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Gravitation

Study Guide — Gravitation

Pre-med/IB-style questions covering Newton's law of gravitation, gravitational field/weight, potential energy and work, satellites/orbits (Kepler relationships), escape speed, and common conceptual traps (field vs potential, weightlessness, scaling with distance).

70 items — Study Guide with Answers

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1 **Two point masses m1 and m2 are separated by distance r. Which expression gives the magnitude of the gravitational force between them?**

- A $F = G(m1 + m2)/r$
- B $F = Gm1m2/r$
- C **$F = Gm1m2/r^2$** ✓
- D $F = (1/2)Gm1m2/r^2$
- E $F = G(m1 - m2)/r^2$

▶ **Explanation:** Newton's law of universal gravitation is $F = Gm1m2/r^2$. The force depends on the product of the masses and the inverse square of their separation (not $1/r$ and not on $m1 \pm m2$).

2 **If the distance between two masses is doubled ($r \to 2r$), the gravitational force magnitude becomes:**

- A Twice as large
- B Half as large
- C **One quarter as large** ✓
- D Four times as large
- E Unchanged

▶ **Explanation:** Because F $1/r^2$, doubling r makes the force $1/(2^2) = 1/4$ of the original. Many confuse inverse-square with inverse.

3 **If both masses in a two-body system are doubled ($m1 \to 2m1$ and $m2 \to 2m2$) while r stays the same, the gravitational force becomes:**

- A Twice as large

- B **Four times as large** ✓
- C Eight times as large
- D Half as large
- E Unchanged

▶ **Explanation:** F m1m2, so doubling both masses multiplies the product by 4. The distance term is unchanged.

4 **Earth exerts a gravitational force on the Moon. Compared to this force, the gravitational force the Moon exerts on Earth is:**

- A Larger, because the Moon moves around Earth
- B Smaller, because Earth is more massive
- C **Equal in magnitude and opposite in direction** ✓
- D Zero, because Earth is the "source" of gravity
- E Equal in direction and magnitude

▶ **Explanation:** Newton's 3rd law: interaction forces come in equal-and-opposite pairs. Different accelerations happen because $a = F/m$, not because forces differ.

5 **Which statement best distinguishes mass and weight?**

- A Mass depends on location; weight is constant everywhere
- B Mass is the gravitational force; weight is the amount of matter
- C **Mass is a measure of inertia; weight is the gravitational force on that mass** ✓
- D Mass and weight are the same physical quantity
- E Weight is measured in kg; mass in newtons

▶ **Explanation:** Mass measures how much an object resists acceleration (inertia). Weight is the gravitational force: W = mg. Units also differ: mass in kg, weight in N.

6 **In a vacuum near Earth's surface, two objects of different masses are dropped from the same height. Which is correct about their accelerations?**

- A The heavier object accelerates more because gravity pulls harder on it
- B The lighter object accelerates more because it has less inertia
- C **They accelerate at the same rate because gravitational and inertial mass cancel in a = F/m** ✓
- D Neither accelerates because gravity is balanced by air resistance
- E Acceleration depends on shape only, not mass

▶ **Explanation:** Force from gravity is F = mg and acceleration is a = F/m = g, independent of the object's mass (in vacuum). The "pull is larger" but inertia is proportionally larger too.

7 **The gravitational field strength g at a point is defined as:**

- A g = m/F
- B **g = F/m (force per unit mass)** ✓
- C g = Fm
- D g = Gm/r
- E $g = r^2/GM$

▶ **Explanation:** By definition, gravitational field strength is the gravitational force experienced per unit mass: g = F/m. This makes g a property of the location, not of the test mass.

8 **Which unit can correctly describe gravitational field strength?**

A kg

B N

C **N/kg** ✓

D J

E kg/s

▶ **Explanation:** Since $g = F/m$, its units are N/kg. Near Earth, N/kg is numerically equal to m/s^2, but conceptually it's force per mass.

9 **Which statement correctly compares G and g?**

A G depends on the planet; g is universal

B **G is universal; g depends on location (mass and radius of the planet)** ✓

C G and g are the same constant written differently

D g is universal; G depends on altitude

E Both G and g depend on the test mass

▶ **Explanation:** G is the universal gravitational constant (same everywhere). g is the gravitational field strength at a location (e.g., near Earth) and depends on distance from the mass creating the field.

