Periodic Motion

I. Circular Motion
- kinematics & centripetal acceleration
- dynamics & centripetal force
- centrifugal force

II. Universal Gravitation
- **Newton's "4th" Law**
- force fields & orbits

III. Simple Harmonic Motion
- pendulums, springs, etc

	The student will be able to:	HW:
1	Define and calculate period and frequency. ✓	
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3	State and correctly apply the relation between speed, radius, and period for uniform circular motion. ✓	
4	State and correctly apply the relation between speed, radius, and centripetal acceleration for uniform circular motion. ✓	1 – 14
5	Distinguish and explain the concepts of centripetal vs. centrifugal force. ✓	15 – 16
6	State and apply Newton's Law of Universal Gravitation.	17 – 28
7	Combine equations of circular motion and gravitation to solve problems involving orbital motion.	29 – 37
8	State and apply the relation between length, period, and *g* for a pendulum.	38 – 40
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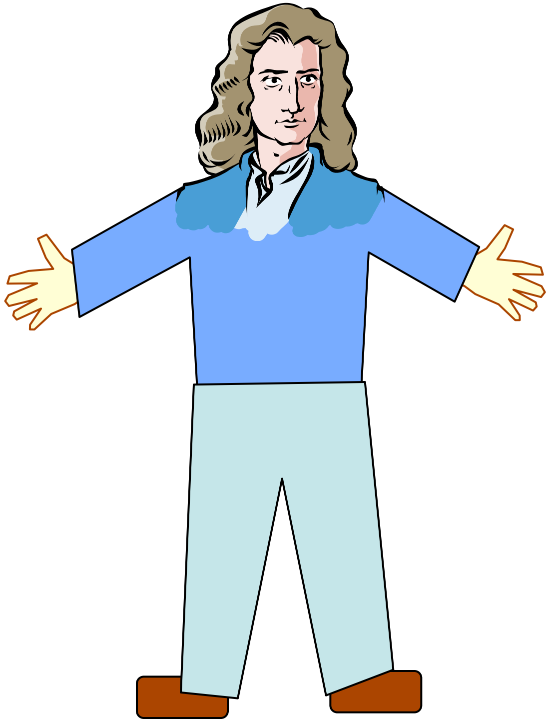
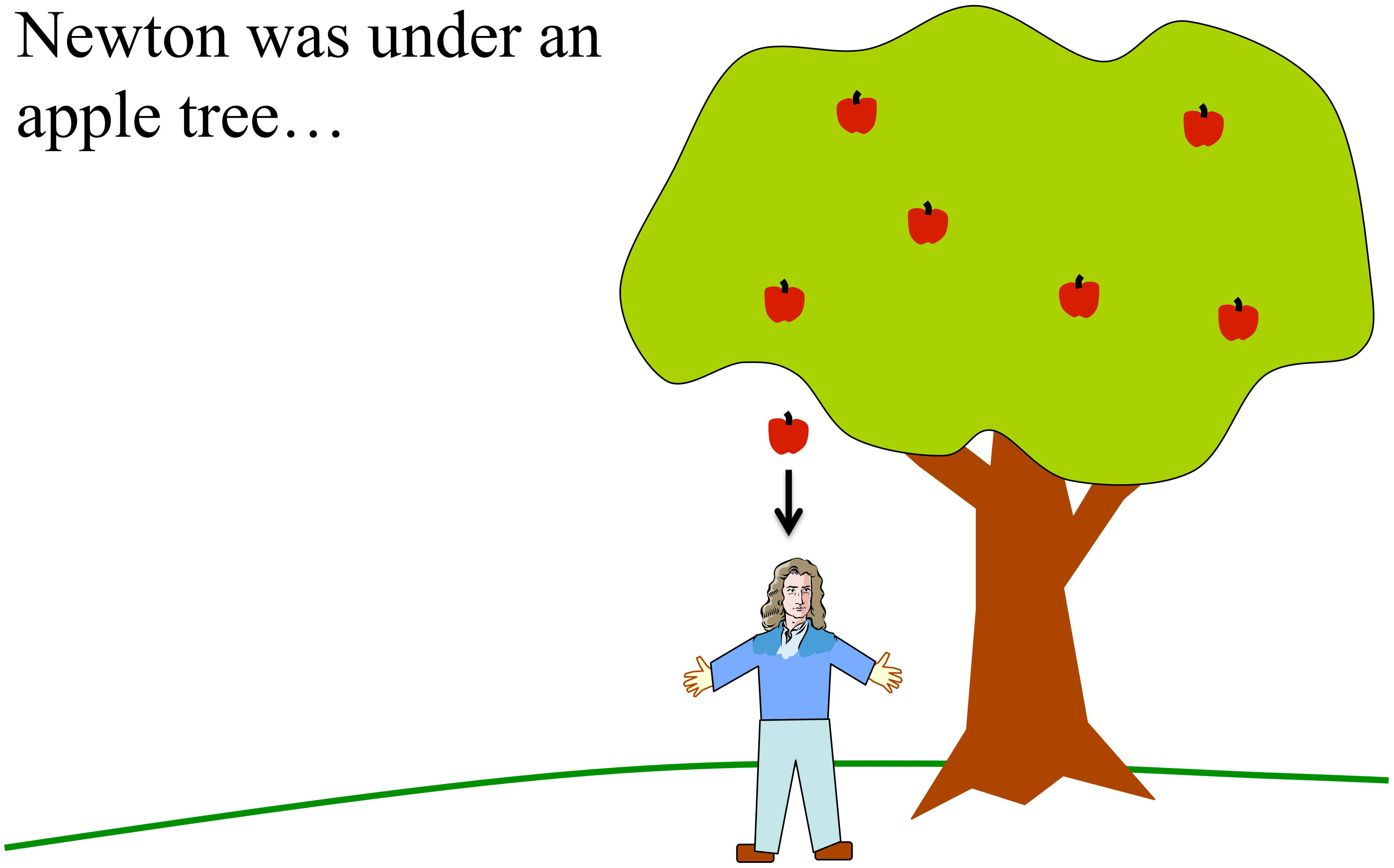
Let's put ourselves in Newton's shoes…



Once upon a time, Isaac Newton was under an apple tree…

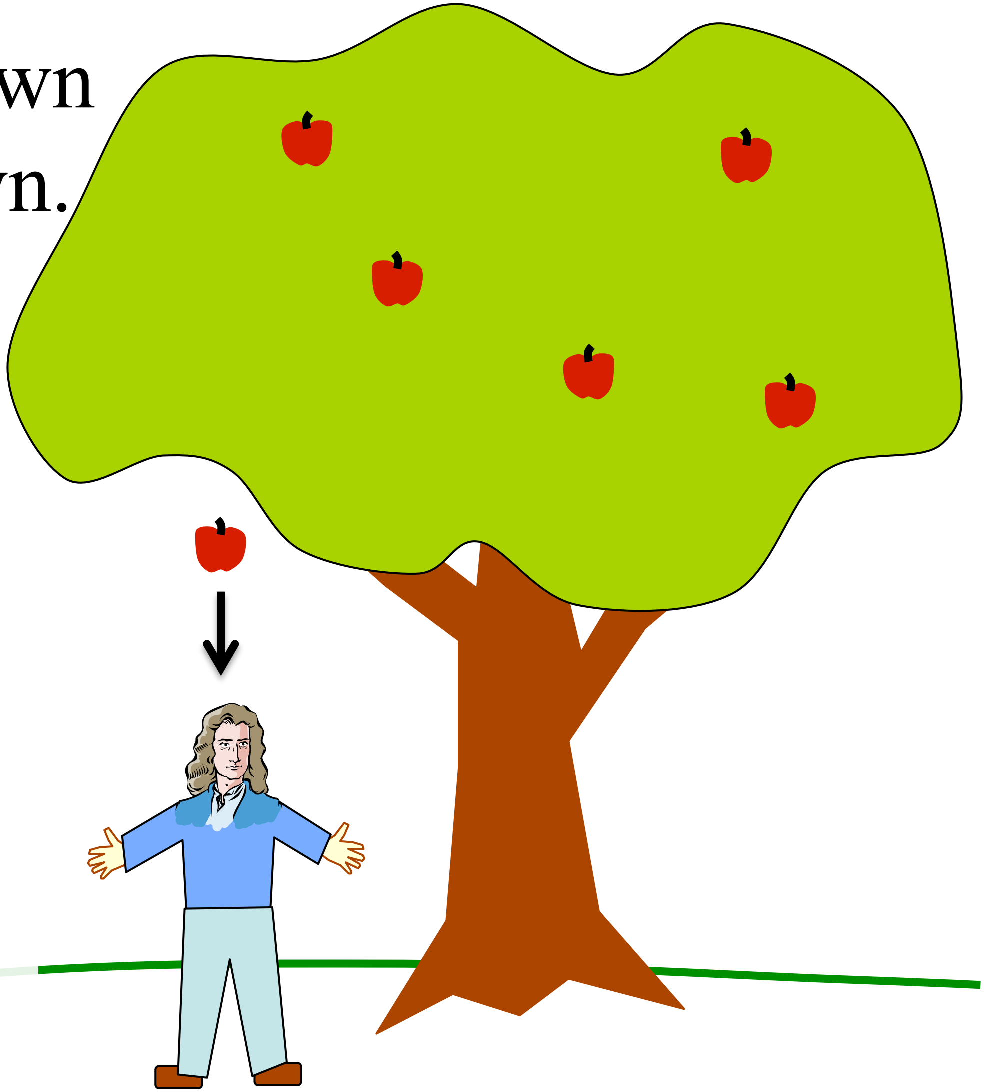


2^{nd} Law:

In order to accelerate down there must be force down.

In order to fall equally, gravity on an apple with twice the mass must be twice as great.

