Answer **Key** **Standard III**

State Exam Review
Standard 3

1. Determine the weight of a 100 kg person using the Law of Universal Gravitation.

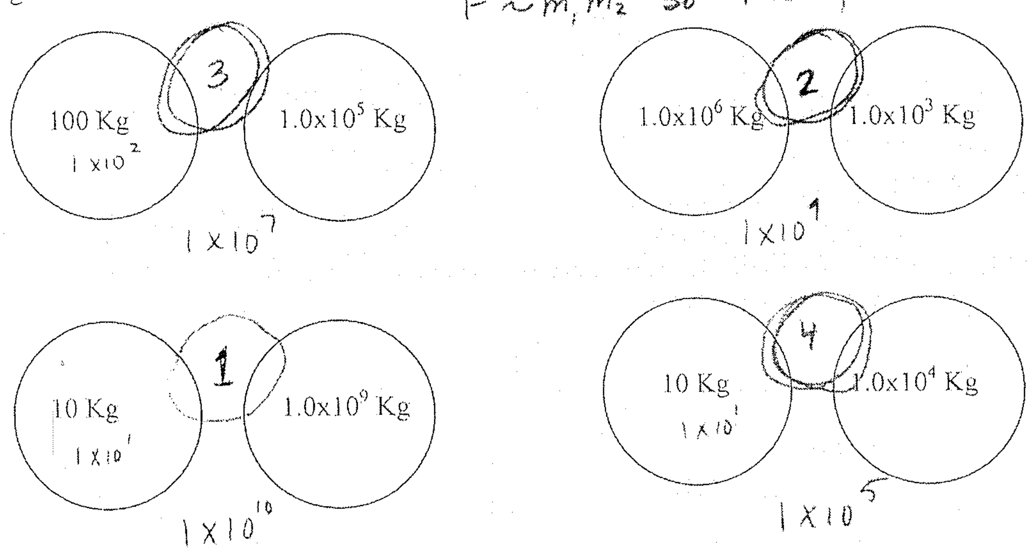
$m_1 = 100 kg$ $m_2 = 5.97 \times 10^{24} kg$ $d = 6.38 \times 10^6 m$

$$F = \frac{G m_1 m_2}{d^2} = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(100 kg)(5.97 \times 10^{24} kg)}{(6.38 \times 10^6 m)^2} = \cancel{980} N$$

980 N

2. Each pair of objects below are all the same distance apart, rank the pairs from the largest to the least gravitational interaction force.

$F \sim m_1 m_2$ so the pair with largest mass product will have the greatest attraction since the distance remains constant



3. An object on Earth has a mass of 500 kg. If that object is taken to a planet that has half as much mass as the Earth and the same volume, what will the mass of the object be on the new planet?

500 kg - mass does not change

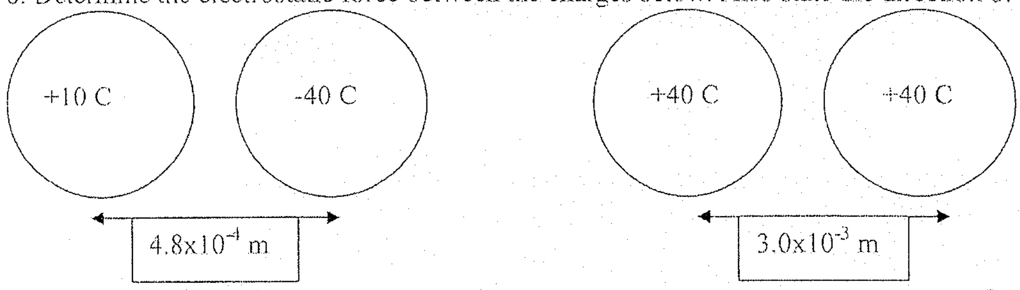
4. If an object has a weight of 100 N on Earth what will the weight of the object be on the new planet in question #3?