10 **At a point outside a spherical planet, the direction of the gravitational field vector is:**

A Tangential to the surface

B Radially outward

C **Radially inward toward the planet's center** ✓

D Always upward relative to an observer

E Perpendicular to the radius

▶ **Explanation:** Gravity is attractive; the field points toward the mass creating it. For a spherically symmetric planet, that means radially inward toward the center.

11 **If we choose gravitational potential energy $U = 0$ at infinite separation, then for two masses attracting each other at distance r, U is:**

A Always positive

B **Always negative** ✓

C Always zero

D Positive only for circular orbits

E Negative only if the masses are equal

▶ **Explanation:** With $U(\infty)=0$, the gravitational potential energy is $U = -GMm/r$ (negative). A bound state has less energy than at infinite separation, so U is negative.

12 **Which statement correctly links gravitational work and potential energy for a conservative gravitational field?**

A $W_{gravity} = +\Delta U$

B $\mathbf{W_{gravity} = -\Delta U}$ ✓

C $W_{gravity} = \Delta K$ only in space

D $W_{gravity}$ is always zero

E $W_{gravity}$ depends on the path taken

▶ **Explanation:** For conservative forces (including gravity), the work done by the force equals the negative change in potential energy: $W = -\Delta U$. Path independence is part of what "conservative" means.

13 **A satellite moves from a lower orbit (closer to Earth) to a higher orbit (farther from Earth). With $U(\infty)=0$, its gravitational potential energy:**

- A Decreases (becomes more negative)
- B **Increases (becomes less negative)** ✓
- C Stays the same
- D Becomes zero immediately
- E Must become positive

▶ **Explanation:** $U = -GMm/r$. Increasing r makes U less negative, so U increases. A common trap is thinking "going up means more negative," but with the infinity-zero convention it's the opposite.

14 **Which statement best describes gravity (in Newtonian physics) as a force field?**

- A Gravity is non-conservative; work depends on path
- B **Gravity is conservative; work depends only on initial and final positions** ✓
- C Gravity does no work in any motion
- D Gravity is conservative only on Earth, not in space
- E Gravity is conservative only for circular orbits

▶ **Explanation:** In Newtonian gravity (ignoring non-gravitational losses), the gravitational force is conservative: the work depends only on endpoints, allowing potential energy to be defined.

15 **Far from Earth's atmosphere, at a distance from Earth's center of 2R (where R is Earth's radius), the gravitational field strength is approximately:**

- A 2g
- B g/2
- C **g/4** ✓
- D 4g
- E 0

▶ **Explanation:** g $1/r^2$. At r = 2R, g becomes $g \cdot (R/2R)^2 = g/4$. Gravity is weaker but not zero.

16 **Compared with sea level, a person's weight at the top of a high mountain is (ignoring Earth's rotation effects):**

- A **Slightly smaller** ✓
- B Slightly larger
- C Exactly the same
- D Zero
- E Negative

▶ **Explanation:** Weight is W = mg and g decreases with distance from Earth's center (inverse-square). Higher altitude means slightly larger r, so slightly smaller g and smaller weight.

17 **In an idealized model of Earth as a perfect sphere with uniform density, the gravitational field strength at Earth's exact center is:**

- A Maximum
- B Equal to g at the surface

C Half of surface g

D **Zero** ✓

E Infinite

▶ **Explanation:** At the center, gravitational pulls from all directions cancel, giving net field $g = 0$. (This is distinct from potential, which is not necessarily zero.)

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18 **In the same uniform-density Earth model, the gravitational field strength at radius r inside Earth ($r < R$) is proportional to:**

A $1/r^2$

B **r** ✓

C r^2

D Constant (independent of r)

E $1/r$

▶ **Explanation:** Inside a uniform sphere, only the mass enclosed within radius r contributes, and enclosed mass r^3. Combining with $1/r^2$ gives g r. Thus g increases linearly from 0 at the center to maximum at the surface.

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19 **A classic result: outside a uniform spherical planet, the gravitational field is the same as if all the planet's mass were concentrated at its center. This is essentially due to:**

A Friction

B **The shell theorem for spherical symmetry** ✓

C Kepler's second law

D The conservation of kinetic energy

E Air resistance

▶ **Explanation:** For spherically symmetric mass distributions, the shell theorem shows that outside the sphere the gravitational effect is equivalent to a point mass at the center. This is why we can use $g = GM/r^2$ outside planets.

