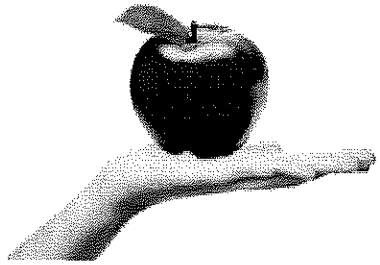
Question:

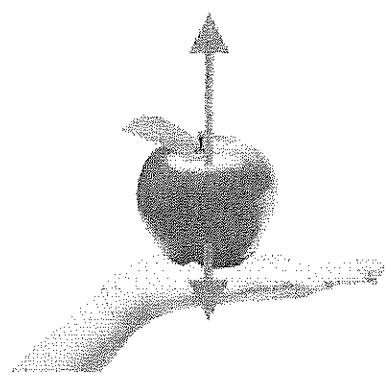


A 0.50-kilogram apple has a weight of about 5 N. A hand holding the apple lifts it upwards, applying a force of 15 N. The acceleration of the apple is about

a. 30 m/s^2 upwards
b. 20 m/s^2 upwards
c. 10 m/s^2 upwards
d. 5 m/s^2 upwards
e. 10 m/s^2 downwards

Answer:

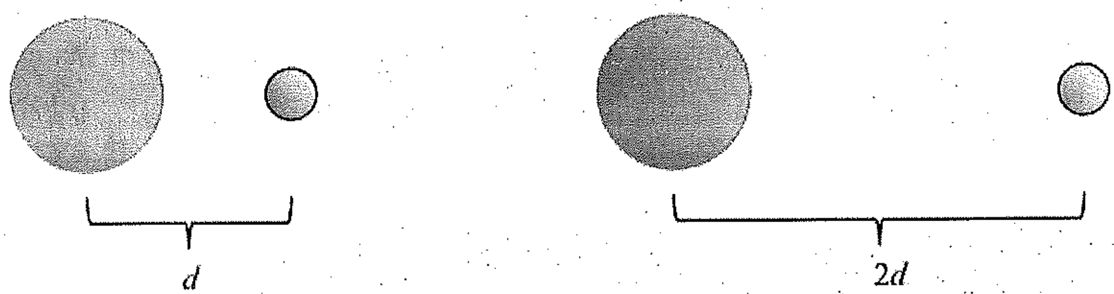
The correct answer is ***b***. The acceleration of the apple can be determined by drawing a free-body diagram, and using Newton's Second Law, and considering the ***net*** (overall) Force acting on the apple.



$$\sum F = ma$$
$$F_{hand} - F_{gravity} = ma$$
$$15N - 5N = (0.50kg)(a)$$
$$a = \frac{10N}{0.5kg} = 20m/s^2$$

Note that the upward Force from the hand is often called the "Normal" force, a term which may be used for any kind of supporting force from a surface. "Normal" in this context means "perpendicular", which is appropriate because the supporting force is oriented perpendicular to the surface.

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:

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:

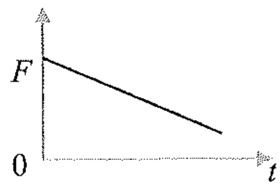
$$F = G\frac{m_1 m_2}{r^2} = \left(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\frac{(12\ \text{kg})(25\ \text{kg})}{(1.2\ \text{m})^2} = \boxed{1.4 \times 10^{-8}\ \text{N}}$$

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.

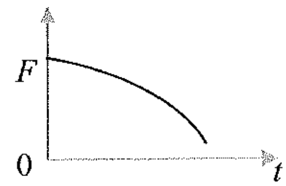
Question:

As part of an experiment, an astronaut in space releases two massive spheres such that they float near each other, initially motionless. Which graph best represents the force of gravitational attraction between the two spheres as a function of time?

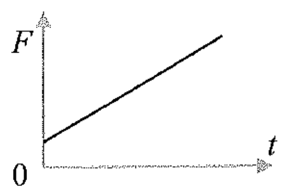
a.



