distance from Earth it is when compared with the apple.
- With actual measurements he found that the Earth’s force is diluted by the square of the distance.
- This proved the Earth must attract the moon, and therefore all objects must attract.
- Calculus was needed to prove it with certainty.

Newton's law of Universal Gravitation

- The force of attraction between two objects is proportional to their masses divided by the square of the distance between them.
- To get the exact equation, a Gravitational Constant must be used. $G = 6.67x10^{-11}Nm^2/kg^2$
- The equation is : $F=Gm_1m_2/d^2$
- Where F is the gravitational force, the m's are the two masses of the objects, and d is the distance between the two centers of mass.
- Once G was discovered, the mass of the Earth was found quickly after.

Inverse Square Laws

- Newton's law of gravitation is one of the inverse square laws.
- Picture beams of light coming from a light bulb.
- The farther you get from the center the weaker the signal gets. (bulb doesn't look as bright)
- This brightness decreases by a factor of the square of the radius.
- If at one radius from the center it has an intensity of 1, then at 2 radii it would be ¼, and at 3 radii, it would be 1/9.

Gravitational Fields

- All fields are forces that effect objects from a distance.
- Fields contain energy that can move objects.
- The value for g (the gravitational field strength) can be found from the following equation:
- $g = Gm/r^2$
- There is a gravitational field inside the Earth as well.
- The field strength at the center is zero because the Earth’s mass is all around pulling equally in all directions.

Weight

- Weight is best defined as the force you apply to a supporting material.
- Weightlessness then is not a lack of gravity, but rather a lack of a support force.
- An elevator going up puts a greater force on you, therefore your weight increases.
- An elevator going down applies less support on you so your weight goes down.
- An elevator falling at the same rate you are applies no force, therefore you have no weight!

Tides

- Tides are created by the moon because the moon is close enough that there is a significant difference between the gravitational attraction on the two sides of the Earth.
- The moon pulls the ocean on one side of the Earth more than the ocean on the other side.
- The sun’s tides are not as strong, why?
- Spring tides are when the sun and moon are aligned.
- Neap tides are when the sun and moon are 90 degrees from each other.

Black Holes

- Black holes are super dense regions that have extremely powerful gravitational fields.
- At far distances, the gravitational effects are the same as any other body with that mass.
- The difference is that the mass is concentrated in such a small volume that you can approach much closer.
- If the mass is great enough, and your distance small enough, then there is no possible speed you can give it great enough to escape.

Escape Velocity

- The vertical speed required to escape a gravitational field is called the escape velocity.
- This is beyond an orbital velocity.
- The equation for escape velocity is $v=\sqrt{2GM/d}$
- The escape speed from the surface of the Earth is 11.2km/s.
- For an object from the Earth to escape the sun, it needs to be 42.2km/s.
- Speeds lower than this will cause the object to go into orbit, or crash down.
- These are instantaneous speeds, lower speeds could still escape Earth if a constant force is applied.

Orbits

- If an object has a great enough horizontal speed then it will fall in orbit around a large gravitational body.
- On Earth, that speed is 8km/s. This will create a circular orbit.
- This is because an object freefalls 5m in one second, and due to the size of the Earth, the horizontal distance it must travel in order to not get closer to the surface is 8000m.
- The period of orbit around the Earth is 90 minutes. (consequently the time it would take to fall through the Earth and back is 90 minutes)

Ellipses

- If the speed of an object is greater than 8km/s but less than 12km/s, then it will settle into a non circular orbit.
- Energy is conserved in an elliptical orbit.
- Whenever the object is farthest from the Earth (apogee) it has the greatest gravitational potential energy.
- That means it moves the slowest.
- When the object is closest to Earth (perogee), it has the greatest kinetic energy, it is moving the fastest.