The force of gravity is proportional to mass!
($F_G = mg$)

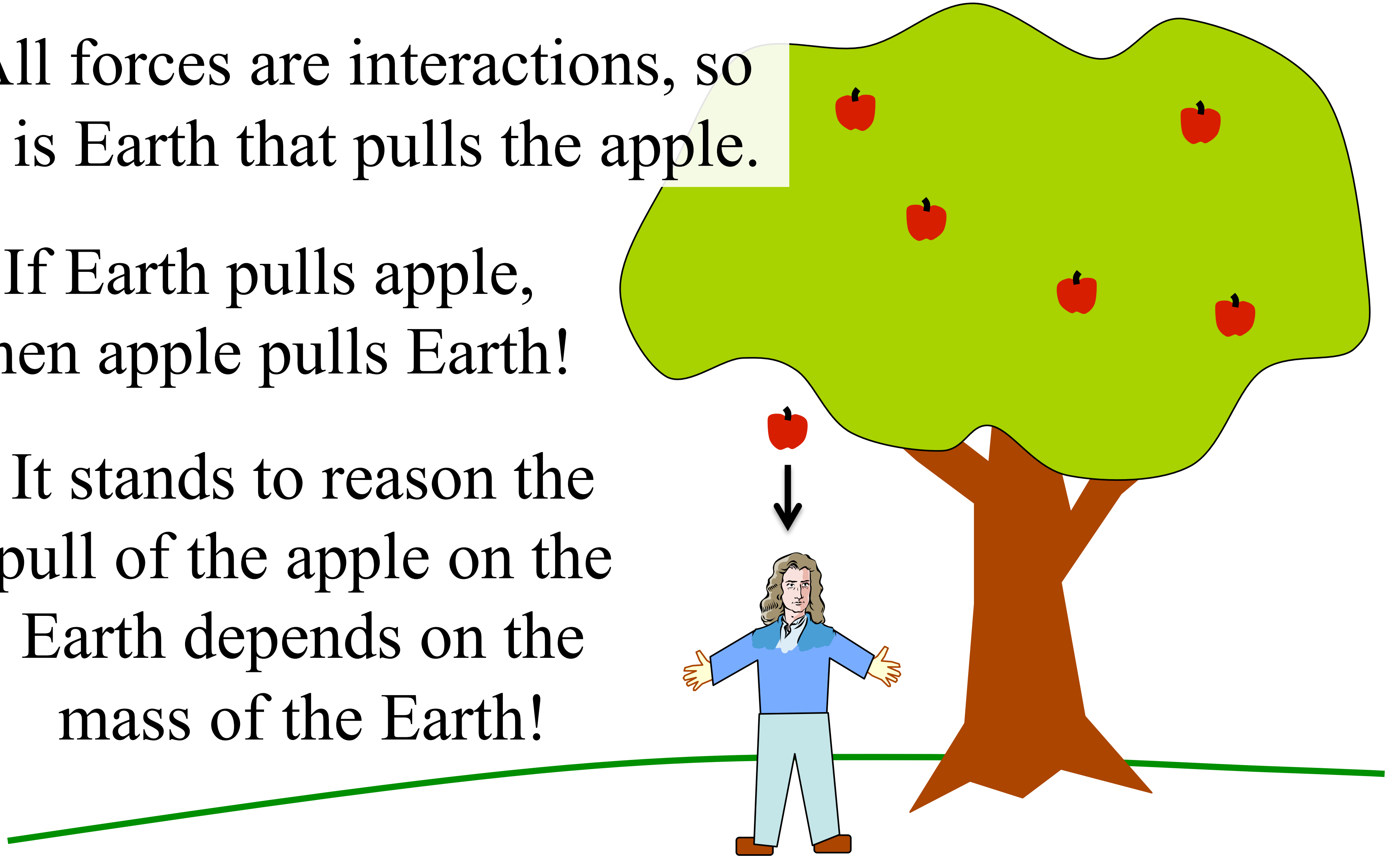


3rd Law:

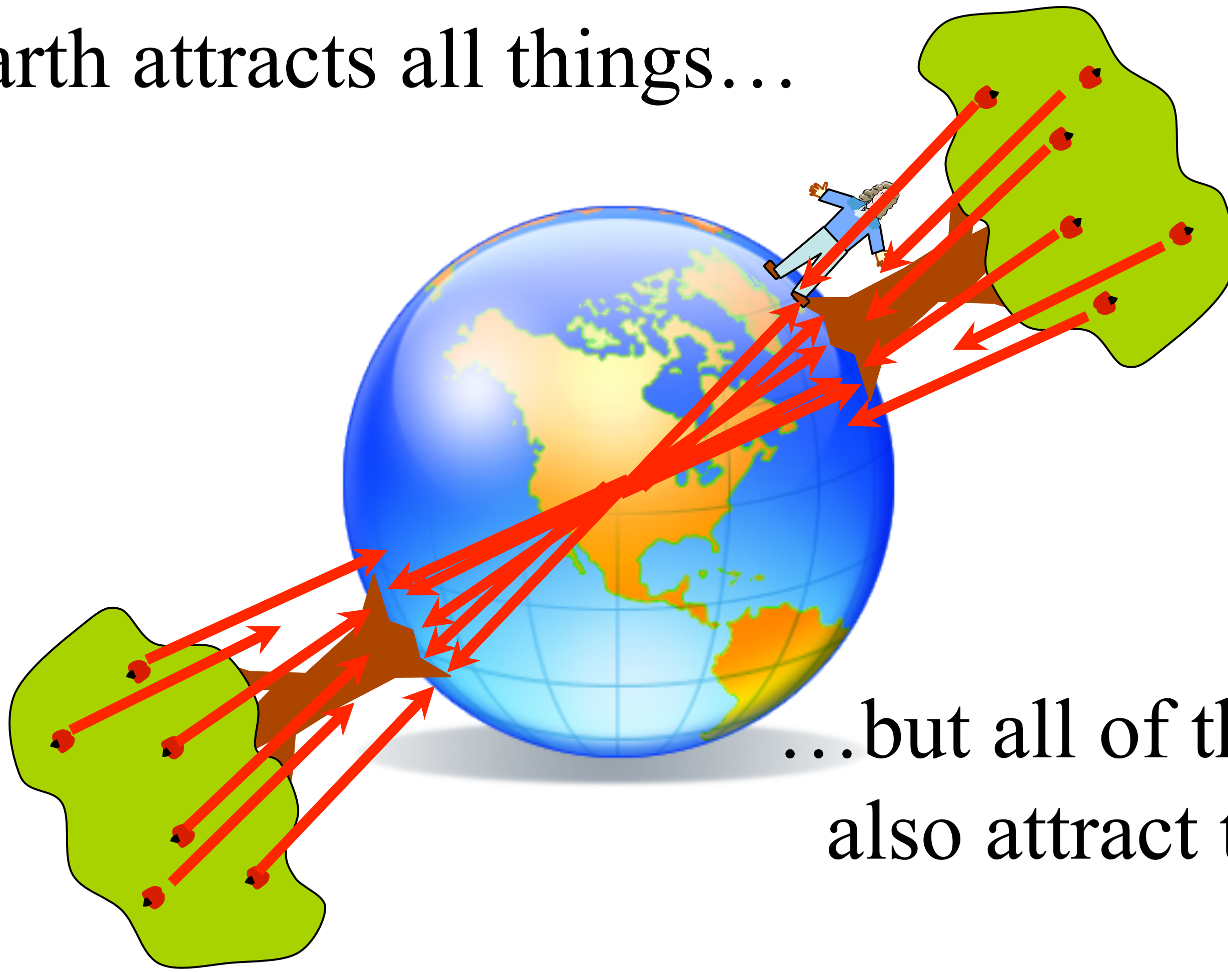
All forces are interactions, so it is Earth that pulls the apple.

If Earth pulls apple, then apple pulls Earth!

It stands to reason the pull of the apple on the Earth depends on the mass of the Earth!

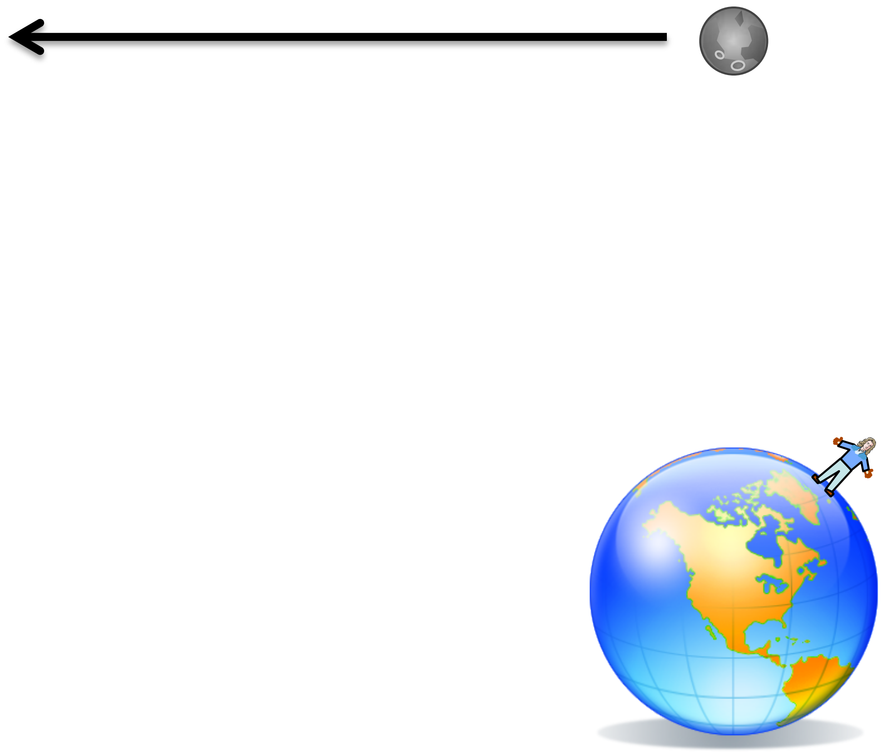


Earth attracts all things…



…but all of those things also attract the Earth.

