Question:

The effects of gravity from a mass

a. extend infinitely far out in space, in all directions
b. are zero for very small masses like atoms
c. can be blocked by hiding behind a sufficiently large mass
d. can be blocked by hiding inside a sufficiently large mass
e. can be reduced by traveling at a sufficiently fast speed.

Answer:

The correct answer is ***a***. It's true that the effects of gravity are reduced at distances that are very great from the mass supplying the gravity, but they do extend out, infinitely.

In many situations, the effects of gravity are so small that we consider them to be negligible. The electric force of repulsion acting between two electrons is far stronger than the force of gravitational attraction between them, so we wouldn't consider gravity's effect when considering that situation.

When masses become large enough, however, their gravitational effects become plain to see, whether it's the moon orbiting the earth, the moon pulling on the ocean creating tides, or the creation of an entire galaxy of stars.

Question:

The Force of gravity acting between the Earth and any other object decreases at a rate proportional to the inverse-square of the distance between their centers of mass. What other quantities decrease according to an inverse-square relationship?

a. Sound intensity as you move away from a source of sound
b. Light intensity as you move away from a source of light
c. Electric fields as you move away from an electric charge
d. Neither *a*, *b*, nor *c* exhibit an inverse-square relationship.
e. Choices *a*, *b*, and *c* all exhibit an inverse-square relationship.

Answer:

The correct answer is *e*. In all of these situations, the strength of the effect decreases as the area of the effect increases.

There is a geometric reason for these inverse-square laws. Because spherical Area increases with the square of the distance for any point source ($A_{sphere} = 4\pi r^2$), the effect distributed over that area becomes less concentrated with the square of the distance.

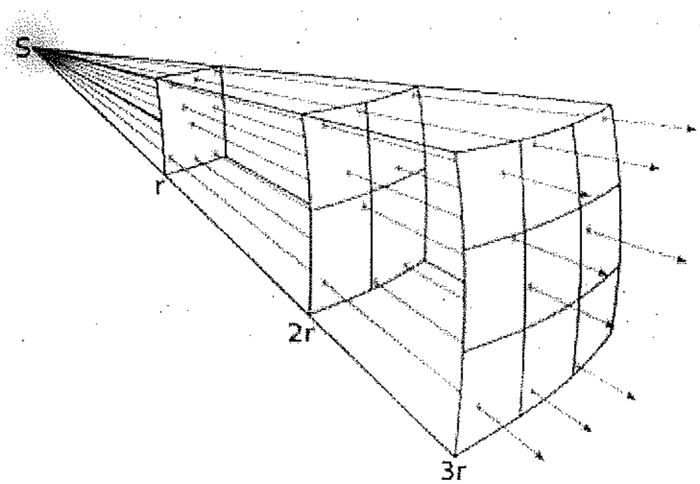


Image via Wikipedia, courtesy of Borb.

Question:

Gravitational Force Calculation

What is the magnitude of the gravitational force that acts on two masses assuming $m_1 = 12$ kg (approximately the mass of a bicycle) and $m_2 = 25$ kg, at a distance of 1.2 m between their centers?

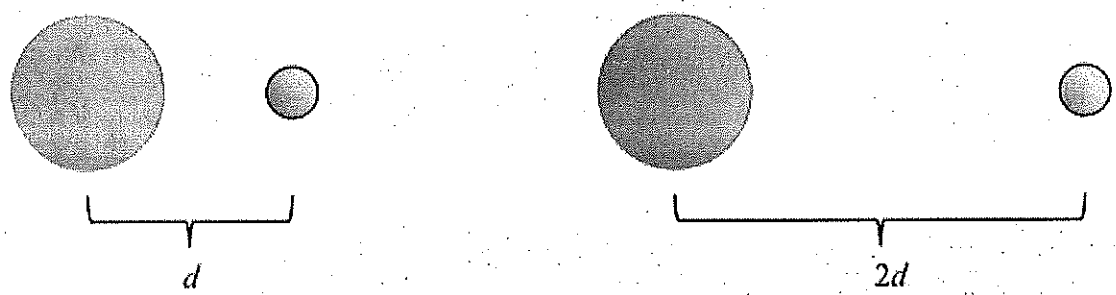
Answer:

