Newton’s Laws and Gravity

Week 3

Which of these statements best describes Kepler's Laws?

A. Kepler's laws describe how planets revolve around the Sun

B. Kepler's laws describe why planets revolve around the Sun

C. Kepler's laws describe how and why planets revolve around the Sun

D. Kepler's laws describe how and why one astronomical body revolves around another astronomical body

Which of these statements best describes Kepler's Laws?

A. **Kepler's laws describe how planets revolve around the Sun**

B. Kepler's laws describe why planets revolve around the Sun

C. Kepler's laws describe how and why planets revolve around the Sun

D. Kepler's laws describe how and why one astronomical body revolves around another astronomical body

Kepler's Laws describe ***how*** one astronomical body moves around another

What do we need to describe ***why*** one object revolves around another?

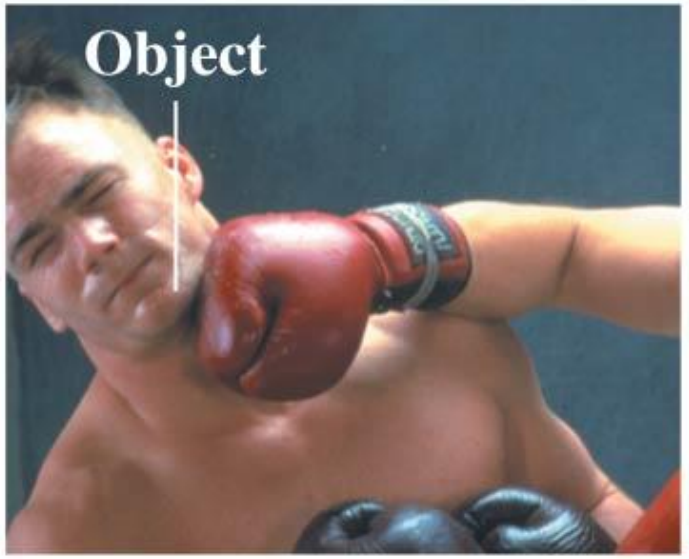
GRAVITY!

- Observation tells us that objects interact with each other
- Through the force of gravity

What Is a Force?

- A force is a *push* or a *pull*.

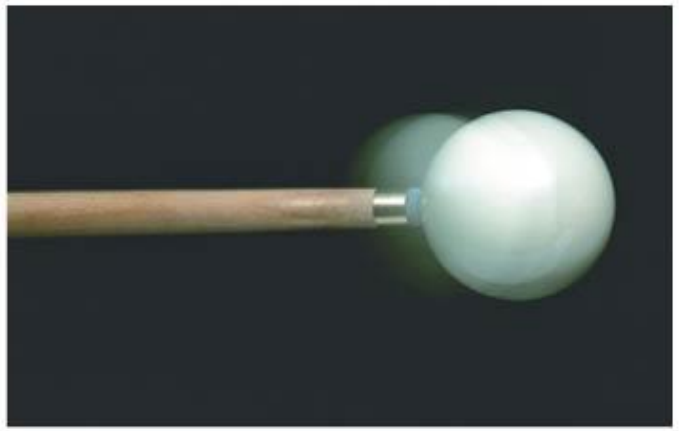
- A force acts on an object.
- Pushes and pulls are applied *to* something.
- From the object's perspective, it has a force *exerted* on it.



What Is a Force?

- A force requires an **agent**, something that acts or exerts power.
- If you throw a ball, your hand is the agent or cause of the force exerted on the ball.

- A force is a **vector**.
- To quantify a push or pull, we need to specify both *magnitude* and a *direction*.



Newton's Laws

0th Law: a force is an interaction, a push or pull, between two bodies.

1st Law: An object that is at rest will remain at rest, or an object that is moving will continue to move ***in a straight line with constant velocity***, if and only if the net force acting on the object is zero.

2nd Law: $F = ma$ or, equivalently: $a = \frac{F}{m}$

Units are in 'Newtons' = N = kg m/s^2

3rd Law: Forces come in pairs, acting on *both* objects involved in an interaction.