$F \sim \frac{m_1 m_2}{d^2}$ New Planet $\frac{\frac{1}{2} m m}{d^2} \sim \frac{1}{2} F$ $\frac{1}{2}(100 N) = 50 N$

5. If the Earth suddenly shrunk to half of its normal diameter and retained its original mass, how much heavier would you be?

$$F \sim \frac{m_1 m_2}{d^2} \; ; \quad \frac{m_1 m_2}{(\frac{1}{2} d)^2} \sim \frac{m_1 m_2}{\frac{1}{4} d^2} \sim 4F \quad \boxed{\text{4x Heavier}}$$

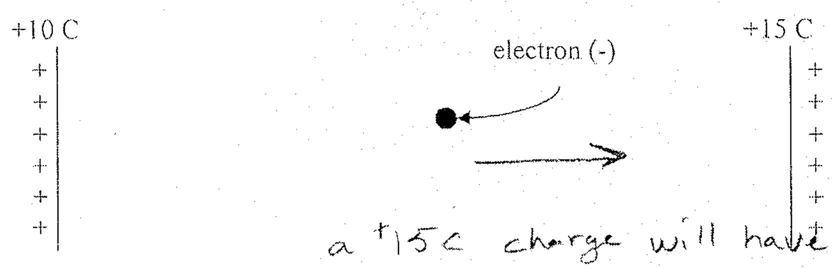
6. Determine the electrostatic force between the charges below. Also state the direction of the force.



$$F = \frac{k q_A q_B}{r^2} = \frac{(9 \times 10^9 \frac{Nm^2}{C^2})(10C)(40C)}{(4.8 \times 10^{-4} m)^2} = \boxed{1.56 \times 10^{19} N, \text{ attracting}}$$

$$F = \frac{(9 \times 10^9)(40)(40)}{(3 \times 10^{-3})^2} = \boxed{1.6 \times 10^{18} N, \text{ Repelling}}$$

7. An electron is positioned directly between two positively charged plates. Assuming the electron is directly in the middle of the two plates, which plate will it move towards?



a +15C charge will have a greater force of attraction on an electron than a +10 C charge if the distances are equal

GRAVITY Concepts

Concept-Development Practice Page **13-2**

Gravitational Interactions

The equation for the law of universal gravitation is

$$F = G\frac{m_1 m_2}{d^2}$$

where F is the attractive force between masses m_1 and m_2 separated by distance d. G is the universal gravitational constant (and relates G to the masses and distance as the constant π similarly relates the circumference of a circle to its diameter). By substituting changes in any of the variables into this equation, we can predict how the others change. For example, we can see how the force changes if we know how either or both of the masses change, or how the distance between their centers changes.

Suppose, for example, that one of the masses somehow is doubled. Then substituting $2m_1$ for m_1 in the equation gives

$$F_{NEW} = G\frac{2m_1 m_2}{d^2} = 2\left(G\frac{m_1 m_2}{d^2}\right) = 2F_{OLD}$$

So we see the force doubles also. Or suppose instead that the distance of separation is doubled. Then substituting $2d$ for d in the equation gives

$$F_{NEW} = G\frac{m_1 m_2}{(2d)^2} = G\frac{m_1 m_2}{4d^2} = \frac{1}{4}\left(G\frac{m_1 m_2}{d^2}\right) = \frac{1}{4}F_{OLD}$$

And we see the force is only 1/4 as much.

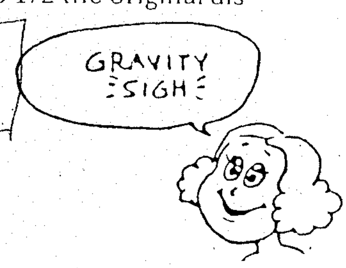
Use this method to solve the following problems. Write the equation and make the appropriate substitutions.

1. If both masses are doubled, what happens to the force?

$$F \sim \frac{2m_1 2m_2}{d^2} = \boxed{4F}$$

2. If the masses are not changed, but the distance of separation is reduced to 1/2 the original distance, what happens to the force?

$$F \sim \frac{m_1 m_2}{\frac{1}{2} d^2} = \frac{F}{\left(\frac{1}{2}\right)^2} = \boxed{4F}$$