20 In the ideal shell theorem model, the gravitational field inside a hollow spherical shell (at any point inside) is:

A **Zero everywhere inside** ✓

B Constant and nonzero

C Maximum at the center

D Pointing outward

E Equal to GM/R^2 inside

▶ **Explanation:** For a uniform spherical shell, gravitational pulls from different parts of the shell cancel at any interior point, giving zero net gravitational field inside the shell.

21 An apple falls toward Earth. Which statement about the gravitational forces is correct?

A Earth pulls harder on the apple than the apple pulls on Earth

B The apple pulls harder on Earth because it is closer to Earth's center

C **Earth and apple pull on each other with equal magnitude forces** ✓

D Only Earth pulls on the apple; the apple exerts no force

E Forces are equal only if masses are equal

▶ **Explanation:** Newton's 3rd law: forces come in equal-and-opposite pairs. Earth's acceleration is tiny because Earth's mass is huge, not because the force is different.

22 **For a satellite of mass m in a circular orbit of radius r around a planet of mass M, the orbital speed v satisfies:**

- A $v = GM/r$
- B **$v = \sqrt{(GM/r)}$** ✓
- C $v = \sqrt{(GMr)}$
- D $v = GM/r^2$
- E $v = \sqrt{(GMm/r)}$

▶ **Explanation:** Set gravity equal to centripetal requirement: $GMm/r^2 = mv^2/r$, so $v^2 = GM/r$ and $v = \sqrt{(GM/r)}$. The satellite mass cancels, so E is a trap.

23 **A satellite moves from a circular orbit of radius r to a circular orbit of radius 4r around the same planet. Its orbital speed changes by a factor of:**

- A 4
- B 2
- C **1/2** ✓
- D 1/4
- E $\sqrt{2}$

▶ **Explanation:** For circular orbit, $v \quad 1/\sqrt{r}$. If r increases by 4×, speed decreases by $\sqrt{4} = 2\times$, so v becomes half.

24 **A satellite moves from a circular orbit of radius r to a circular orbit of radius 4r around the same planet. Its orbital period changes by a factor of:**

- A 2
- B 4
- C **8** ✓
- D 16
- E 1/8

▶ **Explanation:** Kepler/Newton result: T r^(3/2) for orbits around the same central mass. Increasing r by 4× multiplies T by 4^(3/2) = 8.

25 **At a given orbit radius r, the escape speed v_{esc} is related to the circular orbit speed v_{circ} by:**

- A $v_{esc} = v_{circ}$
- B $v_{esc} = \sqrt{2} \cdot v_{circ}$ ✓
- C $v_{esc} = 2 \cdot v_{circ}$
- D $v_{esc} = v_{circ}/2$
- E $v_{esc} = v_{circ}/\sqrt{2}$

▶ **Explanation:** For the same r, $v_{circ} = \sqrt{}(GM/r)$ and $v_{esc} = \sqrt{}(2GM/r)$. Therefore $v_{esc} = \sqrt{2} \cdot v_{circ}$. This is a classic pre-med style proportional trap.

26 **Which statement best defines escape speed from a planet (ignoring air resistance)?**

- A The speed needed to reach the top of the atmosphere

B **The speed needed so the object never returns, reaching infinity with zero final speed** ✓

C The speed needed to orbit once

D The speed needed so weight becomes zero instantly

E The speed needed to cancel gravity at launch

▶ **Explanation:** Escape speed is the minimum launch speed so that the object can reach arbitrarily far away (infinity) with zero speed remaining—i.e., just unbound. It does not mean gravity becomes zero at launch.

27 **Escape speed from a planet depends on:**

A Only the mass of the object trying to escape

B Only the planet's radius

C Only the planet's mass

D **The planet's mass and the launch distance from the planet's center** ✓

E The object's shape and color

▶ **Explanation:** $v_{esc} = \sqrt{(2GM/r)}$. It depends on the central mass M and the distance r from the center at which you start, not on the escaping object's mass.

28 **If a planet's mass doubles while its radius stays the same, the escape speed from its surface changes by a factor of:**

A 2

B **$\sqrt{2}$** ✓

C 1/2

D $1/\sqrt{2}$

E 4

▶ **Explanation:** v_{esc} $\sqrt{M}$ (when r is fixed). Doubling M multiplies v_{esc} by $\sqrt{2}$, not by 2.