Mathematics of force

$$\vec{F} = m\vec{a}$$

F = force (N)

m = mass (kg)

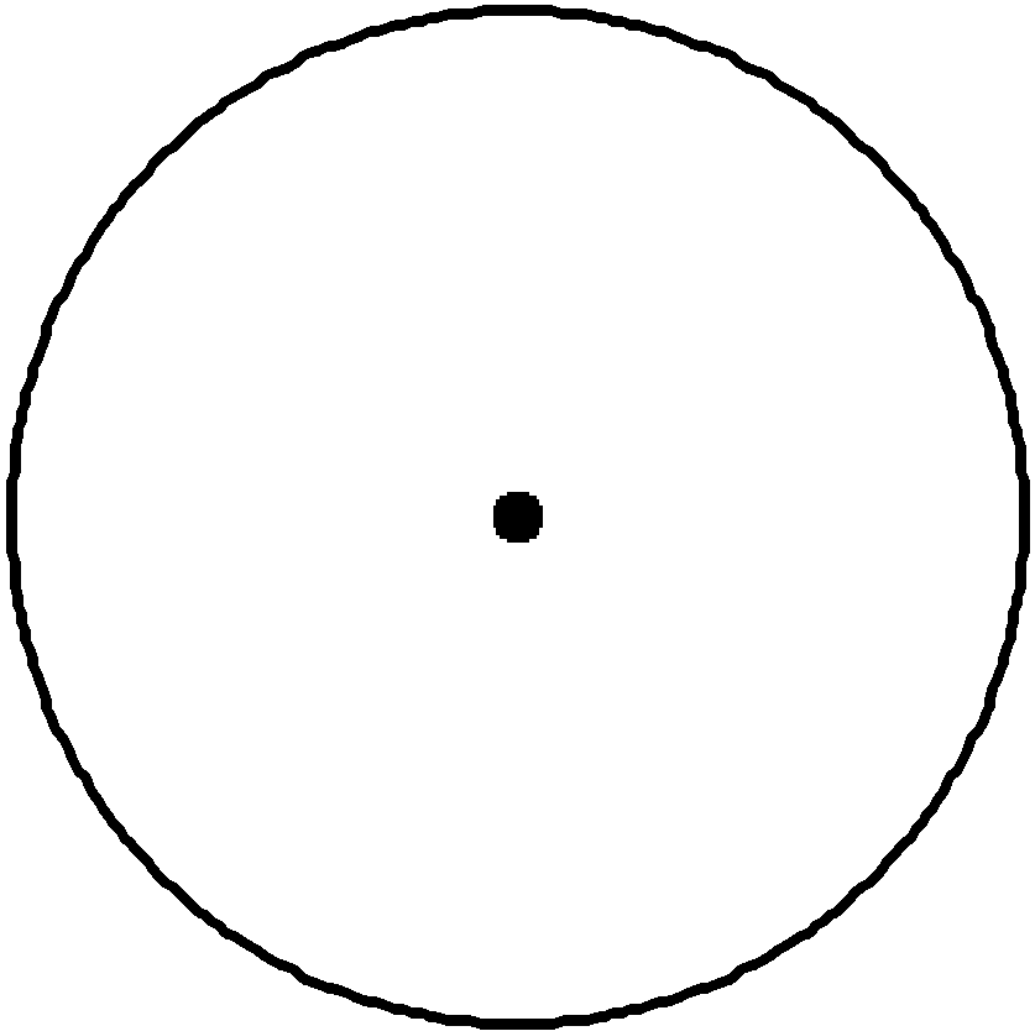
a = acceleration (m/s^2)

= ‘rate of velocity change’