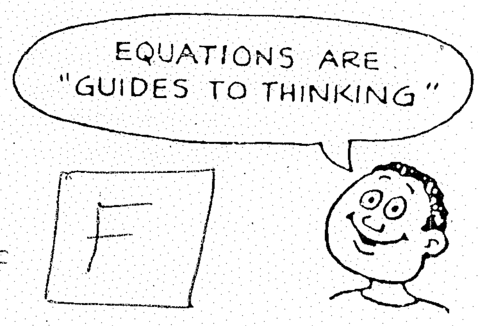


3

3. If the masses are not changed, but the distance of separation is reduced to 1/4 the original distance, what happens to the force?

$$F \sim \frac{m_1 m_2}{\frac{1}{4}d^2} = \frac{F}{\frac{1}{16}} = \boxed{16F}$$

4. If both masses are doubled, and the distance of separation is doubled, show what happens to the force.



$$F \sim \frac{2m_1 2m_2}{2d^2} = \frac{4F}{4} = \boxed{F}$$

5. If one of the masses is doubled, the other remains unchanged, and the distance of separation is tripled, show what happens to the force.

$$F \sim \frac{2m_1 m_2}{3d^2} = \frac{2F}{9} = \boxed{2/9\,F}$$

6. Consider a pair of binary stars that pull on each other with a certain force. Would the force be larger or smaller if the mass of each star were three times as great when their distance apart is three times as far? Show what the new force will be compared to the first one.

$$F \sim \frac{3m_1 3m_2}{3d^2} = \frac{9F}{9} = \boxed{1F \text{ same Force}}$$

Name: ______________________________

Skill Sheet 6.1 Mass and Weight

The mass of an object is a characteristic property and doesn't change unless the object changes. Weight is the result of gravitational attraction and depends on the strength of that attraction. You can calculate changes in weight based on changes in the force of gravity.

1. Mass, weight, and gravity

The key to these problems is to remember that gravity is a force that acts on mass. The result of that interaction is a force that we call weight. Mass is always measured in kilograms, but weight is measured in force units, or newtons.

This is yet another area of confusion within the English system of measurement because pounds are a force unit. Here is the conversion for pounds force to newtons.

$$1 \text{ pound} = 4.45 \text{ newtons}$$

The problem is that we also convert pounds into kilograms, the unit of mass. Here is the conversion for pounds weight to kilograms. You can see that the conversion constants are very similar numerically.

$$1 \text{ pound} = 0.454 \text{ kilograms}$$

It's essential to keep these units clear. For that reason, these skill problems will be done in International System units, newtons and kilograms. Weight in newtons is calculated by multiplying mass (in kilograms) by the acceleration of gravity. On Earth, the acceleration of gravity is 9.8 meters/second/second. On other planets, the acceleration of gravity is different.

Example:

What is the weight of a girl with a mass of 50 kilograms in a space station with an artificial gravity of 7 N/kg?

$$F_w = mg$$

$$F_w = 50 \text{ kg} \times 7 \text{ N/kg}$$

$$F_w = 350 \text{ N} = 78.6 \text{ pounds (force units)}$$

2. Mass and weight practice

1. Science fiction movies depict astronauts landing on large asteroids. The gravitational force of such bodies is typically less that 0.1 N/kg. Given an astronaut with a mass of 77.3 kilograms:

   a. What would his weight be on Earth (g = 9.8 N/kg) in newtons ~~and pounds (force)?~~

   $W = mg = (77.3)(9.8) = \boxed{757.5 \text{ N}}$

   b. What would his weight be on an asteroid (g = 0.08 N/kg) in newtons ~~and pounds (force)?~~

   $W = mg = (77.3)(0.08) = \boxed{6.18 \text{ N}}$

2. If you could embark on Jules Verne's *Journey to the Center of the Earth*, you would discover that the force of gravity would at first increase, as you got closer to the main mass of Earth. But then it would decrease as your progress left more mass behind you and less in front of you. Imagine now that you are very close to the center of Earth and the force of gravity has decreased to 0.001 N/kg. What would you weigh in newtons ~~and pounds (force)~~ if your mass were 52.0 kilograms?