Not only Earth has gravity, the apple also has gravity, and any other thing with mass has gravity!



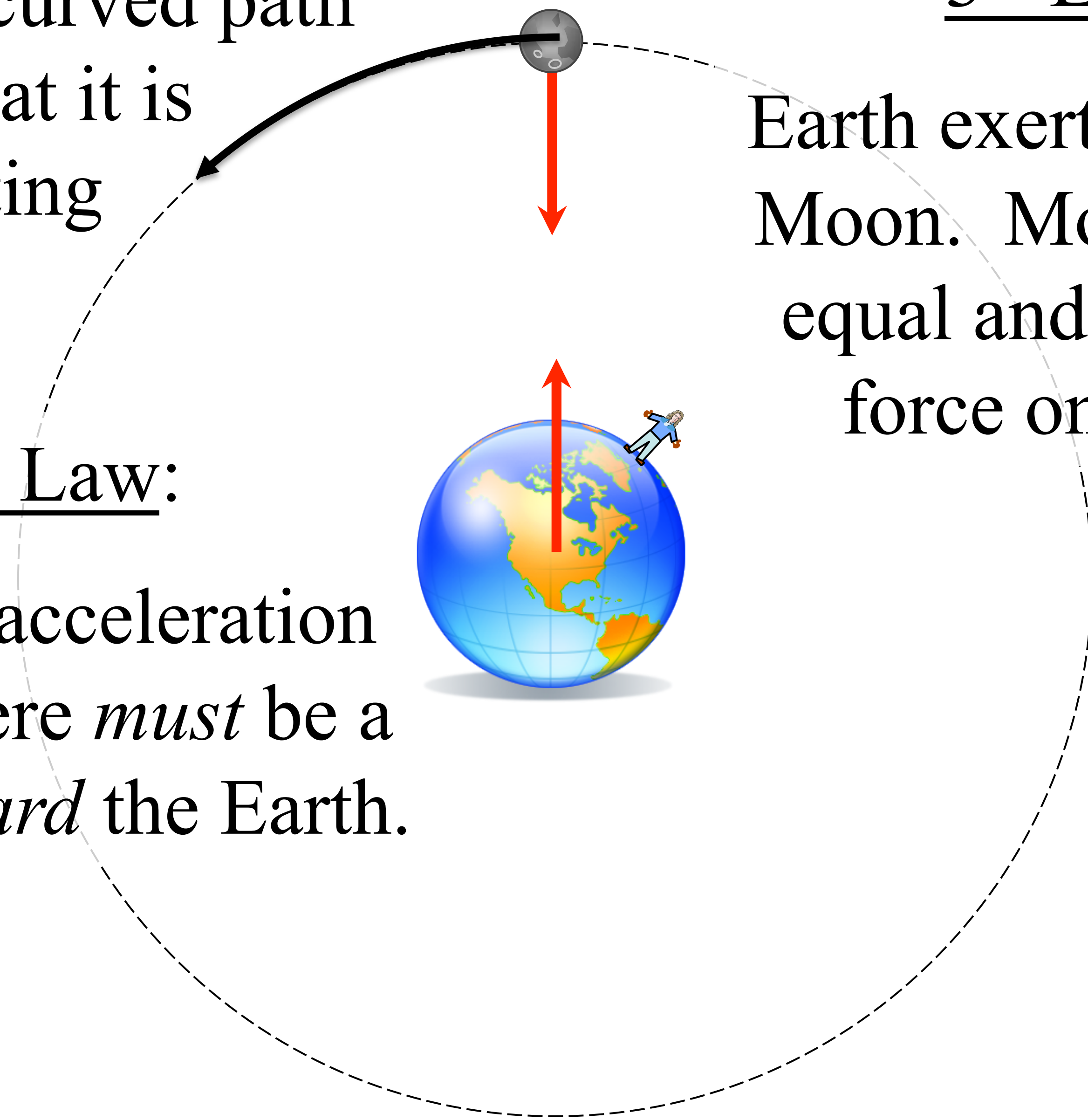
<u>1st Law</u>:

Moon would fly off into space *if* there were *no* force.

Moon’s curved path shows that it is accelerating

3rd Law:

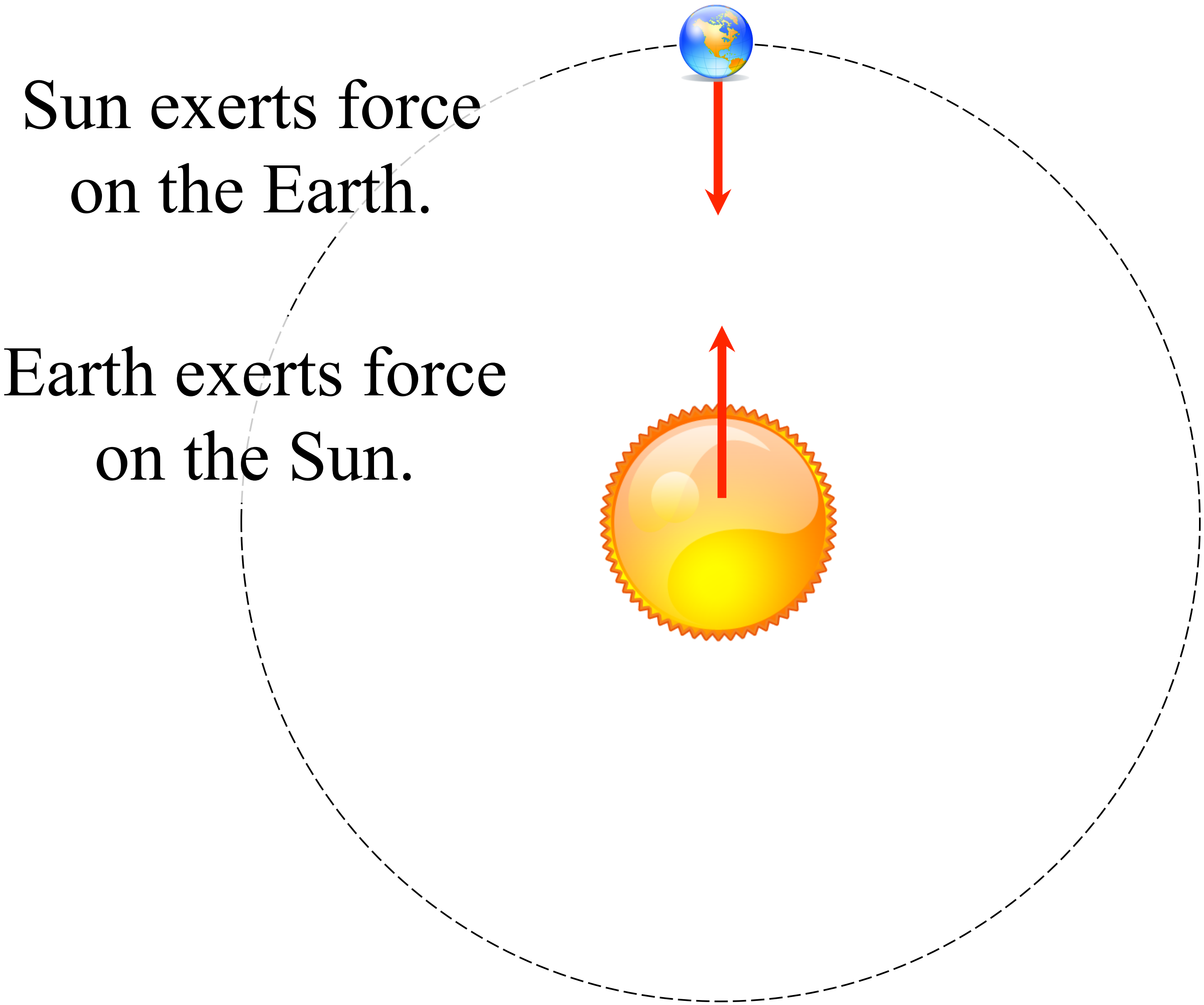
Earth exerts force on Moon. Moon exerts equal and opposite force on Earth.



2nd Law:

Moon’s acceleration shows there *must* be a force *toward* the Earth.

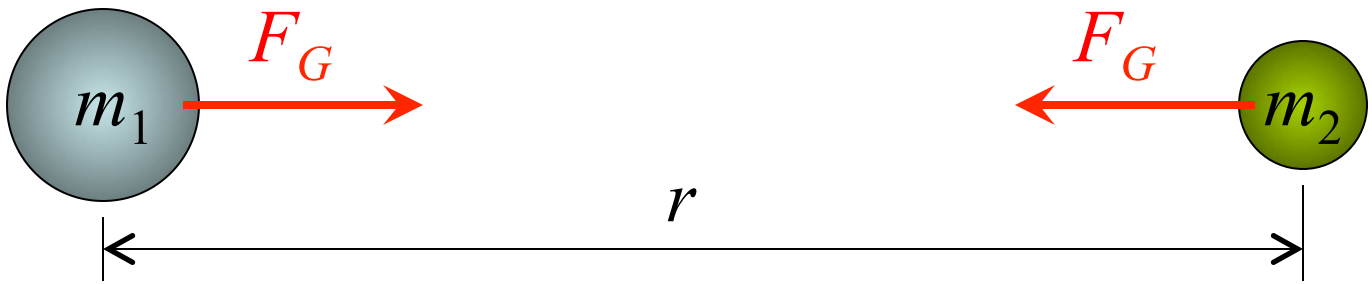
Similarly, Earth must accelerate toward the Sun!



Newton's Law of Universal Gravitation:

Every object in the universe attracts every other object in the universe.