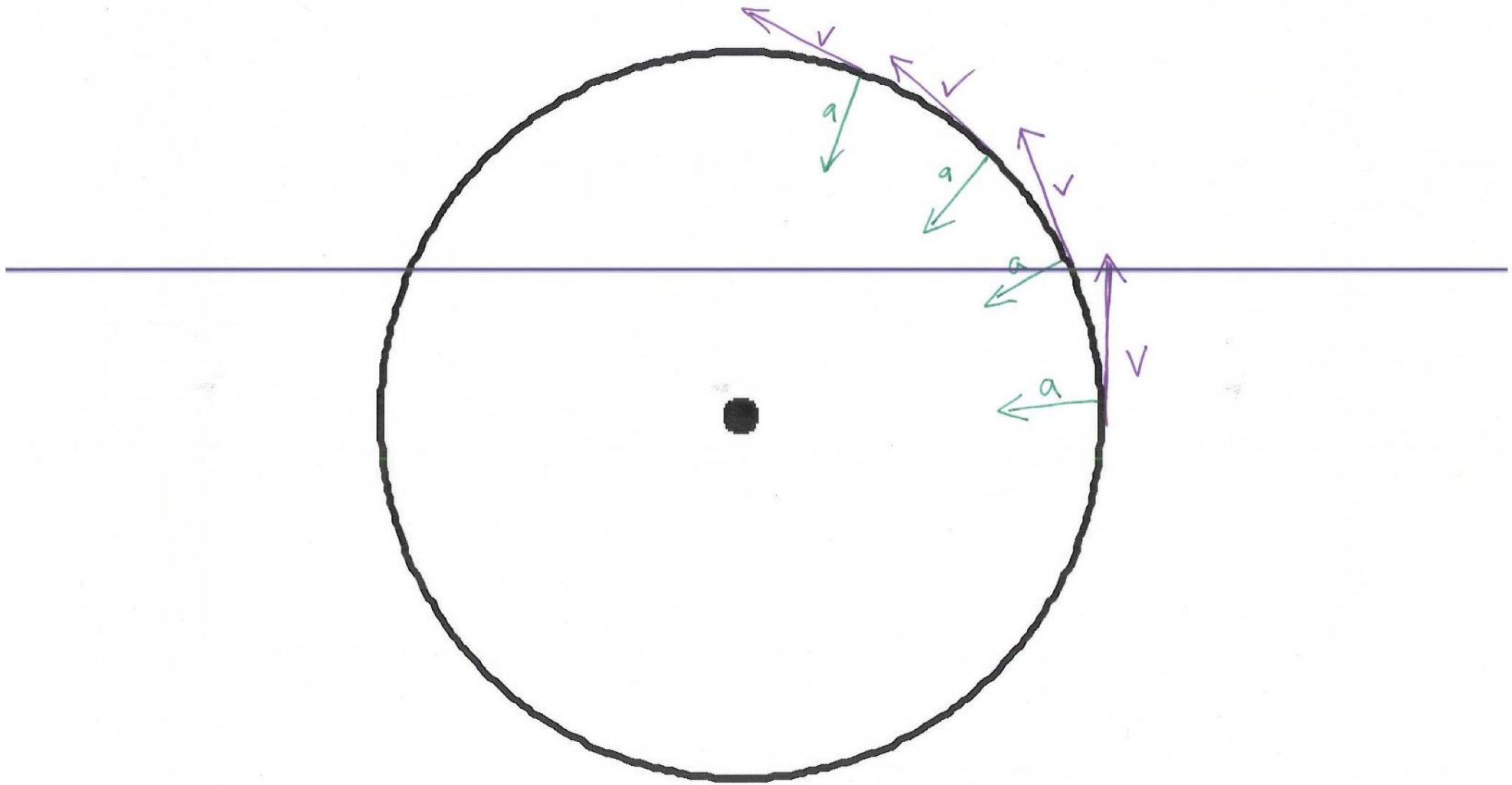
F and *a* have magnitude and direction → *vector* quantities

