CTGravity-1.

Two spherical masses m and M are a distance r apart. The distance between their centers is halved (decreased by a factor of 2). What happens to the magnitude of the force of gravity between them? The force increases by a factor of

A) \( \frac{\sqrt{2}}{2} \)
B) 2
C) \( 2\sqrt{2} \)
D) 4
E) 8

Answer: force decreases by a factor of 4

CTGravity-2. At a particular instant, two asteroids in inter-galactic space are a distance \( r = 20 \) km apart. Asteroid 2 has 10 times the mass of asteroid 1. The magnitudes of the accelerations of asteroids 1 and 2 are \( a_1 \) and \( a_2 \), respectively.

What is the ratio \( \frac{a_1}{a_2} \)?

\( m_1 \)
\( m_2 = 10 \, m_1 \)

A) 10
B) \( \frac{1}{10} \)
C) 1
D) cannot be determined.

Answer: 10 Each mass feels the same sized force. The smaller mass has the bigger acceleration.

CTGravity-3. Planet X has the same mass as the Earth, but 1/2 the radius. (Planet X is more dense than Earth). What is the acceleration of gravity on Planet X?

A) \( g_E \) (same as Earth)
B) 2 \( g_E \)
C) 4 \( g_E \)
D) 8 \( g_E \)
E) None of these.

Answer: 4 \( g_E \)
CTGravity-4. A satellite is in circular orbit at an altitude of 100 miles above the surface of the Earth.

The satellite’s pre-launch weight is its weight measured on the ground. The magnitude of the force of gravity on the satellite while it is in orbit is.

A) slightly greater than its pre-launch weight.
B) the same as its pre-launch weight.
C) slightly less than its pre-launch weight.
D) much less than its pre-launch weight, but not zero.
E) zero.

Answer: slightly less than its pre-launch weight. The satellite is only slightly further from the center of the earth when it is in orbit, compared to when it is on the ground.

CTGravity-5. Two satellites, A and B, are in circular orbit around the earth. The distance of satellite B from the center of the Earth is twice that of satellite A. What is the ratio of the magnitudes of the accelerations of A to B?

\[
\frac{a_A}{a_B} = .... \quad A) \ 1 \quad B) \ 2 \quad C) \ 4 \quad D) \ 1/2 \quad E) \ 1/4
\]

Answer: 4
CTGravity-6. A rock is released from rest at a point in space far from Earth, beyond the orbit of the Moon. The rock falls toward the Earth and crosses the orbit of the Moon. When the rock is the same distance from the Earth as the Moon, the magnitude of the acceleration of the rock is .. (Ignore the gravitational force between the rock and the Moon.)

A) greater  B) smaller  C) the same as the acceleration of the Moon.

Answer: the same as  The acceleration of gravity depends only the distance to the center of the earth.

As the rock falls toward the Earth, its acceleration is.. (neglect Moon’s gravity)
A) constant.  B) not constant.

Answer: not constant, as the rock gets closer to Earth, the acceleration of gravity increases

CTGravity-7. At time t=0, a satellite in circular orbit about the Earth is directly over Denver, 300 miles above the city, and traveling eastward at 16,000 mph. At the same time, a rock is released from rest 300 miles above the city, very near the satellite.

True or False: at t=0+, the accelerations of the rock and the satellite are identical.
A) True  B) False

Answer: True
CTGravity-8. Suppose the Earth had no atmosphere and a projectile was fired from a mountain top with sufficient speed to put it in circular orbit. The magnitude of the acceleration of the projectile while in orbit would be..

A) much less than g (because it doesn't fall to the ground)
B) much greater than g
C) approximately g
D) Impossible to tell.

Answer: approximately g

CTGravity-9. Kepler's third law states that the ratio \( \frac{T^2}{r^3} \) is a constant for all the planets. The period \( T \) of the Earth is 1 year. An astronomical unit (1 A.U.) is defined as the mean distance from the Earth to the Sun, therefore the mean Earth-Sun distance is 1A.U.

Consider an asteroid in circular orbit around the Sun with radius \( r = 2A.U. \). The period of the asteroid is..

A) 2 years.  B) 3 years.  C) \( 2^{3/2} \approx 2.83 \) years.
D) \( 2^{2/3} \approx 1.59 \) years  E) None of these.

Answer: \( 2^{3/2} \approx 2.83 \) years.
CTGravity-10. A planet in elliptical orbit around a stationary star moves from the point in its orbit furthest from the star (A) to the closest point (P). The work done by the force of gravity during this movement is: A) zero B) positive C) negative.

Answer: positive

The planet executes one complete orbit starting from point A and returning to A. The work done by the force of gravity during this orbit is:

A) zero B) Positive C) Negative.

Answer: zero

CTGravity-11. The gravitational PE, \( U(r) = -\frac{GMm}{r} \) of a two mass system (\( m << M \)) is plotted. Mass M is stationary at the origin and mass m is at \( r = r_0 \). Also shown is the total energy \( E_{\text{tot}} \).

Which arrow represents the KE of mass m?
A B C D) none of these

Answer: A KE + PE = \( E_{\text{tot}} \)
CTGravity-12. A projectile is fired from a stationary airless world with a speed \( v = v_{\text{escape}} \). What is the total energy \( E_{\text{tot}} = KE - GMm/r \) of the world/projectile system?