Newton's Law of Universal Gravitation:



$$F_G = G\frac{m_1 m_2}{r^2}$$

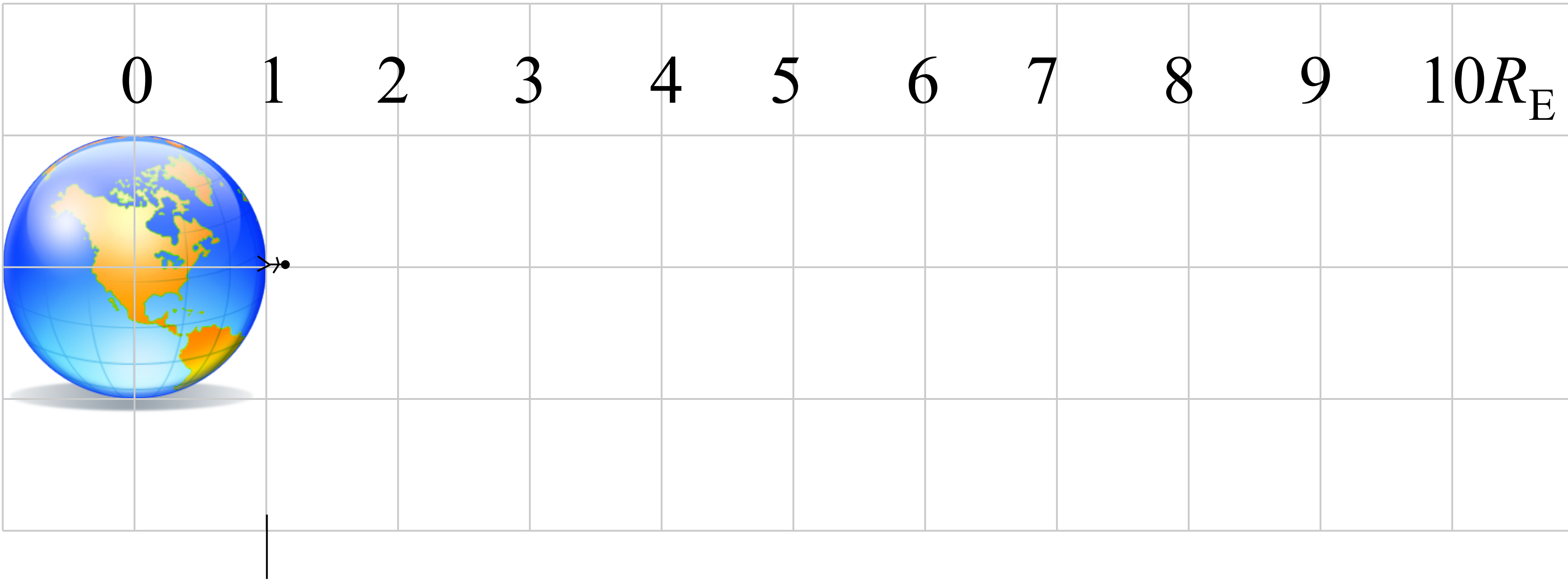
where: m = mass

r = distance between centers

G = universal gravitational constant:

$6.674 \times 10^{-11}\ \text{m}^3/\text{kg s}^2$

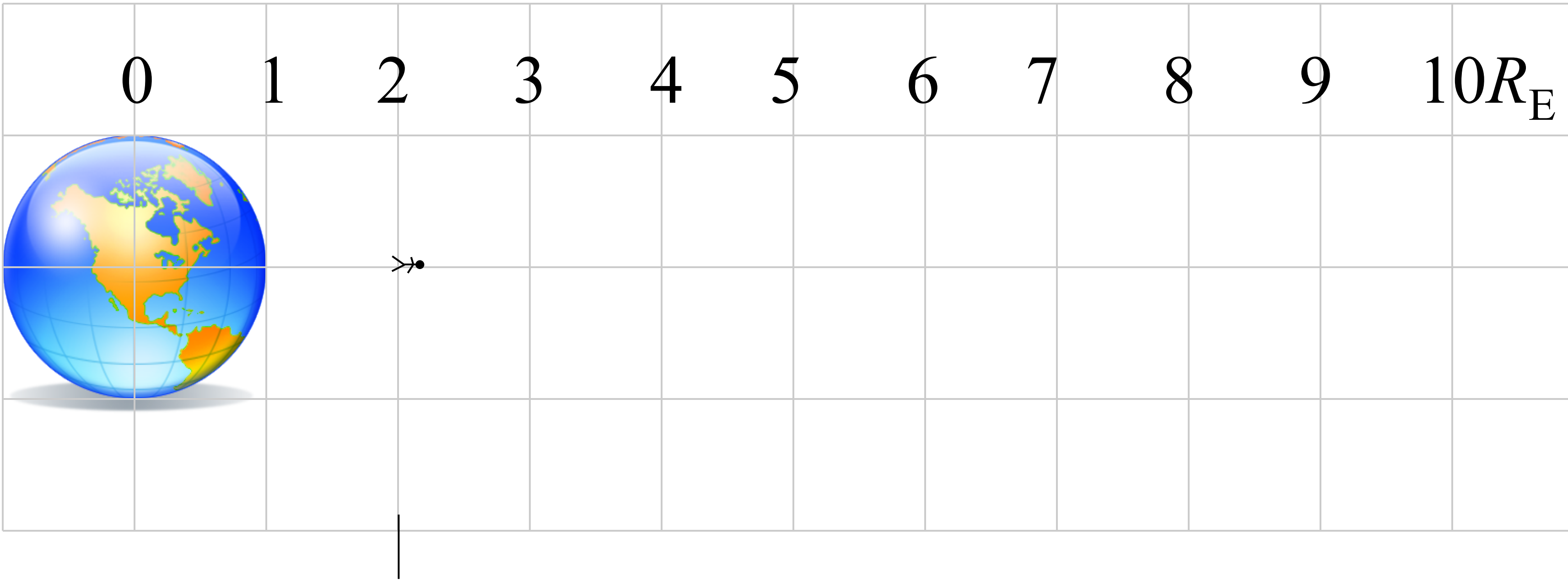
"Inverse Square Law"



720 N

Consider a person that weighs 720 N on the surface of the Earth, who is then transported away to greater and greater distances…

"Inverse Square Law"

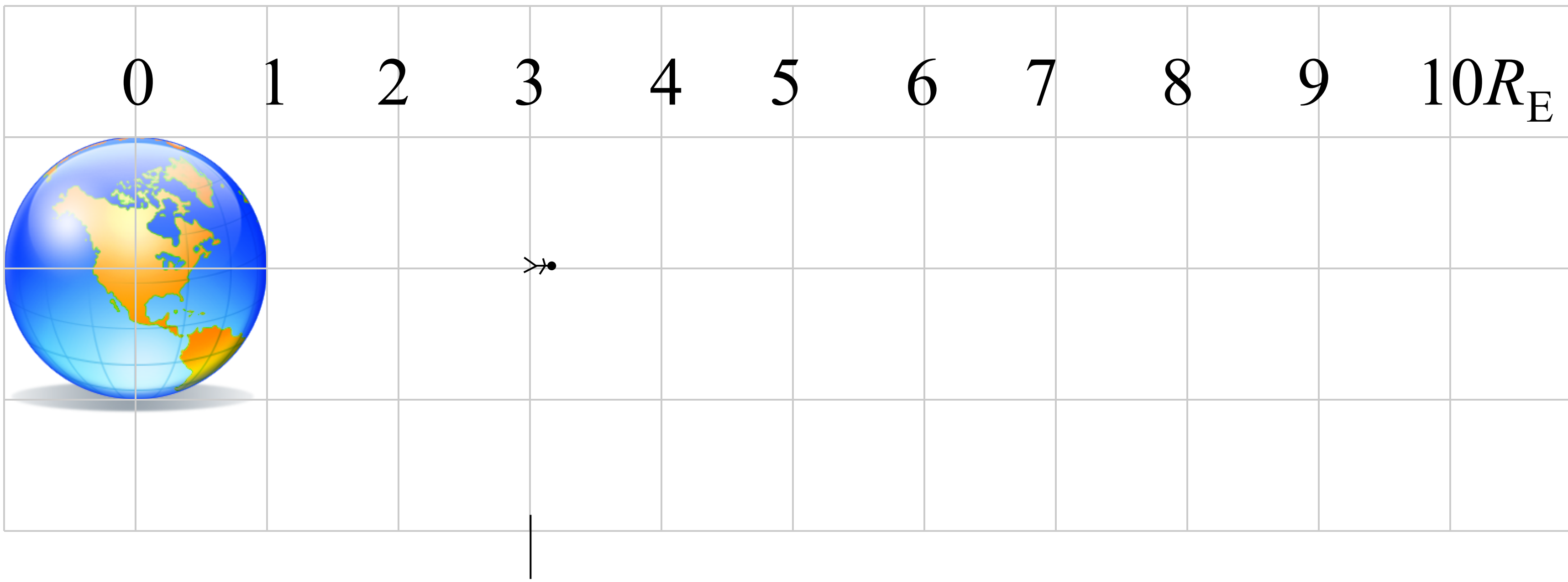


180 N

$$\frac{720}{2^2} = 180$$

At *twice* the distance the person's **mass** is *unchanged*, but his **weight** is one *fourth* its original value.