29 A planet's mass doubles AND its radius doubles. Compared with the original planet, the escape speed from the surface is:

A Larger

B Smaller

C **The same ✓**

D Twice as large

E Half as large

▶ **Explanation:** $v_{esc} = \sqrt{(2GM/R)}$. If $M \to 2M$ and $R \to 2R$, then $v_{esc} \to \sqrt{(2G \cdot 2M/(2R))} = \sqrt{(2GM/R)}$, unchanged. This tests understanding of how M and R compete.

30 A geostationary satellite must:

A Orbit above the North Pole with any period

B **Have a period equal to Earth's rotation and orbit in the equatorial plane in the same direction as Earth rotates ✓**

C Have zero speed relative to Earth

D Be in a very low orbit to stay fixed

E Have no gravity acting on it

▶ **Explanation:** To remain above one point on Earth, the satellite must match Earth's angular speed (period one day), orbit in the equatorial plane, and move eastward with Earth's rotation.

31 **Why is a geostationary satellite necessarily at a high altitude compared with low-Earth orbit satellites?**

- A Because gravity is stronger higher up
- B Because only high altitude reduces air resistance to zero
- C **Because a longer period requires a larger orbital radius for a stable orbit around Earth** ✓
- D Because satellite mass must be large
- E Because Earth's magnetic field forces it higher

▶ **Explanation:** To have a long period (one day), the orbit must be large. In gravitational orbits, larger radius corresponds to longer period (Kepler's third law).

32 **Which orbit type is most suitable for repeatedly passing over (or near) Earth's poles for mapping and Earth observation?**

- A Equatorial geostationary orbit
- B **Polar orbit (near 90° inclination)** ✓
- C Orbit that stays fixed above one city
- D Only an elliptical orbit with apogee at the equator
- E Any orbit, because Earth rotates under it

▶ **Explanation:** A polar orbit passes over high latitudes and the poles. As Earth rotates under the orbital plane, the satellite can cover the whole surface over time—useful for mapping.

33 **Astronauts in the International Space Station feel "weightless" mainly because:**

A Gravity is zero in space

B They are beyond Earth's gravitational field

C **They are in continuous free fall with the station, so the normal (support) force is near zero** ✓

D Their mass decreases significantly in orbit

E Centrifugal force cancels gravity in an inertial frame

▶ **Explanation:** Weightlessness refers to near-zero apparent weight (support force). Gravity still acts and provides centripetal acceleration, but astronauts and station fall together so there's little normal force.

34 Gravitational potential V at a point is defined as:

A $V = U \cdot m$

B **$V = U/m$ (potential energy per unit mass)** ✓

C $V = F \cdot m$

D $V = mg$

E $V = GMm/r^2$

▶ **Explanation:** Gravitational potential is potential energy per unit mass: $V = U/m$. This is useful because it depends on the source mass and position, not on the test mass.

35 Which is a correct unit for gravitational potential V?

A J

B N

C **J/kg** ✓

D N/kg^2

E kg/J

▶ **Explanation:** Since $V = U/m$, it has units $(J)/(kg) = J/kg$. (N/kg is for gravitational field strength.)

36 A spacecraft moves from distance r to distance 2r from a planet's center (r and 2r both outside the planet). With $U = -GMm/r$, the change in potential energy $\Delta U = U_{final} - U_{initial}$ is:

A Negative

B **Positive** ✓

C Zero

D Always equal to mgh

E Undefined because U is negative

▶ **Explanation:** $U_{initial} = -GMm/r$ and $U_{final} = -GMm/(2r)$, which is less negative. So U increases and ΔU is positive. Negative U does not prevent positive changes in U.

37 A mass moves outward from a planet in a purely radial direction. Which statement about the work done by gravity is correct?

A Gravity does positive work because the object is moving

B **Gravity does negative work because its force is inward while displacement is outward** ✓

C Gravity does zero work because it is conservative

D Gravity's work depends on the speed, not displacement

E Gravity does negative work only if the object falls inward

▶ **Explanation:** Work is $W = F \cdot d$. Gravity points inward; outward displacement is opposite direction, so work by gravity is negative. Conservative means path-independent, not zero work.

38 **The near-Earth approximation U mgh is valid mainly when:**

- **A** h is comparable to Earth's radius
- **B** g is changing rapidly with height
- **C** **h is much smaller than Earth's radius, so g is approximately constant over the height change ✓**
- **D** the object is moving at escape speed
- **E** the object is in orbit

▶ **Explanation:** mgh assumes g is constant over the height change. This is a good approximation only for h R_{Ea}rth; for large altitude changes you need $U = -GMm/r$.