A) \( E_{\text{tot}} = 0 \)  
B) \( E_{\text{tot}} < 0 \)  
C) \( E_{\text{tot}} > 0 \)

Answer: \( E_{\text{tot}} = 0 \)

CTGravity-13. Does escape speed depend on launch angle? That is, if a projectile is given an initial speed \( v_0 \), is it more likely to escape an (airless) planet, if fired straight up than if fired at an angle?

A) Yes  
B) No

Answer: No. The escape speed is independent of angle. The derivation of escape speed does not involve the angle.

CTGravity-14. A planet is in elliptical orbit around the Sun. The zero of potential energy \( U \) is chosen at \( r = \infty \), so \( U(r) = -\frac{GMm}{r} \).

How does the magnitude of \( U \) \( (|U| = -U) \) compare to the KE?

A) \( |U| > KE \)  
B) \( |U| < KE \)  
C) \( |U| = KE \)  
D) depends on the position in the orbit.

Answer: \( |U| > KE \)  
Since \( E_{\text{tot}} < 0 \) (bound orbit), the negative \( U \) must be larger in magnitude than the positive KE.
CTGravity-15. Suppose a projectile is fired straight upward from the surface of an airless planet of radius \( R \) with the escape velocity \( v_{\text{esc}} \) (meaning the projectile will just barely escape the planet's gravity -- it will asymptotically approach infinite distance and zero speed.) What is the projectile's speed when it is a distance 4\( R \) from the planet's center (3\( R \) from the surface).

A) \( \frac{1}{2} v_{\text{esc}} \)  
B) \( \frac{1}{4} v_{\text{esc}} \)  
C) \( \frac{1}{9} v_{\text{esc}} \)  
D) \( \frac{1}{3} v_{\text{esc}} \)  
E) None of these is correct.

(Ignore the gravity of the Sun and other astronomical bodies.)

Answer: \( \frac{1}{2} v_{\text{esc}} \)  

Use conservation of energy. \( E_{\text{tot}} = 0 \) (since \( v = v_{\text{esc}} \)), so the magnitude of \( \text{PE} = U \) equals the magnitude of the KE: \( |\text{PE}| = \text{KE} \). If \( r \) increases by a factor of 4, the \( |\text{PE}| \) decreases in magnitude by a factor of 4. If \( |\text{PE}| \) decreases by 4, KE must decrease by 4.

CTGravity-16. A satellite is in circular orbit around a planet that has a very tenuous atmosphere extending up to the altitude of the satellite. Due to atmospheric drag, the satellite...

A) spirals inward  
B) spirals outward  
C) remains in an orbit of constant radius

Answer: spirals inward.

as the orbit decays, the speed of the satellite…

A) increases  
B) decreases  
C) remains constant

Answer: increases! As \( r \) decreases, the orbital speed increases! Very non-intuitive! \( v_{\text{orbit}} = (GM / r)^{1/2} \). As \( r \) decreases, \( v_{\text{orbit}} \) increases.
**CTGravity-17.** A person is standing in an elevator in a building on Earth. The elevator is stopped between floors. Another person is in a small room in a rocket in intergalactic space. The rocket is accelerating at 9.8 m/s$^2$ as shown.

![Diagram](image)

Which person feels heavier?
A) Earth person.  
B) Space person.  
C) They feel exactly the same.

**Answer:** They feel exactly the same. In both cases, the normal force from the floor on the person’s feet has magnitude $N = mg$;

**CTGravity-18.** Astronaut Dave Bowman is standing in the centrifuge of the spaceship Discovery. He drops his pen and observes it fall to the floor. Which statement below is most accurate?
A) After Bowman releases the pen, the net force on the pen is zero.  
B) The pen falls because the centrifugal force pulls it toward the floor.  
C) The pen falls because the artificial gravity pulls it toward the floor.

**Answer:** After Bowman releases the pen, the net force on the pen is zero.

**CTGravity-19.** How does the force of gravity on a space shuttle Astronaut compare to the force of gravity on the astronaut when she is on the earth?
A) Force of gravity on the space shuttle astronaut is zero.  
B) Force of gravity on the space shuttle astronaut is much, much less than on earth, but not zero.  
C) Force of gravity on the space shuttle astronaut is slightly less than when on earth.

**Answer:** Force of gravity on the space shuttle astronaut is slightly less than when on earth.
CTGravity-20. A projectile is fired with initial speed $v_0$ at radius $r_0$ from the center of an airless planet of mass $M$ ($r_0$ is significantly greater than the radius of the planet). The projectile rises to a maximum distance $r_{\text{max}}$ and then falls back down to earth, and achieves a final speed $v_{\text{final}}$ just before it hits the ground.

A student wishes to compute $r_{\text{max}}$. What is the correct Conservation of Energy equation, she should start with?

A) $\frac{1}{2}mv_0^2 - \frac{GMm}{r_0} = -\frac{GMm}{r_{\text{Max}}}$

B) $\frac{1}{2}mv_0^2 - \frac{GMm}{r_0} = \frac{1}{2}mv_{\text{final}}^2 - \frac{GMm}{r_{\text{Max}}}$

C) $\frac{1}{2}mv_0^2 = -\frac{GMm}{r_{\text{Max}}}$

D) $-\frac{GMm}{r_0} = -\frac{GMm}{r_{\text{Max}}}$

E) None of these

Answer: $\frac{1}{2}mv_0^2 - \frac{GMm}{r_0} = -\frac{GMm}{r_{\text{Max}}}$

Recall that $PE_{\text{grav}} = -\frac{GMm}{r}$.

Here, the final point is $r_{\text{max}}$. 