$W = mg = (52.0)(0.001) = \boxed{0.052\ N}$

3. You are a typical young male with a mass of 68.4 kilograms. On Earth, you weigh 670 newtons, or 150.5 pounds (force). If you could survive, what would you weigh on the other planets and the sun? Express your answer in newtons ~~and pounds (force).~~

	Force of gravity	newtons	pounds
Sun	g = 274.4 N/kg	18768 N	omit
Mercury	g = 3.7 N/kg	253 N	
Venus	g = 8.9 N/kg	608.8 N	
Mars	g = 3.7 N/kg	253.1 N	
Saturn	g = 10.4 N/kg	711.4 N	
Uranus	g = 8.8 N/kg	602 N	
Neptune	g = 10.7 N/kg	731.9 N	
Pluto	g = 0.7 N/kg	47.9 N	

Name:

Skill Sheet 21.2 Coulomb's Law

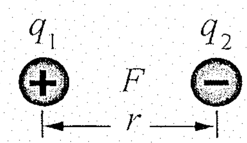
In this skill sheet, you will work with Coulomb's law. There are many similarities and some differences between the equation of universal gravitation and the equation for Coulomb's law. They are both inverse square law relationships, and they both have similar arrangements of variables.

1. Introduction to Coulomb's law

When two charges q_1 and q_2 are separated by a distance r, there exists a force between them that is given by:

Coulomb's law

$$\underbrace{F}_{\text{Force (N)}} = \underbrace{K}_{\text{Constant } (9\times10^9 \text{ N m}^2/\text{C}^2)} \frac{\overbrace{q_1 q_2}^{\text{Charges (C)}}}{\underbrace{r^2}_{\text{Distance (m)}}}$$



where F equals the force in newtons and K is a constant equal to 9×10^9 N-m²/C². The units of q_1 and q_2 are the coulombs (C). Distance is given in meters. Here are a few important points about the relationships of the variables in Coulomb's law.

1. Force is inversely proportional to the square of the distance between the charges. Therefore, if the distance increases by a factor of 2, the force decreases by a factor of 4.
2. Force is proportional to the strength of each charge.
3. When the two charges have the same sign (positive or negative), the force between them is repulsive because like charges repel.
4. When the charges have opposite signs, the force between them is attractive because unlike charges attract.

2. Problems : These are relationship problems. Do Not use K

1. What happens to the force between two charges if the distance between them is tripled?

$F \sim \frac{q_1 q_2}{3^2} = \boxed{1/9\,F}$

2. What happens to the force between two charges if the distance between them is quadrupled?

$F \sim \frac{q_1 q_2}{4^2} = \boxed{1/16\,F}$

3. What happens to the force between two charges if the distance between them is cut in half?

$F \sim \frac{q_1 \cdot q_2}{(1/2)^2} = \frac{F}{\frac{1}{4}} = \boxed{4F}$

4. What happens to the force between two charges if the magnitude of one charge is doubled?

$F \sim \frac{2q_1 q_2}{d^2}$ $\boxed{2F}$

5. What happens to the force between two charges is the magnitude of both charges is doubled?

$F \sim \frac{2q_1 2q_2}{d^2} = \boxed{4F}$

Standard 3: Practice Multiple Choice

26 C 1. According to Newton's law of universal gravitation, the force of attraction between any two masses is *directly related* to the:

A) velocity of the two masses
B) distance between the masses
C) product of the two masses
D) sum of the two masses

27 B 2. As the distance between two objects increases, the force of attraction between the two objects:

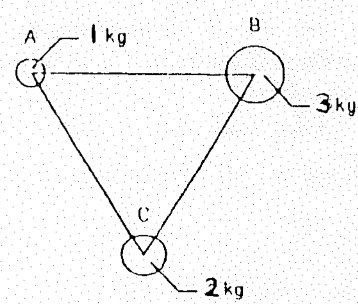
A) increases
B) decreases
C) remains the same

28 C 3. Astronauts in an orbiting space shuttle experience a sensation of weightlessness because:

A) the space shuttle is not affected by Earth's gravity
B) the space shuttle is moving away from Earth
C) the space shuttle is falling freely toward Earth
D) the mass of the space shuttle decreases as the distance from Earth increases.