Reasoning and Solution The magnitude of the gravitational force can be found using:

$$F = G\frac{m_1 m_2}{r^2} = \left(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\frac{(12\ \text{kg})(25\ \text{kg})}{(1.2\ \text{m})^2} = \boxed{1.4\times10^{-8}\ \text{N}}$$

For comparison, you exert a force of about 1 N when pushing a doorbell, so that the gravitational force is exceedingly small in circumstances such as those here. This result is due to the fact that G itself is very small. However, if one of the bodies has a large mass, like that of the earth (5.98×10^{24} kg), the gravitational force can be large.

Question:



A satellite orbits the earth at a certain distance, and is kept in orbit by the force of the earth's gravity. When this same satellite is moved to a location that is twice as far away from the earth

a. the force of gravitation attraction between the satellite and the earth is doubled.
b. the force of gravitation attraction between the satellite and the earth is halved.
c. the force of gravitation attraction between the satellite and the earth is quadrupled.
d. the force of gravitation attraction between the satellite and the earth is decreased by a factor of 4.
e. the force of gravitation attraction between the satellite and the earth is unchanged.

Answer:
The correct answer is ***d***. The force of gravitational attraction between the earth and the satellite is described by Newton's Law of Universal Gravitation:

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

Because the distance r between the two masses is in the denominator and squared, this law is called an *inverse-square law*. If r is doubled, we can see that r^2 is increased by a factor of 2^2, or 4. And because this term is in the denominator, the force is *decreased* by this factor:

$$F_{original} = G\frac{m_{earth} m_{satellite}}{r^2}$$

$$F_{new} = G\frac{m_{earth} m_{satellite}}{(2r)^2} = G\frac{m_{earth} m_{satellite}}{4r^2}$$

$$F_{new} = \left(\frac{1}{4}\right)G\frac{m_{earth} m_{satellite}}{r^2} = \frac{1}{4}F_{original}$$

Question:

A student stands on a scale, and the indicator on the scale reads "75 kg". Which statement is most correct?

a. The student has a *weight* of 75 kilograms.
b. The student has a *mass* of about 750 Newtons.
c. The student has a *weight* of about 750 pounds.
d. The student has a *mass* of about 165 pounds.
e. The student has a *mass* of 75 kilograms.

Answer:

The correct answer is *e*. The student has a *mass* of 75 kilograms, which can also be converted to a *weight* (due to the Force of gravity) of about 750 Newtons, which is also a *weight* of 165 pounds.

$$F_{gravity} = W = mg$$
$$9.8N = (1.00kg)(9.8m/s^2)$$
$$2.20\,pounds = 1.00kg$$

Remember that *mass* is a measure of "how much matter" there is in an object. Mass can be measured with a spring scale that has been correctly calibrated for a given location (like the surface of the earth), but that spring scale won't work at other locations, say on a high mountain top, or out in space. Spring scales measure *forces*, the force of gravity due to the earth varies with location. *Mass* is more correctly measured by comparing the mass of an unknown object with the a known mass, using a *balance*.

Question:

Based on the results of his experiments involving gravity, Henry Cavendish made it possible to calculate

I. the mass of the Earth.
II. a value for the gravitational force between any two masses.
III. a value for the gravitational field strength at any point from the Earth's center.

a. I only
b. II only
c. III only
d. I and II only
e. I, II and III

Answer:

e.

Question:

Two objects of equal mass, m_1 and m_2, are separated by a distance r, and experience a force of gravitational attraction as described by Newton's Law of Universal Gravitation. When the mass of m_2 is doubled

a. the force of attraction acting on both objects is doubled.
b. the force of attraction acting on m_1 only is doubled.
c. the force of attraction acting on m_2 only is doubled.
d. the force of attraction acting on both objects is increased by a factor of four.
e. the force of attraction acting on both objects is halved.