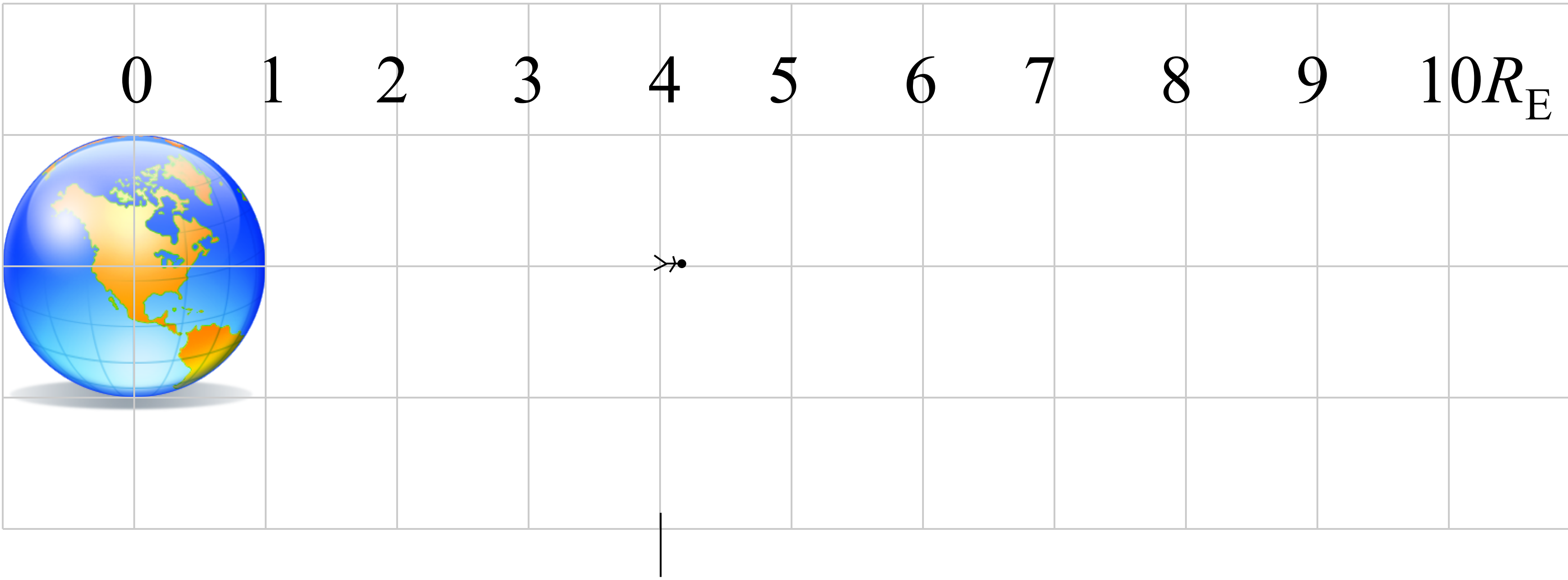
“Inverse Square Law”



80 N

$$\frac{720}{3^2} = 80$$

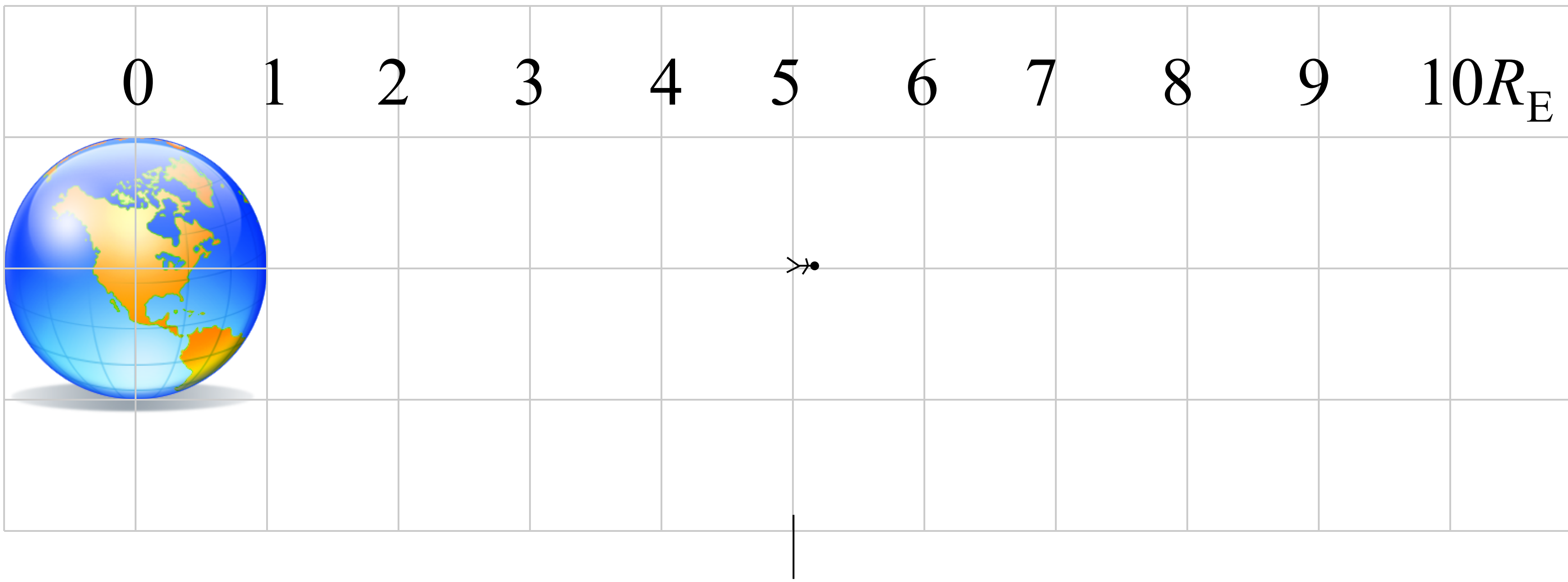
“Inverse Square Law”



45 N

$$\frac{720}{4^2} = 45$$

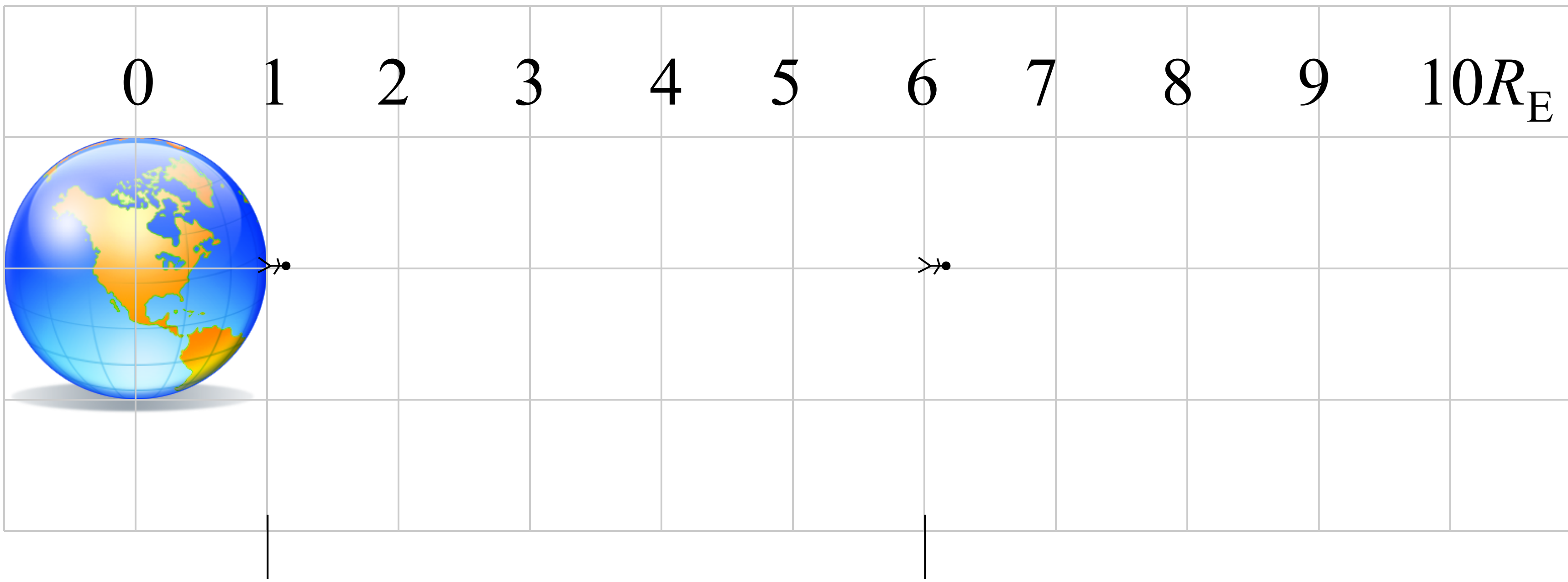
“Inverse Square Law”



29 N

$$\frac{720}{5^2} = 29$$

“Inverse Square Law”