39 **A person's apparent weight is slightly smaller at the equator than at the poles mainly because:**

- **A** g is larger at the equator due to Earth's bulge
- **B** **Earth's rotation requires centripetal acceleration, reducing the normal force needed to support the person at the equator ✓**
- **C** Gravity points upward at the equator
- **D** Mass is smaller at the equator
- **E** Air density is lower at the equator

▶ **Explanation:** At the equator, you move in a circle due to Earth's rotation. The required centripetal acceleration is toward Earth's axis, meaning the ground needs to provide a slightly smaller normal force. This reduces the scale reading (apparent weight).

40 **Which statement about gravity in low Earth orbit is correct?**

A Gravity is essentially zero, so satellites float

B **Gravity is still significant; satellites are in free fall while moving sideways fast enough to keep missing Earth** ✓

C Satellites stay up because there is no air resistance

D Satellites stay up because centrifugal force cancels gravity in an inertial frame

E Gravity points outward at that altitude

▶ **Explanation:** At low Earth orbit, g is only somewhat smaller than at the surface. Satellites remain in orbit because they are continuously falling around Earth with sufficient horizontal speed, not because gravity disappears.

41 **A satellite in circular orbit experiences no engine thrust. Which statement is correct about the satellite's acceleration?**

A Acceleration is zero because speed is constant

B Acceleration is tangent to the orbit because it is moving forward

C **Acceleration is toward Earth's center because gravity provides centripetal acceleration** ✓

D Acceleration points outward due to centrifugal force

E Acceleration alternates between inward and outward each orbit

▶ **Explanation:** Even with constant speed, velocity direction changes, requiring centripetal acceleration toward the center. Gravity supplies that inward acceleration.

42 **A spacecraft is in a circular orbit. If its speed is increased slightly (but still below escape speed) at one point, its new path becomes:**

- A — A smaller circular orbit immediately
- B — A larger circular orbit immediately
- C — **An ellipse with the burn point as the perigee (closest point)** ✓
- D — An ellipse with the burn point as the apogee (farthest point)
- E — A straight line tangent to the orbit

▶ **Explanation:** In a bound orbit, increasing speed at a point raises the opposite side of the orbit. The point where speed is increased becomes the closest point (perigee), and the spacecraft reaches a higher apogee later.

43 **A spacecraft is in a circular orbit. If its speed is decreased slightly at one point (still moving forward), its new path becomes:**

- A — A larger circular orbit immediately
- B — A smaller circular orbit immediately
- C — **An ellipse with the burn point as the apogee (farthest point)** ✓
- D — An ellipse with the burn point as the perigee (closest point)
- E — It instantly stops

▶ **Explanation:** If speed is reduced at a point, that point becomes the highest/slowest point of the new ellipse (apogee). The orbit then dips to a lower perigee, potentially leading to re-entry if low enough.

44 **For an elliptical orbit around a planet, where is the satellite's speed greatest?**

- A — At apogee (farthest point)
- B — **At perigee (closest point)** ✓
- C — Speed is constant everywhere in an ellipse

D At the midpoint of the orbit

E It depends only on the satellite mass

▶ **Explanation:** Kepler's second law (equal areas in equal times) implies the satellite moves fastest when it is closest to the planet (perigee) and slowest when farthest (apogee).

45 Kepler's second law ("equal areas in equal times") is most directly connected to conservation of:

A Energy

B Linear momentum

C **Angular momentum** ✓

D Mass

E Charge

▶ **Explanation:** For a central force (gravity toward the center), there is no external torque about the center, so angular momentum is conserved. This leads to equal areas swept out in equal times.

46 Two equal masses are placed at positions $x = -a$ and $x = +a$ on a line. At $x = 0$ (the midpoint), the net gravitational field is:

A Maximum

B **Zero** ✓

C Pointing to the right

D Pointing to the left

E Undefined because fields cannot cancel

▶ **Explanation:** Gravitational field is a vector. At the midpoint, each mass produces a field of equal magnitude but opposite direction, so they cancel and the net field is zero.