Answer:

The correct answer is ***a***. The force of attraction between the two objects is doubled according to Newton's Law of Universal Gravitation, $F = G\frac{m_1 m_2}{r^2}$. The force of gravitational attraction acts on both objects— m_1 pulls on m_2 and m_2 pulls on m_1 as force pairs described by Newton's Third Law of Motion.

Question:
An astronaut in a space shuttle that is orbiting the earth releases an apple that floats in space. Which statement is true?

a. The apple experiences no gravitational attraction from the earth—it is weightless.
b. The apple experiences no gravitational attraction from the earth—it is shielded by the space shuttle.
c. The apple experiences a gravitational attraction from the earth, but this force is cancelled by the apple's force of attraction on the earth.
d. The apple experiences a gravitational attraction from the earth, but the force is very small.
e. none of the above statements are true.

Answer:
The correct answer is *e*. Newton's Law of Universal Gravitation describes the force of gravitational attraction between any two masses separated by a distance. As the distance increases, the force decreases, but it is still there.

In this particular example, the force of gravitational attraction between the apple and the earth *has* diminished—it is farther away from the center of the earth—but is still rather significant. (At an orbital altitude of 1000 kilometers above the earth's surface, the acceleration due to gravity is still 7.3 m/s^2.)

So why don't astronauts see an apple fall when released in the space shuttle? The apple is accelerating toward the earth at the same rate that the shuttle itself is—both objects are falling toward the earth as they orbit.

Question:

To launch a spaceship from the earth, an escape velocity of v_{escape} is necessary. For that same spaceship to launch from Saturn, with a radius approximately 10 times that of the Earth, and a mass approximately 100 times that of the Earth, what escape velocity is required?

a. $\dfrac{\sqrt{10}}{v_{escape}}$

b. $\sqrt{10}\ v_{escape}$

c. $10\ v_{escape}$

d. $\dfrac{v_{escape}}{10}$

e. $1000\ v_{escape}$

Answer:

The correct answer is *b*. The relationship between escape velocity, mass, and radius can be derived using conservation of energy:

$$U + K = 0$$

$$\frac{-GMm}{r} = \frac{1}{2}mv^2$$

$$v_{escape} = \sqrt{\frac{2GM}{r}}$$

Now we can use values given in the problem to determine the Saturn escape velocity as a function of v_{escape}:

$$v_{escape}' = \sqrt{\frac{2G(100M_{earth})}{(10r_{earth})}} = \sqrt{10}\ v_{escape}$$

Question:

Newton's Law of Universal Gravitation states that

a. There is a force of gravitational attraction between all objects that have mass.
b. The force of gravity can act both as an attraction and as a repulsion.
c. Masses have the effect of distorting space-time in their vicinity.
d. The force of gravity between two masses increases in direct proportion to the distance between them.
e. The force of gravity between two masses increases in direct proportion to the square of the distance between them.

Answer:

The correct answer is ***a***. Newton's Law of Universal Gravitation, published in his groundbreaking *Philosophiae Naturalis Principia Mathematica* in 1687, is summarized in this mathematical expression:

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

The equation states that the Force of gravitational attraction between any two masses is dependent upon, and proportional to, the masses of the two objects, m_1 and m_2. It is also inversely proportional to the square of the distance between the two objects, r.

It has been suggested that Newton stumbled upon the idea of an attractive Force between masses by considering the accelerations of an apple falling near the surface of the earth, and the centripetal acceleration of the moon as it "falls" toward the center of the earth that it circles. Even as he worked to develop a form of the expression above that satisfactorily offered evidence of the factors affecting gravitational attraction, Newton was uncomfortable with the idea that a gravitational force could act "at a distance" through space.