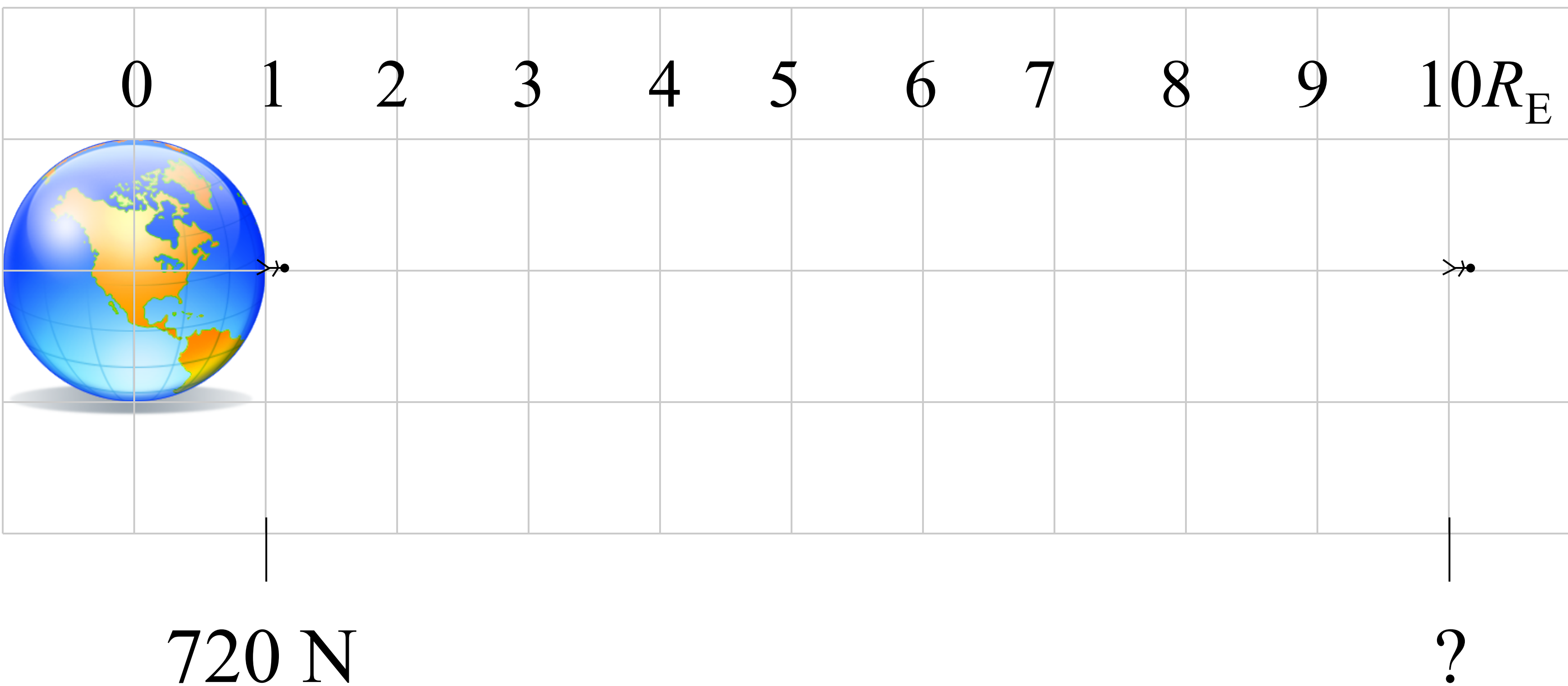


720 N

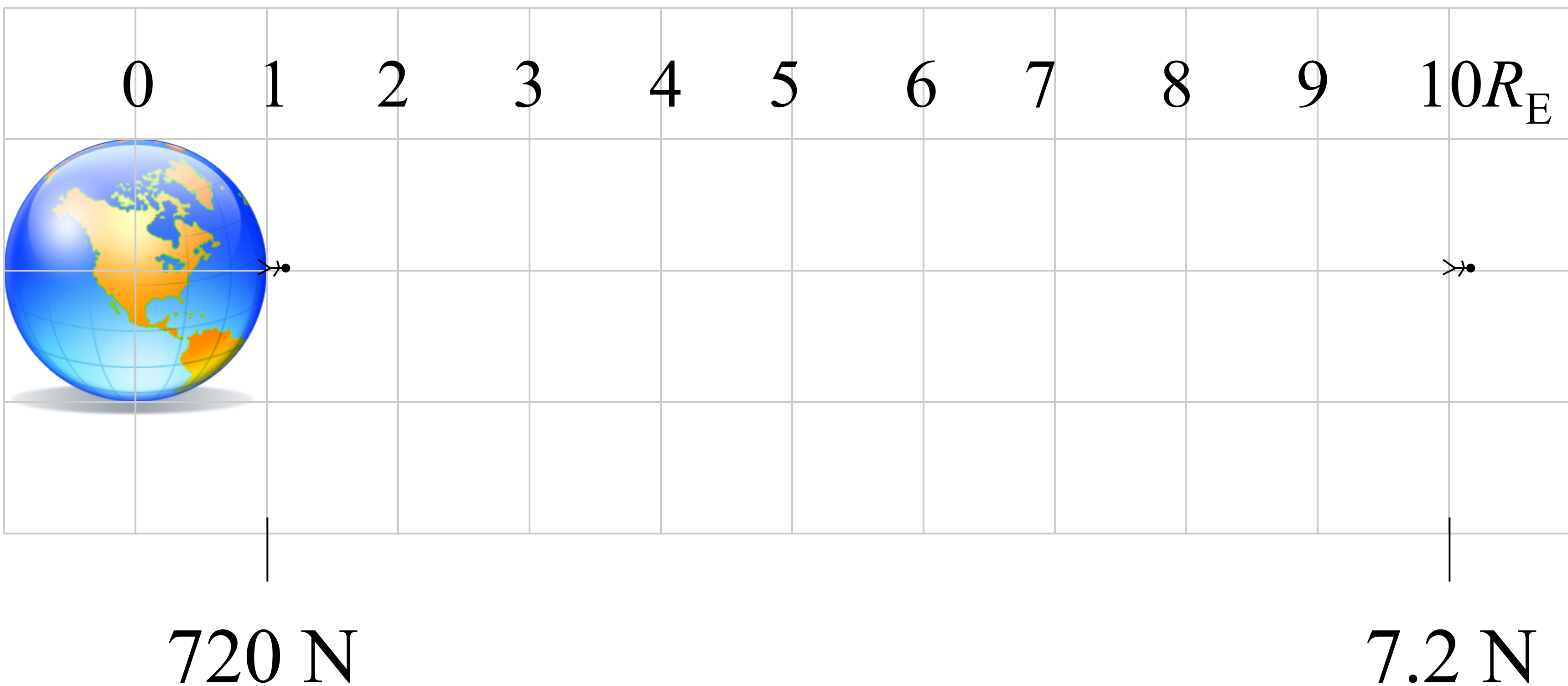
20 N

$$\frac{720}{6^2} = 20$$

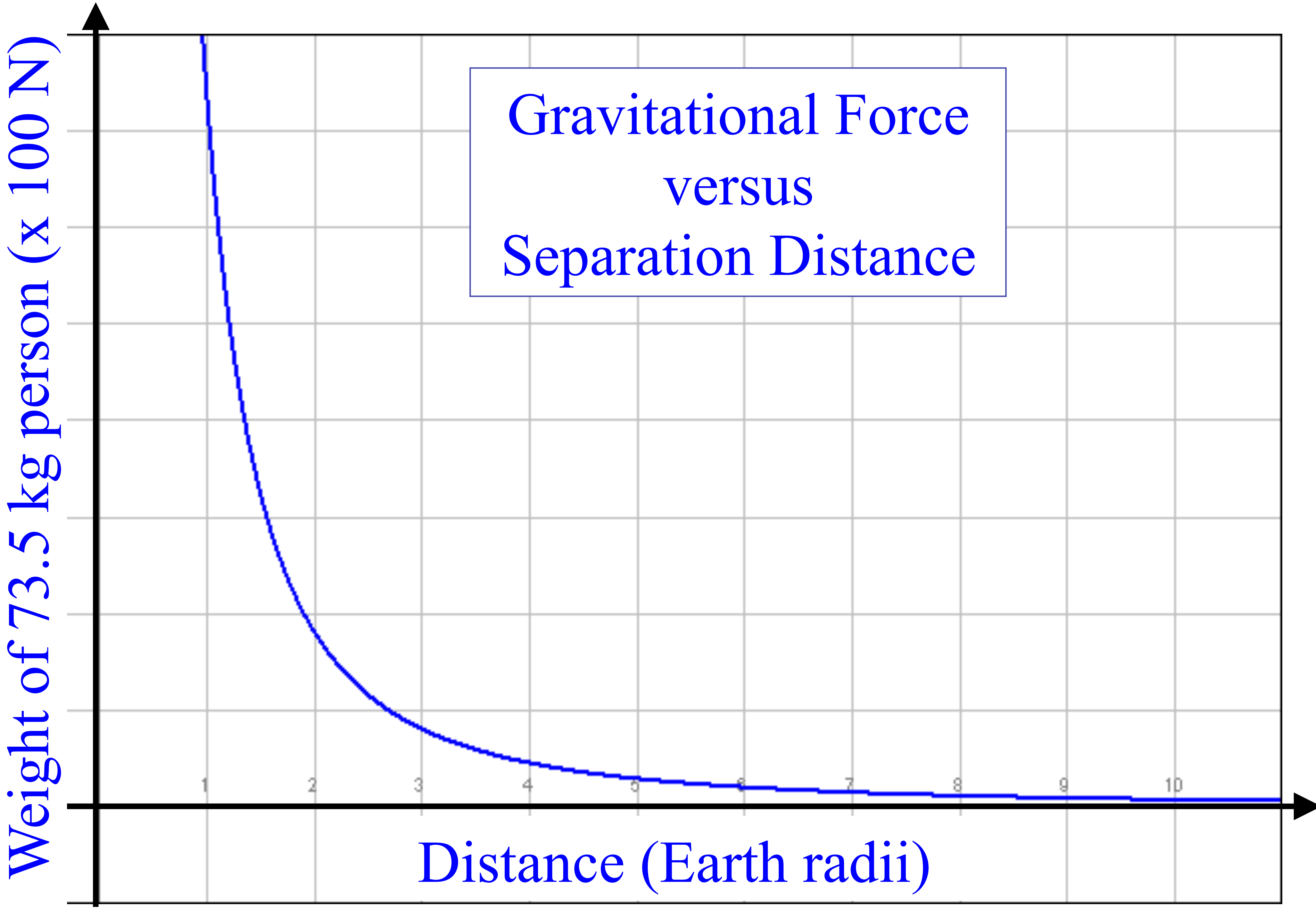
"Inverse Square Law"



“Inverse Square Law”



$$\frac{720}{10^2} = 7.2$$



Gravitational Force
versus
Separation Distance
Weight of 73.5 kg person (x 100 N)
Distance (Earth radii)
1
2
3
4
5
6
7
8
9
10

