Newton's Law of Universal Gravitation

Law of Universal Gravitation:

Every object attracts every other object with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Published in: The Principia in 1687

Two identical basketballs are floating in deep space.

a) What will happen?

drift towards each other

b) If basketball #1 pulls on basketball #2 with a force of 10. N, how strongly does basketball #2 pull on basketball #1?

10.N equal and opposite forces

c) Explain this behavior using one of Newton's laws of motion.

Third Law

d) Compare the accelerations of the two basketballs.

F=ma If the balls have the same mass, they have the same $\vec{a}$.

Basketball #2 is now replaced with a bowling ball.

e) If the mass of the bowling ball is approximately 20 times the mass of the basketball, how strong is the new force pulling on basketball #1?

200N

f) How much force does the basketball exert on the bowling ball? 200N

g) Compare the accelerations of the two balls. $(m_1)20a = (20m_1)a$

$m_1A = M_2a$

Calculating the Force of Gravity

IB 11

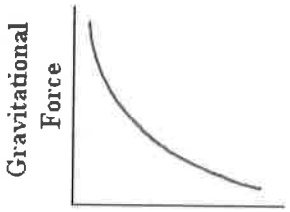
Variable	Fg	G	m	(d) r
Quantity	• Force of gravity • Weight (mg) • Gravitational Force of attraction	Universal Gravitational Constant $G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$	mass	distance between centers
Units	N		Kg	m
Type	vector	scalar	scalar	scalar

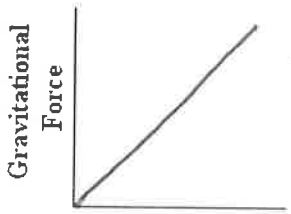
r = center to center radial separation

Formula

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

Graphical relationships





inverse square law:

$F_g \propto \frac{1}{r^2}$ $F_g \propto m_1$ or m_2

1. Calculate the gravitational force of attraction between a basketball and a bowling ball that are 1.50 meters apart.

$m = 0.62\ kg$ $m = 12.4\ kg$

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

$$\boxed{F_g = 2.3 \times 10^{-10}\ N}$$

2. Calculate the force holding the Moon in orbit around the Earth. pg 242 chart

$M_E = 5.97 \times 10^{24}\ kg$

$M_m = 7.35 \times 10^{22}\ kg$

$r = 382{,}500\ km$ → $F_g = \boxed{2.00 \times 10^{20}\ N}$

From book $r = 3.84 \times 10^8\ m$ → or $\boxed{1.98 \times 10^{20}\ N}$

3. a) Calculate the gravitational force of attraction between you and the Earth.

$$F_g = \frac{G M_E m}{(R_E)^2} = \frac{(6.67\times10^{-11}\ \frac{N m^2}{kg^2})(5.97\times10^{24}\ kg)(70.0\ kg)}{(6.37\times10^{6}\ m)^2}$$

$$= \boxed{687\ N}$$

b) For an object on or near the surface of a planet . . .

r = radius of the planet

c) What is another name for this force? Demonstrate this.

$F_g = mg \quad (70.0\ kg)(9.81\ \frac{m}{s^2}) = \boxed{687\ N}$

---

4. a) What is the gravitational force of attraction between a 60. kilogram student and the Earth if the student is in a plane at an altitude of 6.37×10^6 m?

$$F_g = \frac{G m_1 m_2}{(r_1 + r_2)^2} = \frac{G m_1 m_2}{(2R_E)^2} = \frac{1}{4} F_g = 147.15\ N$$

$$F_g = mg \quad (60\ kg)(9.81\ \frac{m}{s^2}) = 588.6\ N$$

b) When an object is above the surface of a planet . . . .

$r = R_p + \text{altitude}$ $\quad R_p$ = radius of planet

c) How could your answer to (a) be arrived at by proportional reasoning?

$$F_g \propto \frac{1}{r^2}$$