Physics 20 Unit 2 - Gravity

# Field Theory and Universal Gravitation

**Let's think of some types of forces...**

| Contact | Action at a Distance |
| --- | --- |

**How can we explain these action at a distance forces?**

# Enter: Field Theory

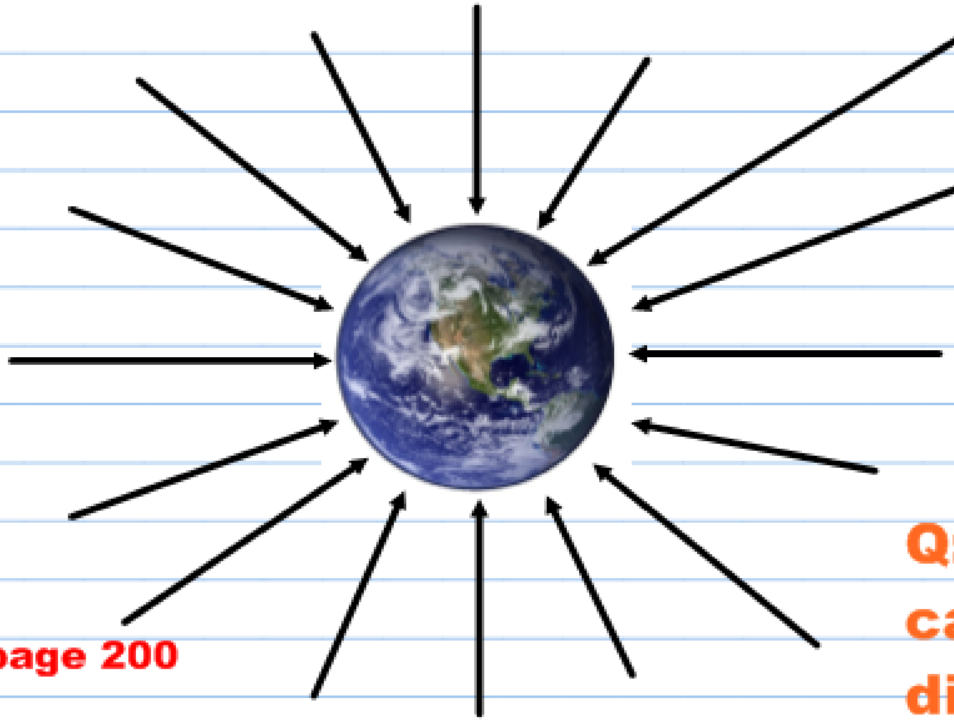
**Invisible gravitational fields surround all objects at all times. Every mass in the universe creates its own gravitational field.**

Field: a sphere of influence surrounding an object

**Campfire analogy -**

**Examples of other fields:**

**A gravitational field is made up of field lines. The lines are vectors which point towards the centre of the Earth.**

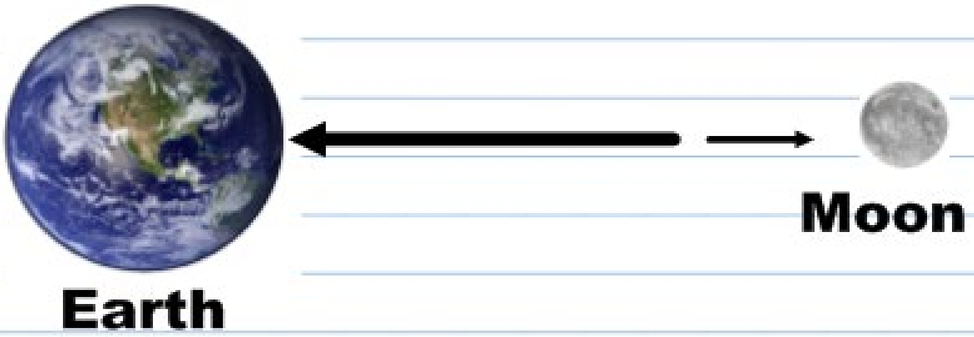


**The closer the field lines are together, the stronger the field.**

*Text page 200

**Q: What conclusion can be drawn from this diagram?**

Field lines can add together like other vectors:




Q: What is the direction of the resultant gravity field between the earth and the moon?

# Test Object Formula

- **When an object is experiencing a gravitational force because it is trapped in the gravitational field created by a larger mass object, we can use this formula to describe the field / force it experiences:**

$$g = \frac{F_g}{m}$$

- **The mass in this equation *must* be the test mass (ie: the mass of the object *experiencing* gravity)**

**We know what direction field lines will move in, now here's how we can work out the magnitude:**

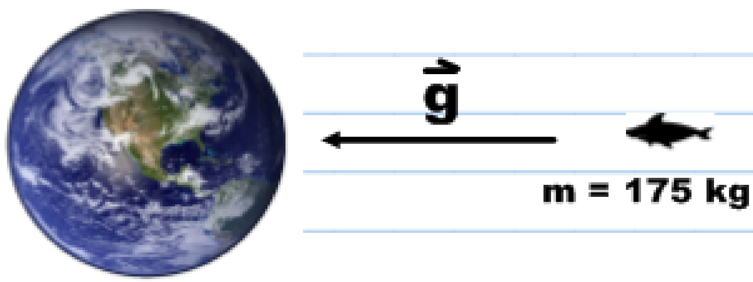
$$\vec{g} = \frac{\vec{F}_g}{m}$$

**where:**

**$\vec{g}$ = strength of gravity field**
**$\vec{F}_g$ = force of gravity on test object**
**m = mass of test object**

***Note: this is just Newton's second law revisited.**

**If we release a test object in a gravity field, it will accelerate in the direction of the field with a force proportional to the mass of the object**