Henry Cavendish determined G in 1798

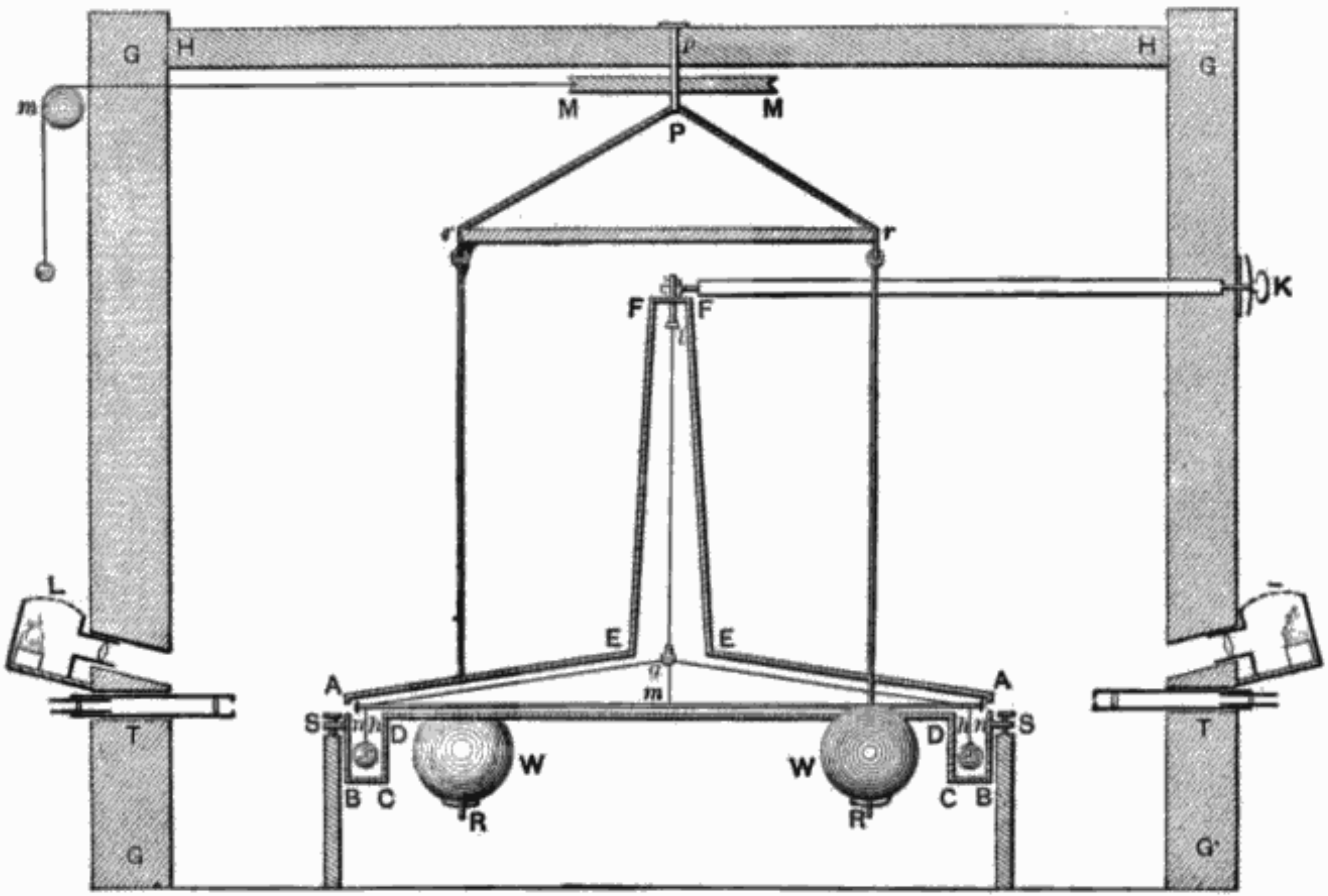
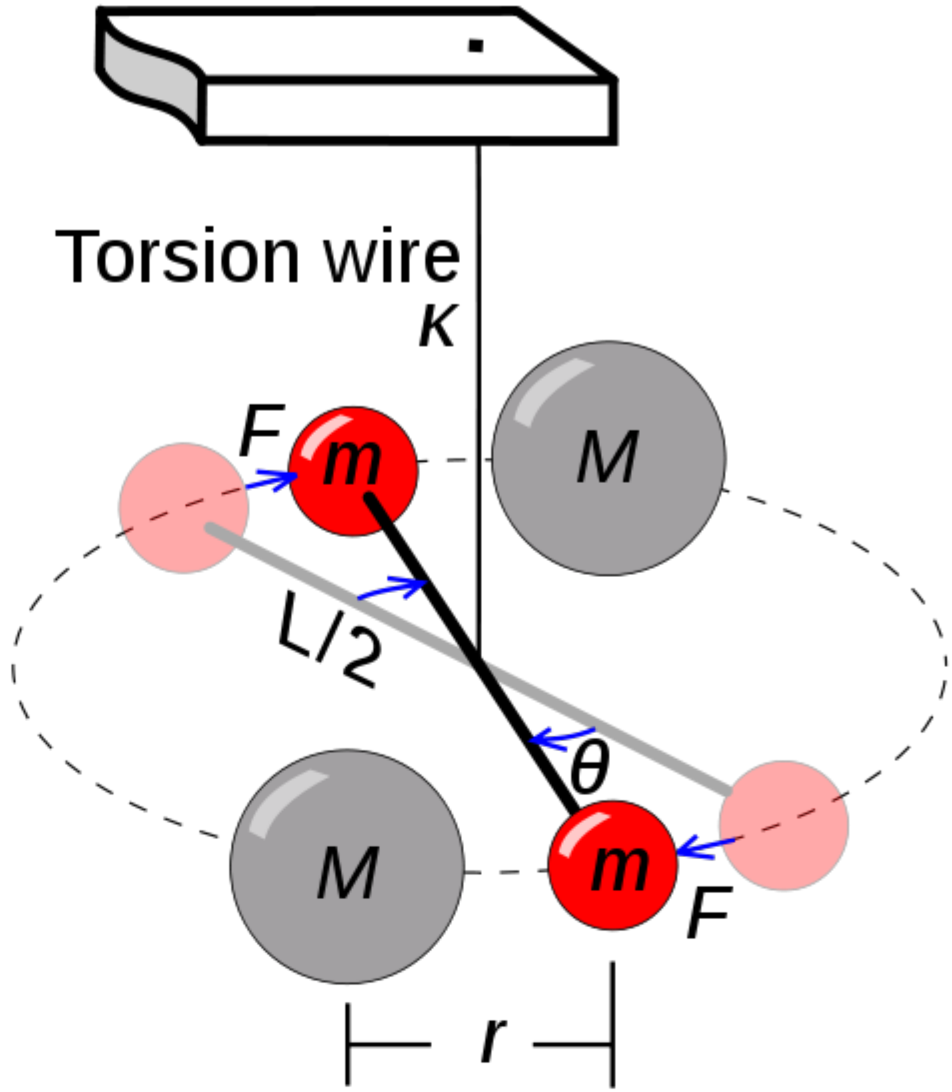


Fig. 1



Torsion wire
κ
F
m
M
L/2
θ
M
m
F
r

Periodic Motion

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- dynamics & centripetal force
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- **force fields & orbits**

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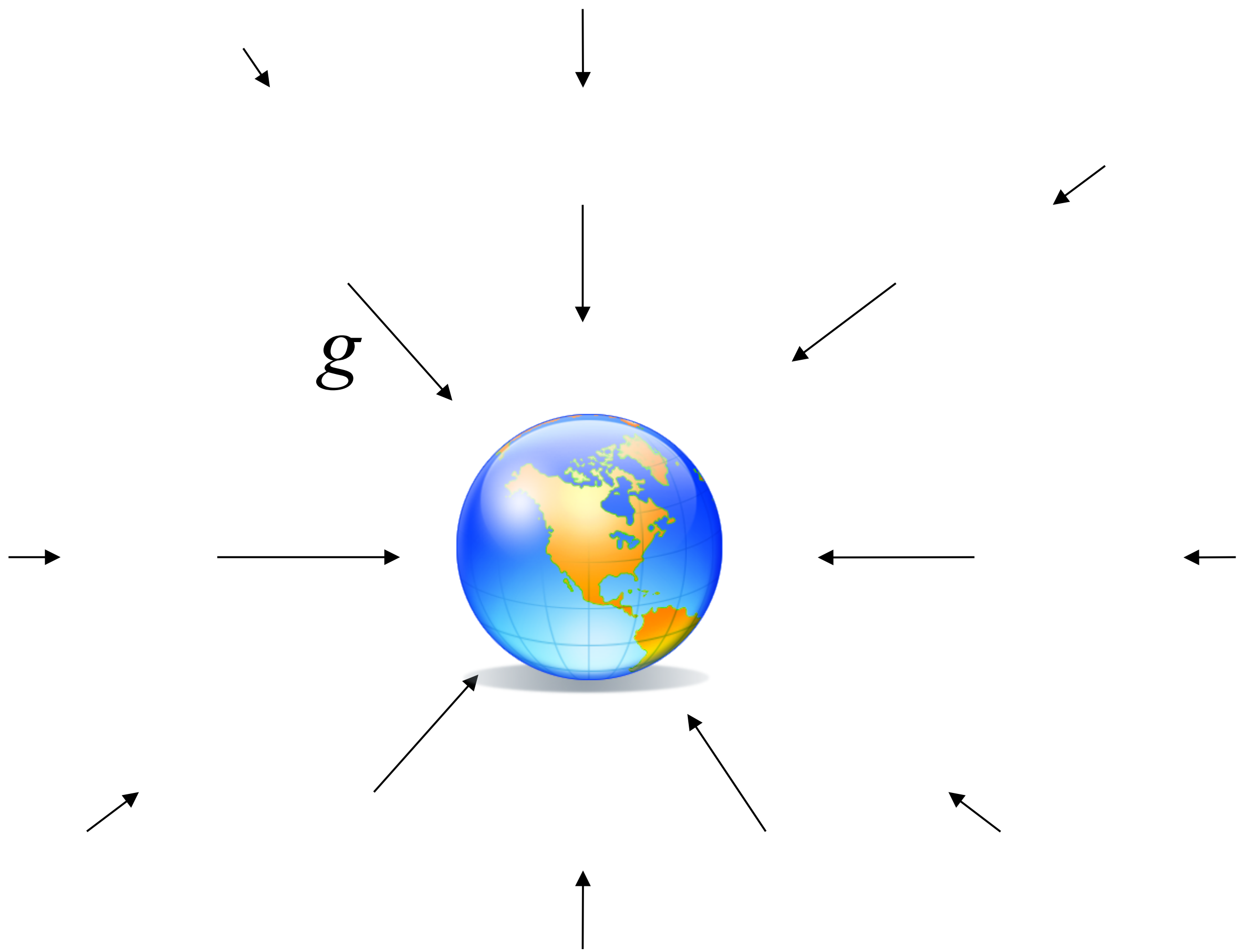
Force Fields

A **field** is a region where a particular force has influence. There are many types of fields in physics: gravitational fields, magnetic fields, electric fields, etc.