Question:

The planet Mars exerts a gravitational force F_{Mars} on its moon Phobos. Phobos, which has a smaller mass than Mars, also exerts a gravitational force F_{Phobos} on Mars. Which one of these statements is true?

a. $F_{\text{Mars}} > F_{\text{Phobos}}$
b. $F_{\text{Phobos}} > F_{\text{Mars}}$
c. $F_{\text{Mars}} = F_{\text{Phobos}}$
d. Which one attracts more strongly depends on the distance between the two bodies.
e. Which one attracts more strongly depends on how close Mars's second moon, Deimos, is located.

Answer:

The correct answer is *c*. The force of gravitational attraction between any two masses is equal, and given by $F = G\frac{m_1 m_2}{r^2}$.

The magnitude of this force varies with distance *r*, of course, but at any given distance, the forces between the two bodies are equal. And while the presence of the second moon will affect the *net* force of gravitational attraction acting on a body, it doesn't change the force exerted by a different body.

Question:
At the surface of a planet with radius R, a mass experiences a gravitational acceleration *g*. At a height of 3R above the surface of the planet, the gravitational acceleration is:

a. $\frac{g}{3}$

b. $3g$

c. $\frac{g}{9}$

d. $9g$

e. $\frac{g}{16}$

Answer:
The correct answer is *e*. The acceleration due to gravity for a mass M can be determined using Newton's Law of Universal Gravitation:

$$F_g = G\frac{Mm}{r^2}$$

$$mg = G\frac{Mm}{r^2}$$

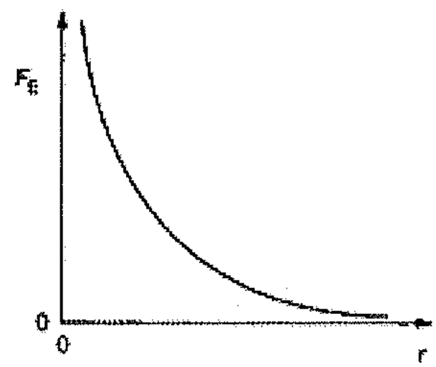
$$g = G\frac{M}{r^2}$$

For the mass at the planet's surface, $g_R = G\frac{M}{R^2}$, where r is the distance between the mass's location and the center of the planet. For the mass above the planet's surface, the acceleration is $g_{4R} = G\frac{M}{(4R)^2} = G\frac{M}{16R^2} = \frac{1}{16}g_R$.

Question:

Newton's law of gravity between two interacting objects is expressed with the equation given below. If the masses of the two interacting objects are held constant, then the graph to the right below shows how the force of gravity between the two objects changes as a function of distance.