**ex) If a shark of mass 175 kg experiences a force of 1480 N towards the Earth, what is the strength of the field at the shark?**

**ex) A test object of mass m experiences a field strength of g. If the mass doubles and the force acting on the object is the same, what must happen to the field strength?**

# Source Object Formula

- **When we want to calculate the force of gravity or gravitational field *created* by a source object, we need to use a different formula.**

- **First, let's look at what factors may affect how big the gravity created from an object will be:**

**In the last problem, you found that the field strength is directly proportional to mass.**

$$\vec{g} \propto m$$

**It was also found through experimental means (page 203) that the value was also inversely proportional to the square of the distance between the test object and the gravity producing object.**

$$\vec{g} \propto \frac{1}{r^2}$$

http://www.makingthemodernworld.org.uk/learning_modules/maths/06.TU.02/?section=6

If we combine these two proportions together, we get one statement:

$$\vec{g} \; \alpha \; m \qquad\qquad \vec{g} \; \alpha \; \frac{1}{r^2}$$

$$\vec{g} \; \alpha \; \frac{m}{r^2}$$

To remove this proportion symbol, we must introduce a constant of proportionality.

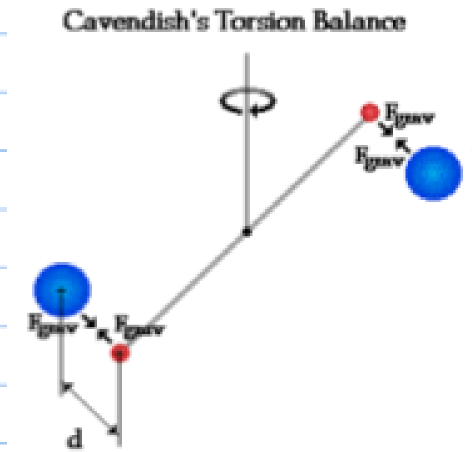
$$\vec{g} = \frac{Gm}{r^2}$$

*On formula sheet

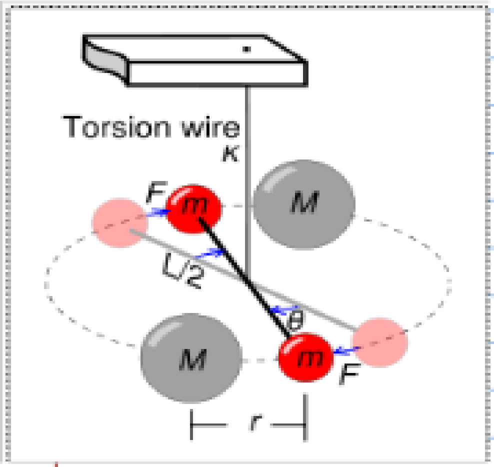
$\vec{g}$ = gravitational field ($m/s^2$)
G = universal gravitational constant
m = mass of gravity producing object
r = distance between test object and gravity producing object

# G

**The constant G was proposed by Newton and finally calculated some years later through the results of Henry Cavendish's Cavendish experiment (which was used to determine the mass of the Earth).**

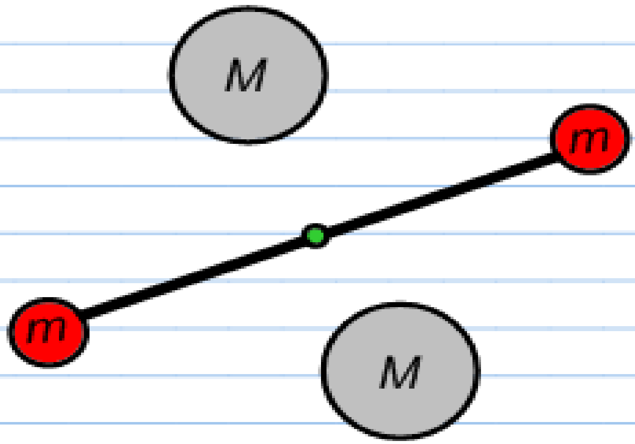




**See pg. 205-206**




**This experiment uses a torsion balance. Two large fixed masses (M) attract two small masses (m) attatched to a bar hanging from a wire.**

**Top View**




**The large masses attract the small masses, and the wire (holding the bar) twists. By measuring the amount of twist, the value of G can be calculated.**

The value of G was calculated from Cavindish's data to be:

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

This value is quoted on your formula sheet and is the same everywhere in the universe!

Also remember that this is an exact value and is not subject to sig-digs.

**ex) Calculate the gravitational field strength on the surface of the Earth.**

**ex) Calculate the gravitational field strength on the highest peak of Everest (8848 m above the earth).**

**ex) Calculate gravitational field strength on the planet LDtopia, whose mass is 1/8 that of Earth and whose radius is three times larger.**

# Newton's Law of Universal Gravitation

**Newton not only worked out a formula for field strength: he also combined this formula with his second law to determine the <u>Law of Universal Gravitation.</u>**

$$\vec{g} = \frac{Gm}{r^2} \quad \text{and} \quad \vec{F}_g = m\vec{g}$$

$$\vec{F}_g = \frac{Gm_1m_2}{r^2}$$

**where:**

$F_g$ = force of gravity between objects 1 and 2
G = Universal Gravitational Constant
$m_1$ = mass of object 1
$m_2$ = mass of object 2
r = distance between centres of objects

**ex) What is the force of gravity between myself and _______ right now?**

**ex) What is the force of gravity between two neutrons placed 150 pm apart?**

**ex) If the distance between two objects doubles, and the mass of the objects stay the same, what can be said of the force of gravity between them?**

**ex) If the distance between two objects halves, and the mass of one of the objects stay the same while the other triples, what can be said of the force of gravity between them?**