m has magnitude only → *scalar* quantity

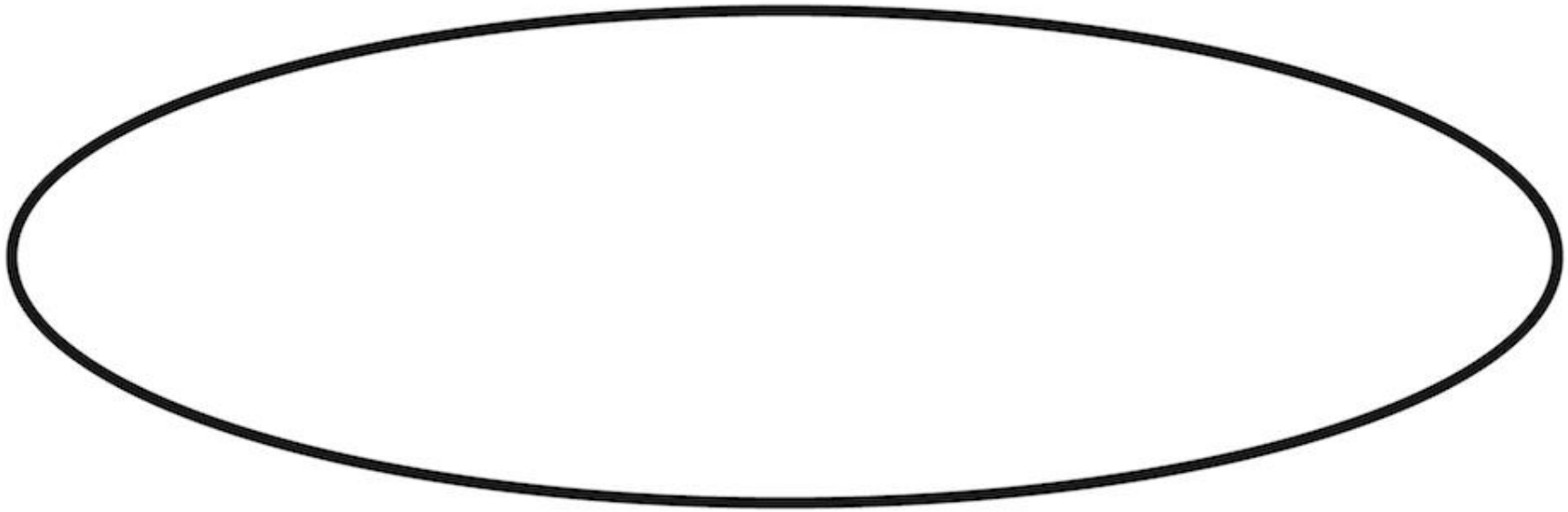
Explaining Kepler’s Laws with Newton’s



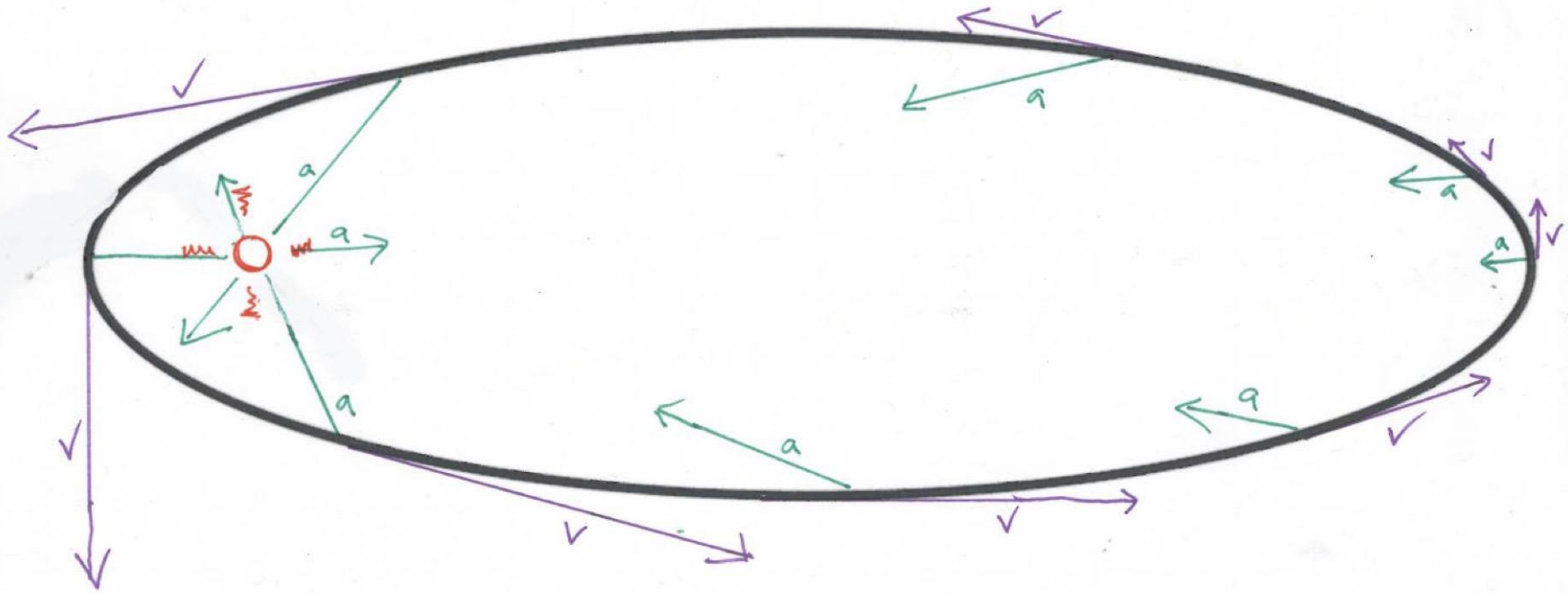
Explaining Kepler's Laws with Newton's