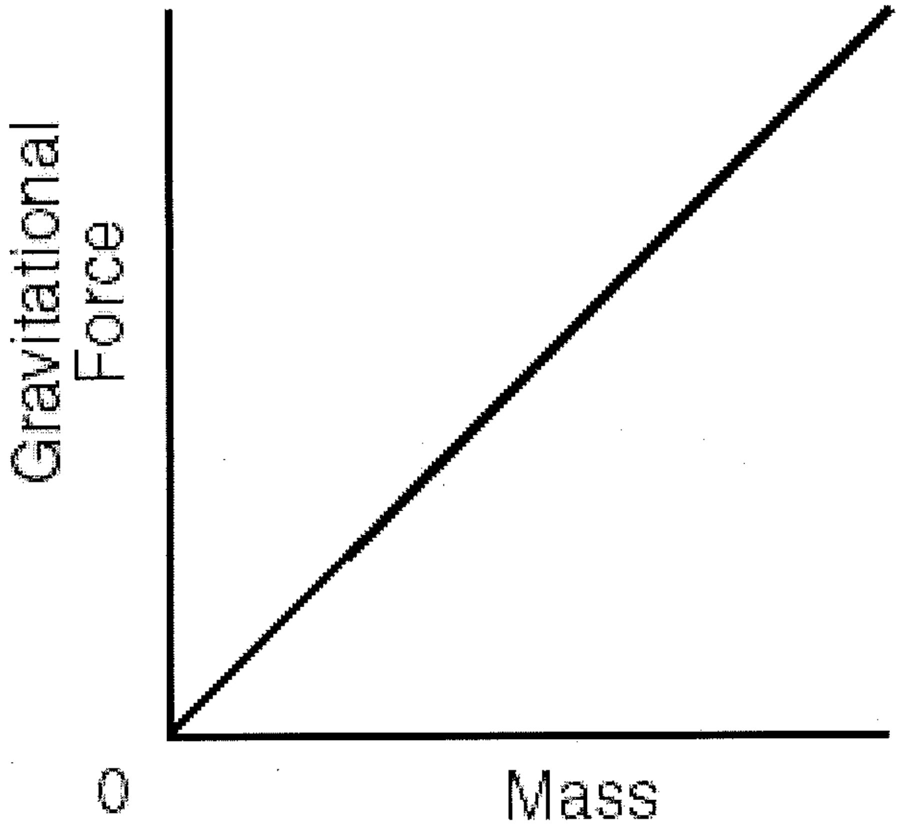
$$F_g = G\frac{m_1 m_2}{r^2}$$



Suppose instead of the situation given above, the distance between the two interacting objects is held constant and the mass of one of the objects changes.

In the space below, draw the graph that represents how the gravitational force between the two objects changes as a function of mass for this second situation.

Graph of gravitational force vs mass



Question:

Which of the following is correct when evaluating the gravitational force between two masses?

I. **The gravitational force between two masses increases as the masses of the objects increase.**

II. **The gravitational force between two masses increases as the distance between the masses increases.**

III. **The gravitational force between two masses is <u>always</u> an attractive force and <u>never</u> a repulsive force.**

a. I only
b. II only
c. III only
d. I and III
e. I, II and III

Answer:

d.

Question:

In his experiments involving gravity, Henry Cavendish designed an apparatus to measure

I. **the acceleration due to gravity *g* .**
II. **a value for the universal gravitational constant *G*.**
III. **the value for the gravitational force between two small spheres.**

a. I only
b. II only
c. III only
d. II and III
e. I, II and III

Answer:

c.

Question:

Identify which Kepler's law describes each of the following:

1. A planet moves fastest in its orbit at *perihelion.*
2. The sun is located at one *foci* of a planet's elliptical orbit.
3. The *orbital period* of a planet increases with increasing *orbital radius*.

a. 1. 1st Law 2. 2nd Law 3. 3rd Law
b. 1. 2nd Law 2. 3rd Law 3. 1st Law
c. 1. 3rd Law 2. 1st Law 3. 2nd Law
d. 1. 3rd Law 2. 1st Law 3. 2nd Law
e. 1. 2nd Law 2. 1st Law 3. 3rd Law

Answer:

e. 1. 2nd Law 2. 1st Law 3. 3rd Law

Question:

A satellite of mass m is in a circular orbit about the earth (mass = M) at a height h above the surface, where $h = r$, the radius of the earth. What velocity should this satellite have in order to maintain its orbit?

a. $v = \sqrt{\frac{GM}{r}}$

b. $v = \frac{GM}{2r}$

c. $v = \sqrt{\frac{GM}{2r}}$

d. $v = \sqrt{\frac{GMm}{2r}}$

e. $v = \frac{\sqrt{GM}}{2r}$

Answer:

The correct answer is *c*. The centripetal force that keeps the satellite in orbit about the earth is supplied by the force of earth's gravity.

$$F_c = \frac{mv^2}{r}$$

$$F_g = G\frac{mM}{r^2}$$

$$G\frac{mM}{r^2} = \frac{mv^2}{r}$$

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

Because the satellite is located one earth radius above the surface,

$$r_{satellite} = h + r = 2r$$

$$v = \sqrt{\frac{GM}{2r}}$$

Question:

Two massive objects are separated by a certain distance, and experience a force of gravitational attraction between them. If the mass of both objects is doubled and the distance between them is doubled, the new force of gravitational attraction between the objects is

a. the same as it was before.
b. twice what it was before.
c. four times what it was before.
d. half of what it was before
e. one-fourth of what it was before.