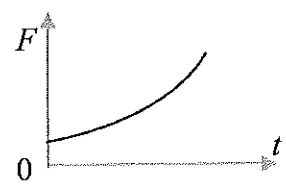
b.



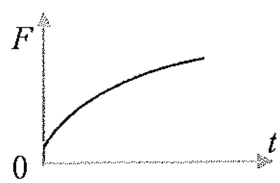
c.



d.



e.



Answer:
The correct answer is *d*. As the two spheres move closer to each other, the force of their gravitational attraction will increase. This force increases as the inverse-square of the distance, causing the spheres to accelerate toward each other at an increasing rate.

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.

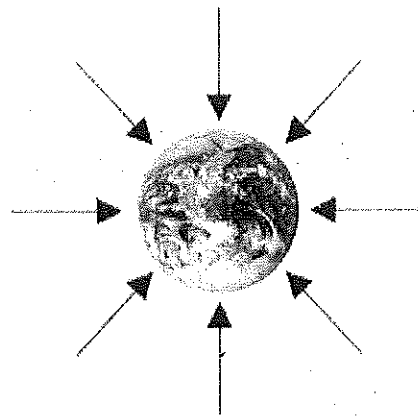
Answer:

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:

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:

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 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:

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:

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

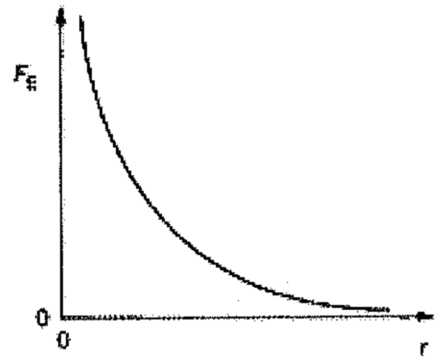
The equation states that the Force of gravitational attraction between any two masses is dependent upon, and proportional to, the masses of the two objects, m_1 and m_2. It is also inversely proportional to the square of the distance between the two objects, r.

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:

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.

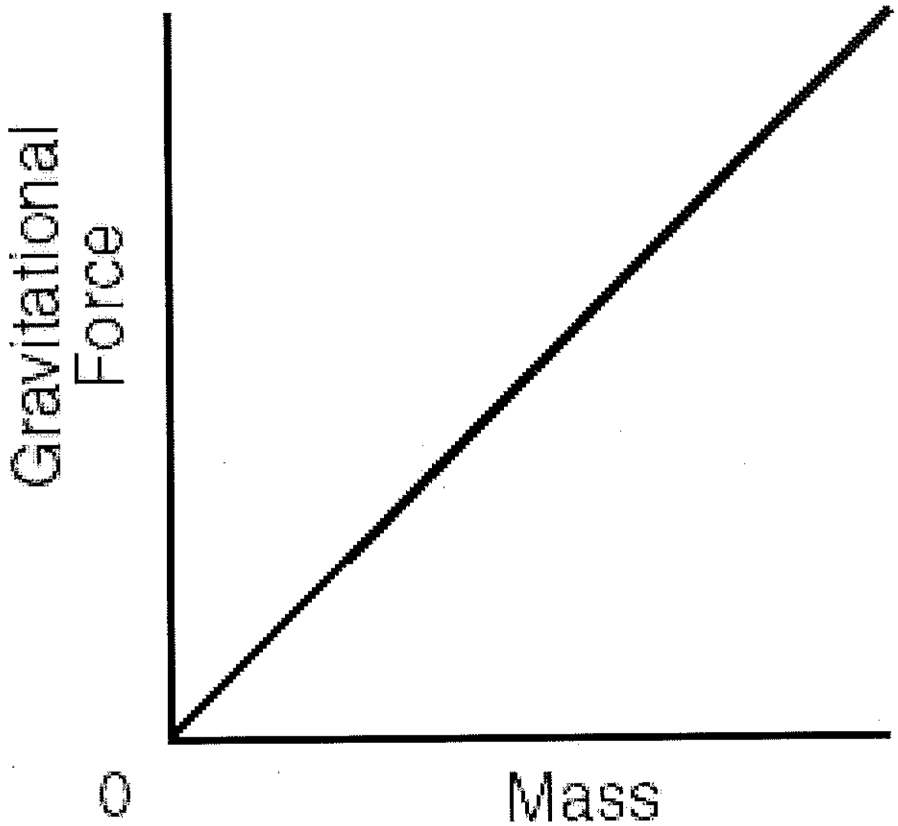
$$F_g = G\frac{m_1 m_2}{r^2}$$



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:

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:

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:

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:

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.