Explaining Kepler’s Laws with Newton’s

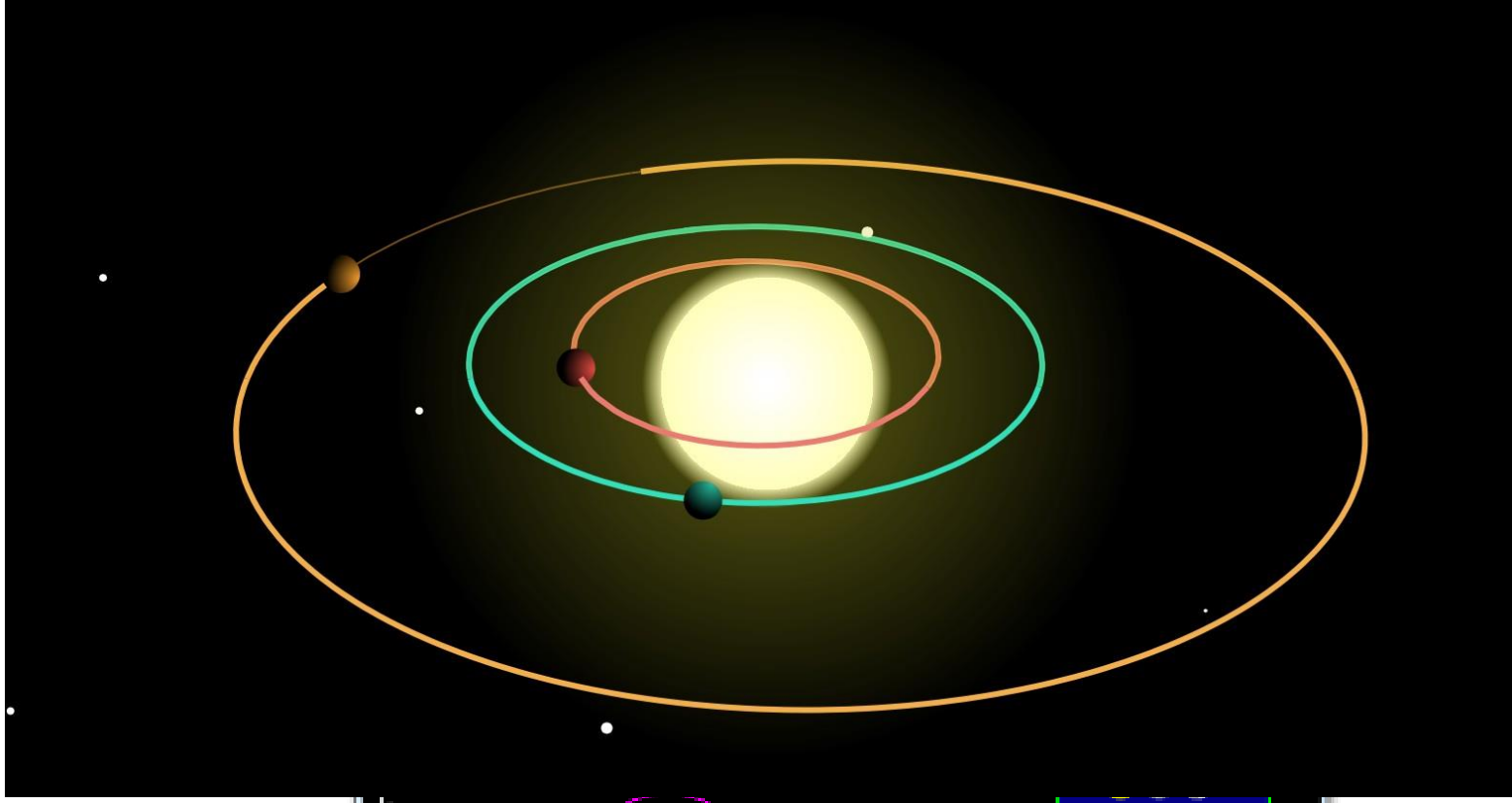


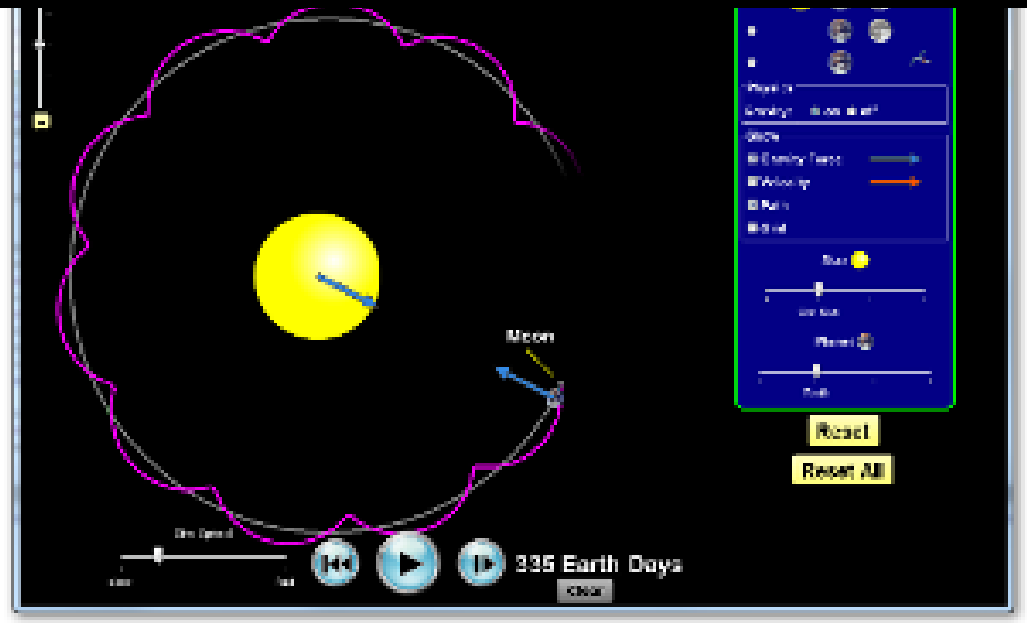
Explaining Kepler's Laws with Newton's



Orbital Playgrounds

- http://save-point.herokuapp.com/orbits/?mission=gravitykit&
- http://phet.colorado.edu/en/simulation/gravity-and-orbits
- http://solarsystem.nasa.gov/planets/





Explaining Kepler's Laws with Newton's
(Kepler's Third Law & Newton's Third Law)