Answer:

The correct answer is ***a***. Doubling the mass of each object increases the gravitational force by $2 \times 2 = 4$, but doubling the distance between them decreases the gravitational force by a factor of 4. Thus, the net Force is unchanged.

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

$$F_{new} = G\frac{2m_1 2m_2}{(2r)^2} = G\frac{4m_{earth}m_{satellite}}{4r^2} = G\frac{m_1 m_2}{r^2}$$

Question:

Which statement is correct concerning concepts of gravity?

I. Cavendish was able to determine an experimental value for the acceleration due to gravity *g*.
II. An object's weight and the gravitational force acting on it are equal.
III. The gravitational field strength and the acceleration due to gravity are two terms used to represent the same quantity.

a. I only
b. II only
c. I and II
d. II and III
e. I, II and III

Answer:

d.

Question:

The mass of the planet Saturn is approximately one hundred times the Earth's mass, and its radius is approximately ten times greater than the Earth's radius. An object that has a weight *W* at the surface of the earth would have what weight at Saturn's surface?

a. 0

b. W

c. $10W$

d. $100W$

e. $\frac{W}{10}$

Answer:

The correct answer is *b*. The weight of an object is simply the force of gravity exerted on that object, and can be calculated using Newton's Law of Universal Gravitation $F_g = G\frac{Mm}{r^2}$. Here, we the Weight of the object at the earth's surface is simply:

$$W = G\frac{M_{earth}m_{object}}{r_{earth}^2}$$

We can get the weight of the object on Saturn by substituting in the appropriate values given:

$$W_{Saturn} = G\frac{M_{Saturn}m_{object}}{r_{Saturn}^2} = G\frac{100(M_{Earth})m_{object}}{(10r_{Earth})^2} = W_{Earth}$$

Question:

The earth has a radius of approximately 6000 km. A 600 Newton astronaut, orbiting the earth at an altitude of 12000 km above the surface, has a weight of approximately:

a. 300 N
b. 33 N
c. 200 N
d. 67 N
e. 150 N

Answer:

The correct answer is *d*. The force of earth's gravity varies with the inverse square of the distance between the centers of mass for the two objects. In this case, the astronaut is three times farther away from the center of the earth, so the weight is $\frac{1}{3^2} = \frac{1}{9}$ of the originial.

$$\frac{600N}{9} = 67N$$

Using Newton's Law of Universal Gravitation more formally:

$$F_g = G\frac{Mm}{r^2}$$

$$600N = G\frac{M(60kg)}{r_{earth}^2}$$

$$F_{g-final} = G\frac{M(60kg)}{(3r_{earth})^2}$$

$$F_{g-final} = \frac{r_{earth}^2}{(3r_{earth})^2}600N = 67N$$

Question:

Earth and Jupiter both travel in a roughly circular orbit around the sun. Jupiter's orbit is approximately 5 times the radius of the Earth's orbit. What is the approximate relationship between the centripetal acceleration of each planet?

a. $a_{Earth} = a_{Jupiter}$
b. $a_{Earth} = 5\ a_{Jupiter}$
c. $a_{Earth} = 25\ a_{Jupiter}$
d. $a_{Jupiter} = 5\ a_{Earth}$
e. $a_{Jupiter} = 25\ a_{Earth}$

Answer:

The correct answer is *c*. The centripetal acceleration of each planet is driven by the force of gravity, and the acceleration of a planet can be calculated as follows:

$$F_g = G\frac{Mm}{r^2}$$

$$F_g = ma_g$$

$$ma_g = G\frac{Mm}{r^2}$$

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

We can see that acceleration due to gravity is inversely proportional to the square of the radius. Jupiter, with its radius 5 times that of the Earth, has $1/5^2$, or $1/25$, the acceleration of the Earth. This relationship is consistent with answer *c*.