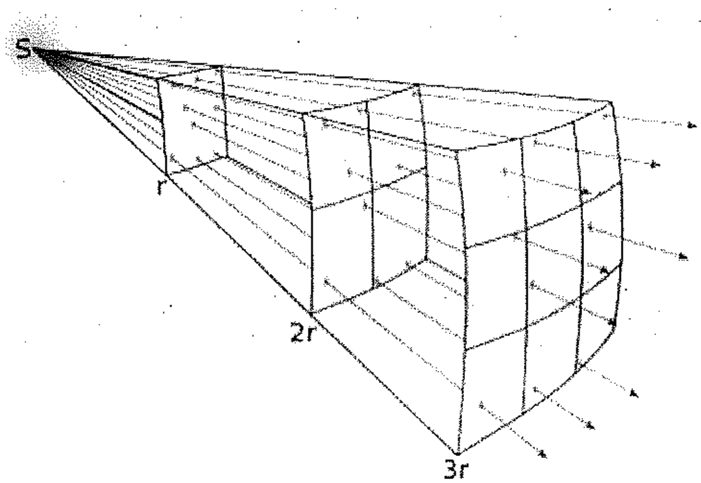


Image via Wikipedia, courtesy of Borb.

Question:

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:

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*.

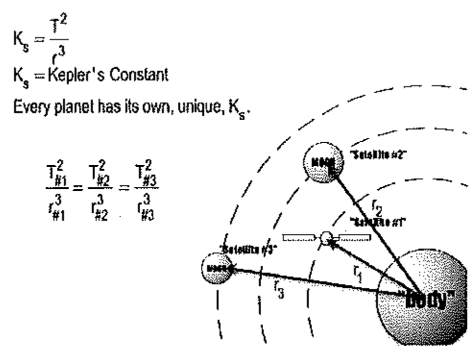
a. 1. 1st Law 2. 2nd Law 3. 3rd Law
b. 1. 2nd Law 2. 3rd Law 3. 1st Law
c. 1. 3rd Law 2. 1st Law 3. 2nd Law
d. 1. 3rd Law 2. 1st Law 3. 2nd Law
e. 1. 2nd Law 2. 1st Law 3. 3rd Law

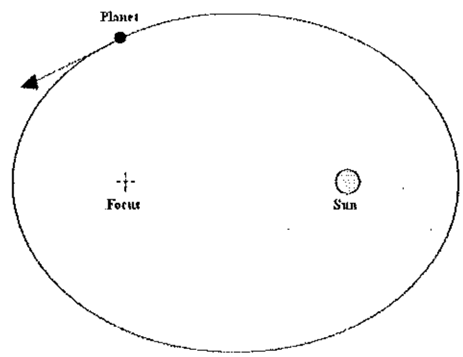
Answer:

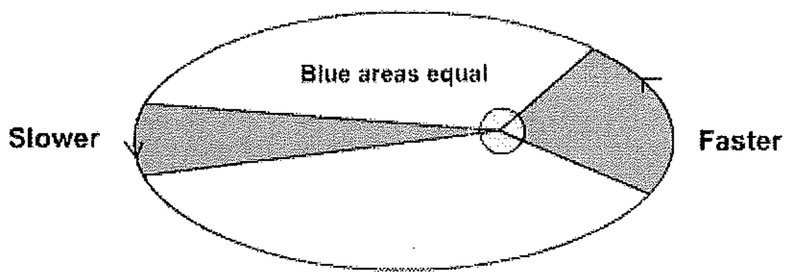
e. 1. 2nd Law 2. 1st Law 3. 3rd Law

Question:

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

a. 

b. 

c. 

Answer:

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

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.