Field strength is defined as the amount of force per unit of affected property.

A field has direction the same as the force. A field can be visualized as a series of vectors or lines that point in the direction of the force.

Earth's Gravitational Field



g = 9.80 N/kg at Earth's surface

Gravitational Field

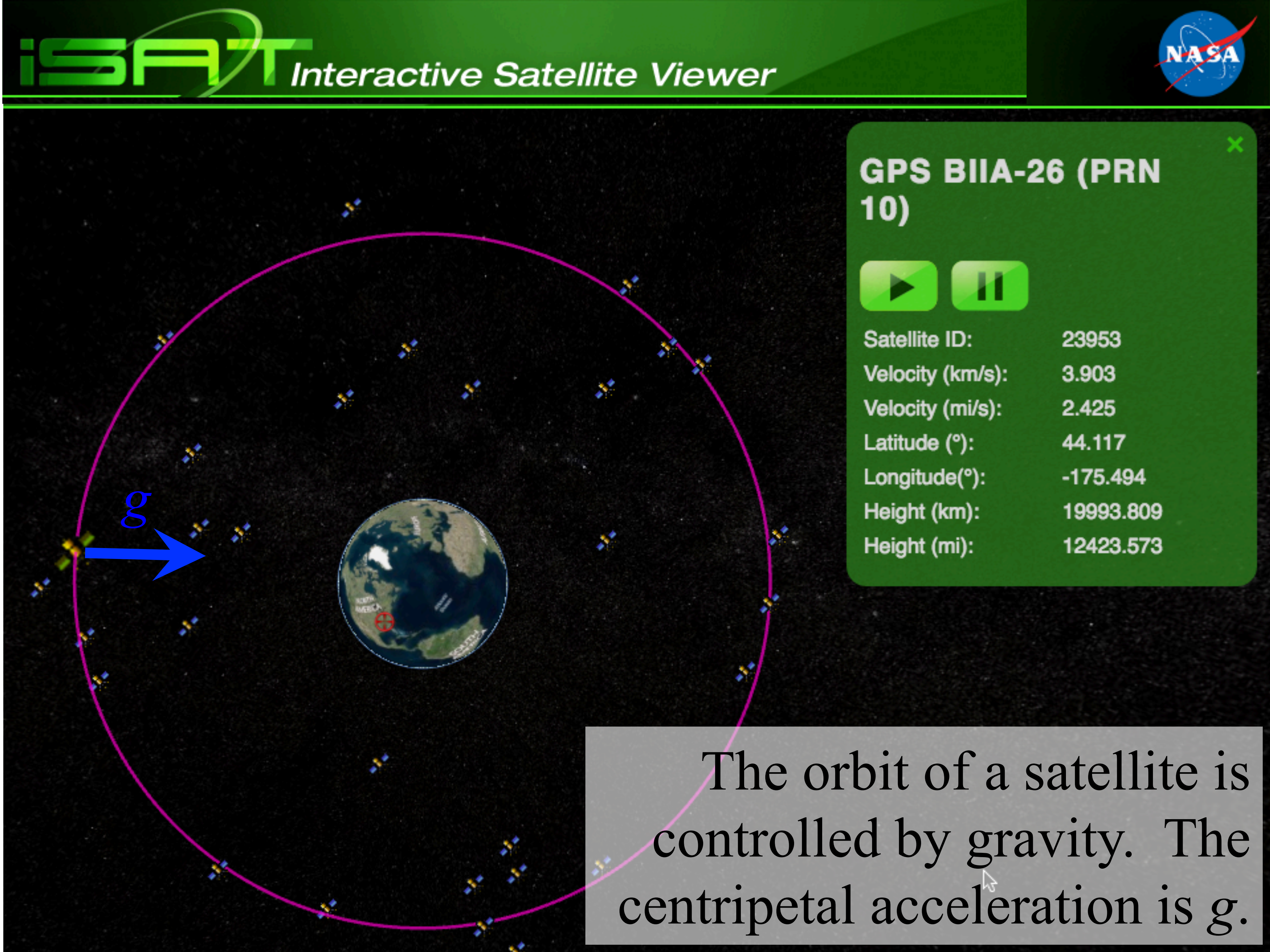
$$g = G\frac{M}{r^2}$$

where: M = mass of the field's *source*

r = distance between centers

G = universal gravitational constant:

$6.674 \times 10^{-11}\ \mathrm{m^3/kg\ s^2}$

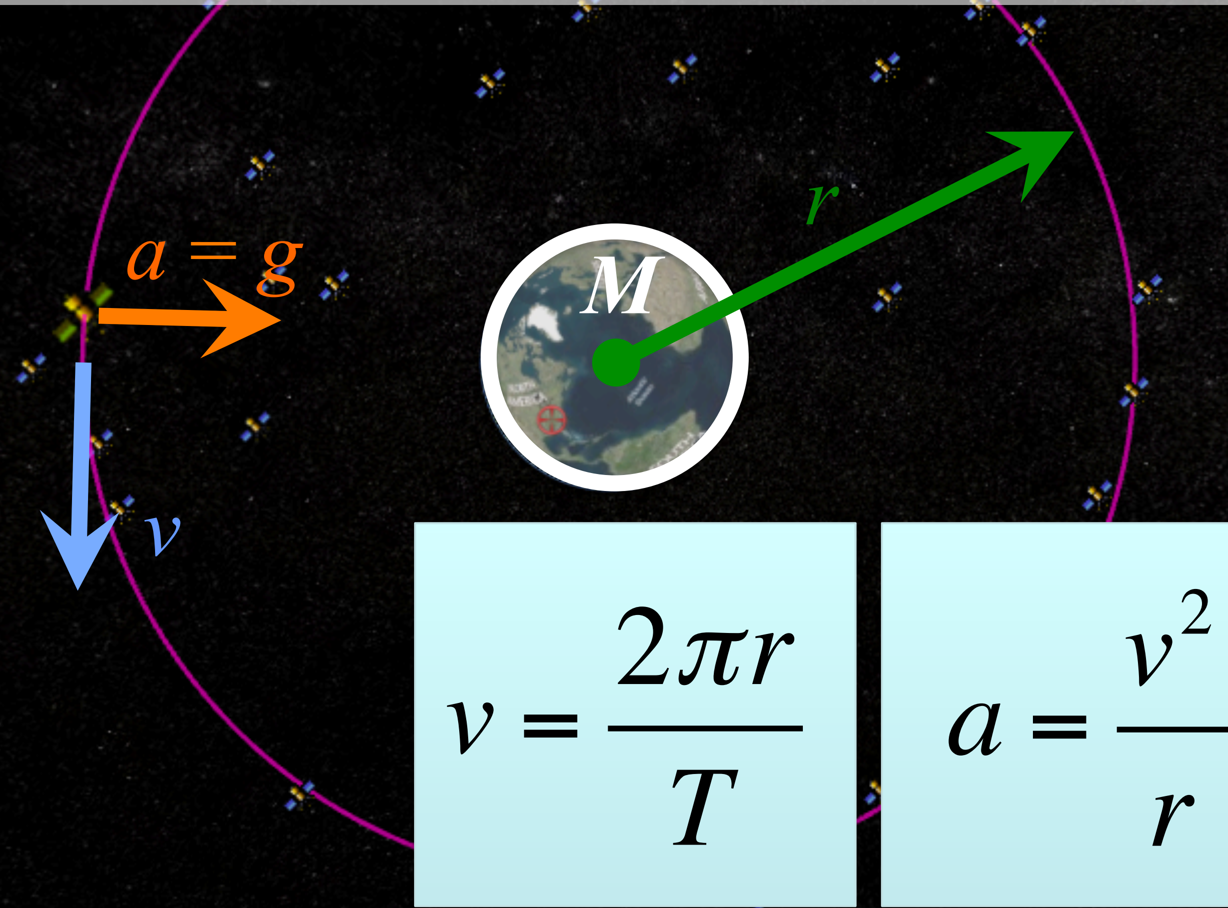


The orbit of a satellite is controlled by gravity. The centripetal acceleration is *g*.

iSAT Interactive Satellite Viewer

NASA

A circular orbit for an object under the sole influence of gravity satisfies three equations:



GPS BIIA-26 (PRN 10)

Satellite ID:	23953
Velocity (km/s):	3.903
Velocity (mi/s):	2.425
Latitude (°):	44.117
Longitude(°):	-175.494
Height (km):	19993.809
Height (mi):	12423.573

$$v = \frac{2\pi r}{T}$$

$$a = \frac{v^2}{r}$$

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