Question:
In a science fiction story, a planet has half the radius of the Earth, but the same mass as the earth. What is the acceleration due to gravity at the surface of this planet as a function of **g**?

a. **4g**
b. **2g**
c. **g**
d. $\frac{1}{2}$**g**
e. $\frac{1}{4}$**g**

Answer:
The correct answer is ***a***. The acceleration due to gravity can be determined using Newton's Law of Universal Gravitation:

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

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

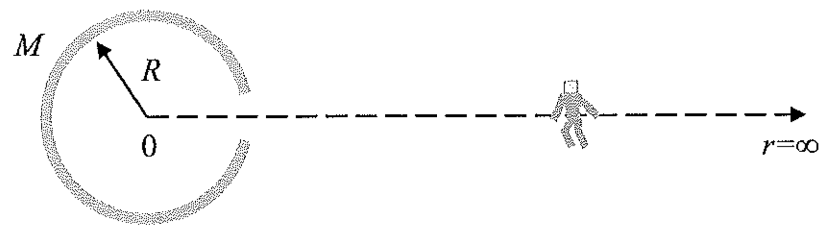
$$\mathbf{g} = \frac{Gm_{earth}}{r^2}$$

Now, determine $a_{gravity}$ for the new planet:

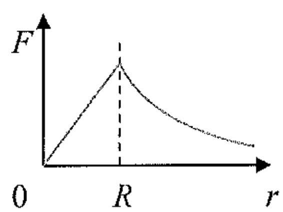
$$a_g = \frac{Gm_{planet}}{r_{planet}^2} = \frac{Gm_{earth}}{\left(\frac{1}{2}r_{earth}\right)^2} = \frac{4Gm_{earth}}{r_{earth}^2}$$

$$a_g = 4\mathbf{g}$$

Question:



A large, massive, satellite is hollow, with all of its mass *m* located at a radius R from its center, as shown above. Which graph best represents the Force of gravity experienced by an astronaut at a distance *r* from the center of the satellite, where *r* goes from 0 to ∞?

a.


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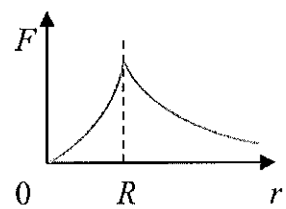

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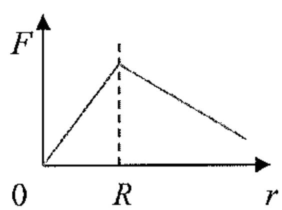
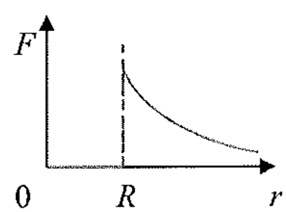
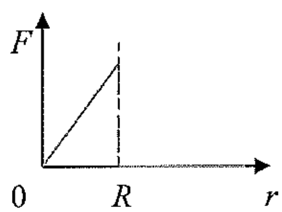


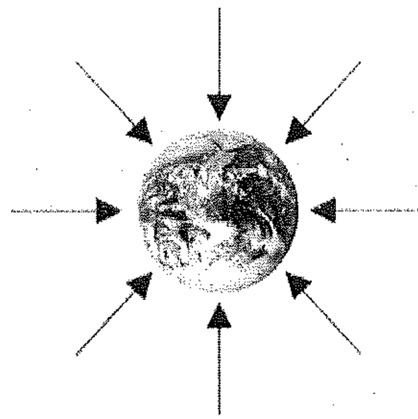
d.


e.


Answer:
The correct answer is *d.* Outside the satellite, its force of gravity acts on the astronaute as an inverse-square law, as if the mass were all located at the center-of-mass. Inside the satellite, the gravitational effects of the distribution of mass add up to produce a net gravitational force of 0 on the astronaut.