A 4. The pair of spheres that experiences the greatest force of attraction is:

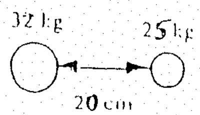
A) **B** and **C**
B) **A** and **B**
C) **A** and **C**

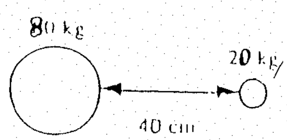


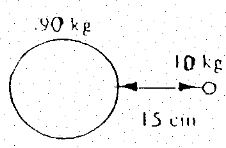
30 A 5. The attractive force between two objects is a measure of:

A) gravitational mass
B) orbital velocity
C) radius of the object
D) universal gravitational constant

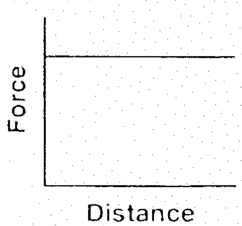
C 6. Which of the pairs of masses below will have the greatest force of attraction between the spheres?

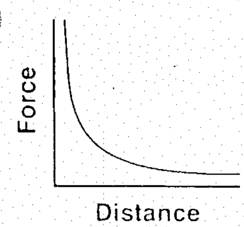
A) 

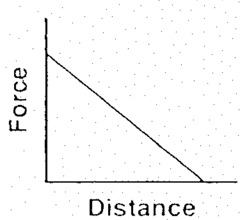
B) 

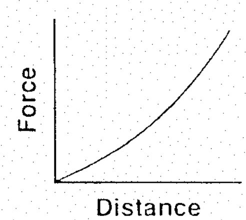
C) 

B 7. A space probe is launched into space from Earth's surface. Which graph represents the relationship between the magnitude of the gravitational force exerted on Earth by the space probe and the distance between the space probe and the center of Earth?

A) 

B) 

C) 

D) 

A 8. A distance of 1.0 meter separates the centers of two small charged spheres. The spheres exert gravitational force F_g and electrostatic force F_e on each other. If the distance between the spheres' centers is increased to 3.0 meters, the gravitational force and electrostatic force, respectively, may be represented as

A) $\frac{F_g}{9}$ and $\frac{F_e}{9}$

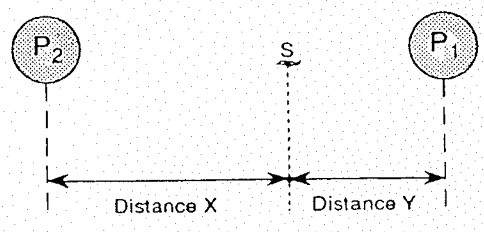
B) $\frac{F_g}{3}$ and $\frac{F_e}{3}$

C) $3F_g$ and $3F_e$

D) $9F_g$ and $9F_e$

B 9. Base your answer to the following question on the information and diagram below.

Spacecraft S is traveling from planet P_1 toward planet P_2 At the position shown, the magnitude of the gravitational force of planet P_1 on the spacecraft is equal to the magnitude of the gravitational force of planet P_2 on the spacecraft.



(not drawn to scale)

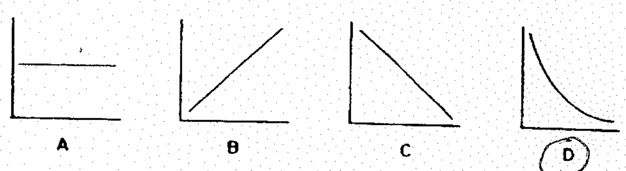
As the spacecraft moves from the position shown toward planet P_2 , the ratio of the gravitational force of P_2 on the spacecraft to the gravitational force of P_1 on the spacecraft will

A) decrease B) increase
C) remain the same

A 10. Two point masses are located a distance, *D*, apart. The gravitational force of attraction between them can be quadrupled by changing the distance to

A) *D*/2 B) 2*D* C) 1/4 *D* D) 4*D*

D 11. Base your answer to the following question on the graphs below which represent various phenomena in physics. [Note: A graph may be used more than once.]



Which graph best represents the relationship between gravitational force and distance from the Earth for an object traveling away from the Earth?

A) *A* B) *B* C) *C* D) *D*

D 12. Two bodies attract each other with a gravitational force of 10.0 Newtons. What will be the force of attraction if the mass of each body is doubled?

A) 5 N B) 10 N C) 20 N D) 40 N