Let's start with **Newton's Law of Gravitation**

http://astro.unl.edu/classaction/animations/renaissance/gravcalc.html

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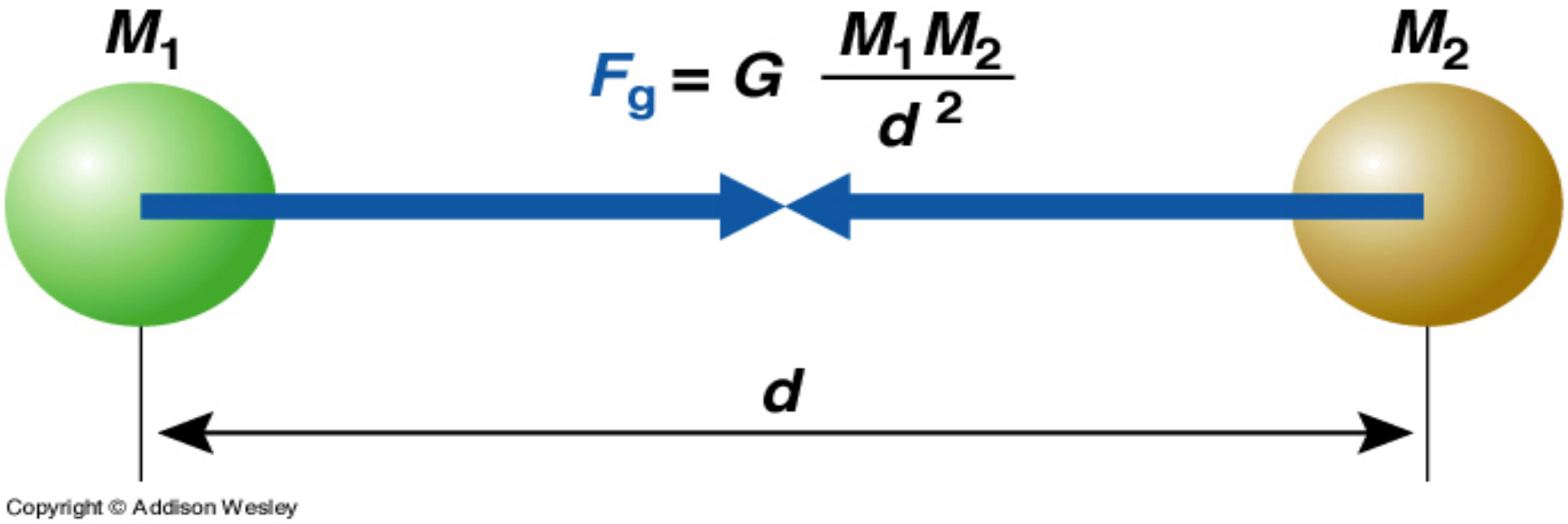
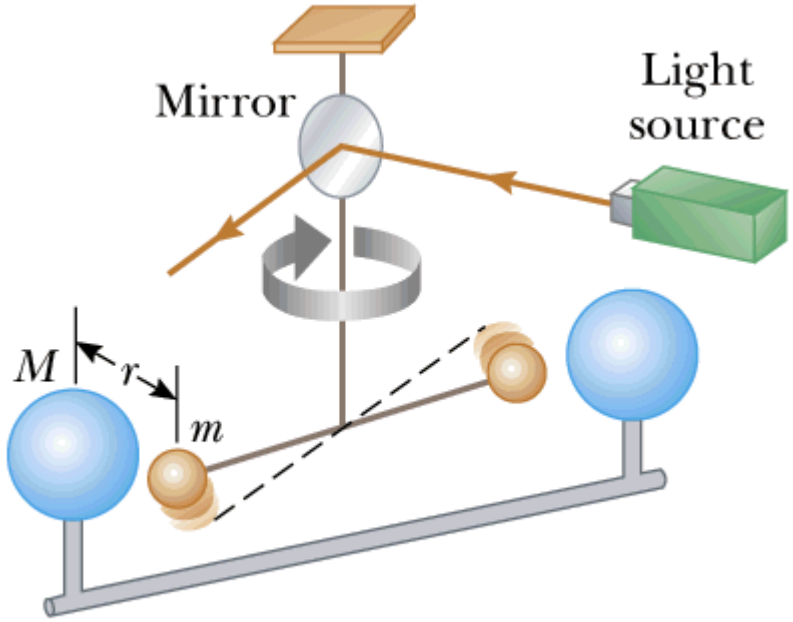


http://astro.unl.edu/classaction/animations/renaissance/gravalgebra.html

What is **G**?

- Go to the Canvas content page on the Cavendish Experiment

https://www.youtube.com/watch?v=lfDllu2GBhg



Serway, Physics for Scientists and Engineers, 5/e
Figure 14.3 Harcourt, Inc.

➢ **$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$**

$N = \text{newton} = kg\ m/s^2$

➢ $G = 6.67 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$

Measuring the mass of the Sun w/ Newton's Laws

If we can measure the period & semi-major axis of an orbit carefully **using meters and seconds**, we get the mass of the body being orbited (in kilograms).