Question:

In the vicinity of the earth, objects experience a force of gravitational attraction toward the center of the earth. Which of the following statements is true?



a. The force of gravity is proportional to the square of the distance between the object and the earth's center.
b. The force of gravity acting on the object doesn't depend on the object's mass.
c. If there is no object to experience a force of gravity, then the earth has no gravity field.
d. The earth and the object both create their own gravity fields.
e. The earth's force of gravity on the object is greater than the object's force of gravity on the earth.

Answer:

The correct answer is ***d***. All objects with mass influence the space around them, and create a gravity field. Objects in the gravity field experience a force of gravitational attraction toward the center of mass of the source of gravity field.

It's important to realize although we can talk about the force of gravity acting on an object in a gravity field, the gravity field due to a mass continues to exist, even if there's no object there to experience a force. The idea of a *field* allows us to draw lines like those in the diagram above so that we can picture the effect that the field has, even when not specifically considering a moon, or an apple, or any other mass that might be in the field.

Question:

Which of the following is the correct order of Kepler's Laws for the following planetary features?

1. **A planet's velocity changes as it orbits the sun.**
2. **The shape of the planet's orbits are not circular, but elliptical.**
3. **A planet's orbital period is related to its average distance from the sun.**

a. 1^{st} Law, 2^{nd} Law, 3^{rd} Law
b. 1^{st} Law, 3^{rd} Law, 2^{nd} Law
c. 3^{rd} Law, 2^{nd} Law, 1^{st} Law
d. 2^{nd} Law, 1^{st} Law, 3^{rd} Law
e. None of the above

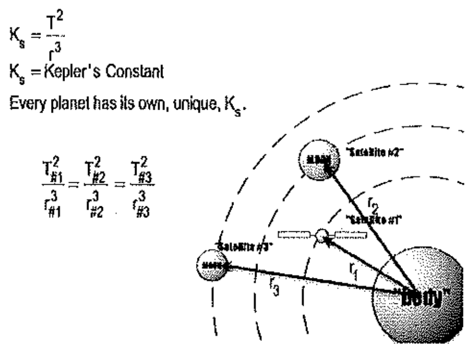
Answer:

d.

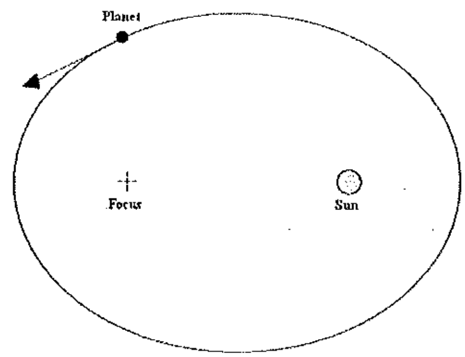
Question:

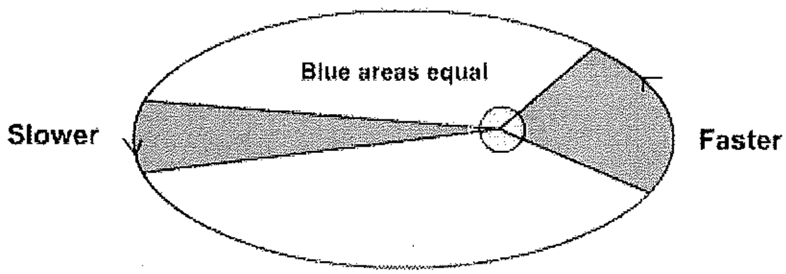
Examine the diagrams below. Match each with the Kepler law that correctly represents it.

a.



b.





c.

Answer:

a. Kepler's 3[rd] Law **b. Kepler's 1[st] Law** **c. Kepler's 2[nd] LAw**

Question:

Which statement regarding Kepler's laws of planetary motion is correct?

I. The planets move in circular orbits around the Sun.
II. A planet's speed is greatest at *aphelion* and least at *perihelion*.
III. The square of a planet's orbital period is proportional to the cube of its average distance from the Sun.

a. I only
b. II only
c. III only
d. II and III
e. I, II and III

Answer:

c.