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

P = orbital period in seconds

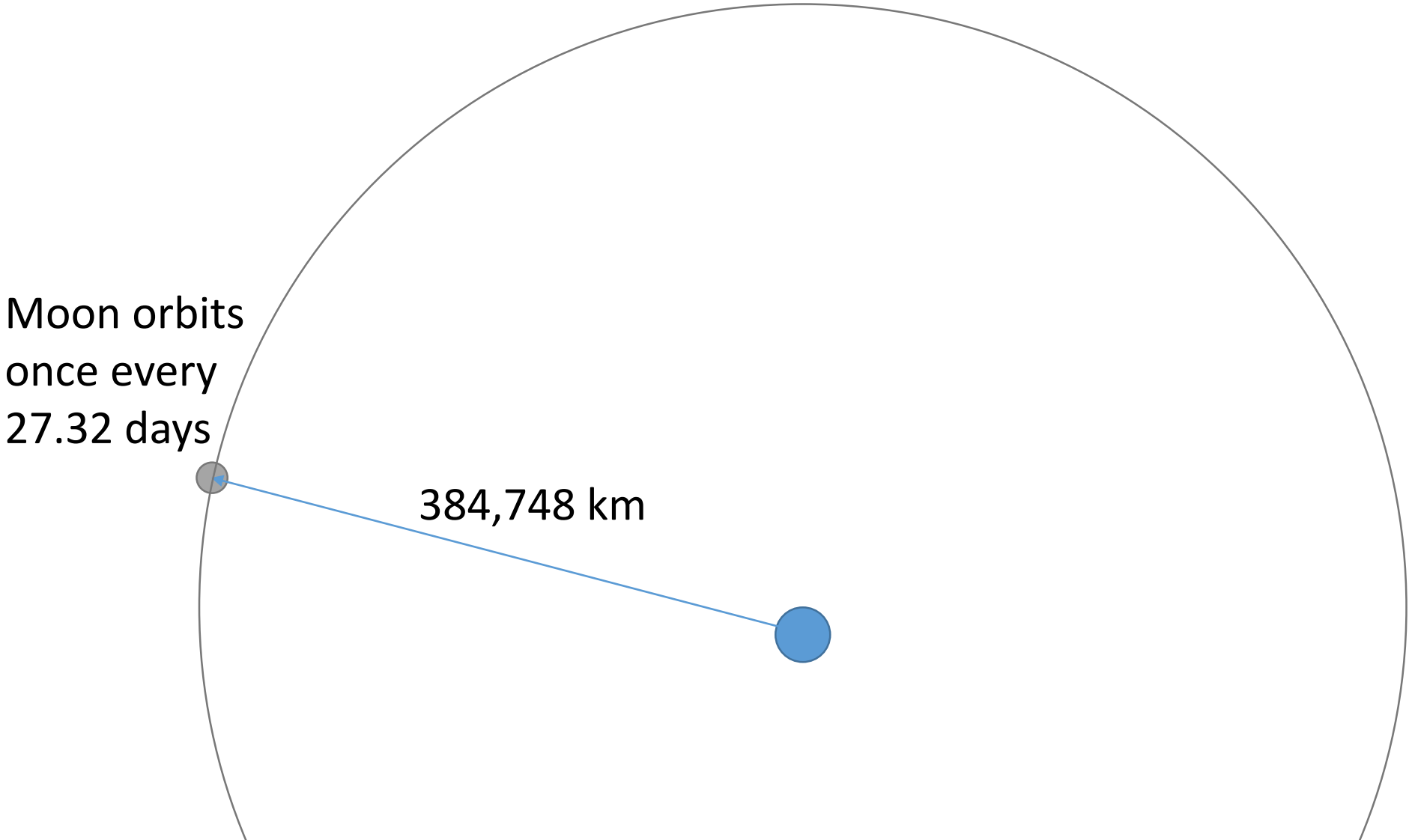
M = mass of body being orbited

a = semi-major axis of orbit in meters

G = gravitational constant (6.67×10^{11} N m^2/kg^2)

What's the mass of Earth?

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



Remember to convert distances to meters and time to seconds for use with G.