47 **Two masses are placed on a line: a large mass M and a smaller mass m separated by distance d. The point between them where the net gravitational field is zero is:**

- A Exactly halfway between them
- B Closer to the larger mass M
- C **Closer to the smaller mass m** ✓
- D At the position of the smaller mass
- E Outside the segment between them, always

▶ **Explanation:** To cancel fields, the weaker mass must be closer to the cancellation point to produce a stronger field there. So the zero-field point between them lies closer to the smaller mass.

48 **At the midpoint between two equal masses, the net gravitational field is zero. What about the gravitational potential (with $V = 0$ at infinity) at that midpoint?**

- A Zero, because the field is zero
- B Positive, because potentials add
- C **Negative, because potentials (scalars) from both masses add and each is negative** ✓
- D Infinite
- E Undefined

▶ **Explanation:** Gravitational potential is a scalar and adds algebraically. Each mass contributes a negative potential, so the sum is negative even though the vector fields cancel to zero.

49 **At the point between two unequal masses where the net gravitational field is zero, which statement about the gravitational potential is correct (with V=0 at infinity)?**

- A Potential is always zero where field is zero
- B Potential must be positive
- C **Potential is negative (sum of two negative contributions) and generally not zero** ✓
- D Potential is undefined because forces cancel
- E Potential is zero only if masses are unequal

▶ **Explanation:** Zero field means the vector sum of fields cancels. Potential is a scalar sum; each mass contributes negative potential, so the total remains negative and does not need to be zero.

50 **Which graph best represents how gravitational force magnitude F between two point masses changes with separation distance r?**

- A A straight line decreasing with r (F 1/r)
- B **A curve decreasing like $1/r^2$ (steep at small r, flattening at large r)** ✓
- C A straight line increasing with r
- D A constant horizontal line
- E A curve increasing like r^2

▶ **Explanation:** Newton's law gives F $1/r^2$, so the force decreases rapidly at small r and approaches zero as r becomes large (but never becomes negative).

51 **Which qualitative graph best represents gravitational potential energy U (with U=0 at infinity) as a function of separation r?**

- A U is positive and decreases toward 0 as r increases
- B **U is negative and increases toward 0 as r increases** ✓
- C U is zero for all r
- D U increases without bound as r increases
- E U alternates sign periodically with r

▶ **Explanation:** $U = -GMm/r$ is negative and approaches 0 from below as $r \to \infty$. Many confuse this with mgh being positive because of a different reference choice.

52 **Gravitational field lines around an isolated spherical mass point:**

- A Outward because the mass is a "source"
- B **Inward toward the mass** ✓
- C Tangential to circular paths
- D Randomly; there is no direction
- E Only upward

▶ **Explanation:** Gravitational field lines indicate the direction of force on a small positive test mass, so they point toward the attracting mass (inward).

53 **A small object is released from rest far from a planet and falls inward (no air resistance). Which energy change is correct as it falls?**

- A Kinetic energy decreases and potential energy increases
- B Both kinetic and potential energy increase

C **Kinetic energy increases as gravitational potential energy decreases (becomes more negative)** ✓

D Both kinetic and potential energy decrease

E Total energy must increase because gravity adds energy

▶ **Explanation:** As r decreases, $U = -GMm/r$ becomes more negative (decreases). By energy conservation, the lost potential energy becomes kinetic energy, so kinetic increases.

54 **With the convention $V(\infty)=0$, the gravitational potential V at infinity is:**

A **0** ✓

B $-\infty$

C $+\infty$

D Equal to g

E Equal to GM

▶ **Explanation:** The reference choice sets $V(\infty)=0$. Potentials near masses are negative, approaching 0 as distance grows without bound.

55 **For a satellite in a circular orbit of radius r around mass M, which statement about energies is correct?**

A $K = -U$

B $K = U/2$

C $\mathbf{K = -U/2}$ ✓

D Total energy is zero

E U is positive in orbit

▶ **Explanation:** For circular orbit: $U = -GMm/r$ and $v^2 = GM/r$, so $K = (1/2)mv^2 = GMm/(2r) = -U/2$. This is a classic trap: K is positive even though U is negative.

56 **For the same circular orbit, the total mechanical energy $E = K + U$ equals:**

- A $+GMm/(2r)$
- B 0
- C **$-GMm/(2r)$** ✓
- D $-GMm/r$
- E $+GMm/r$

▶ **Explanation:** Using $K = GMm/(2r)$ and $U = -GMm/r$, total energy $E = GMm/(2r) - GMm/r = -GMm/(2r)$. Negative total energy means the orbit is bound.

57 **A satellite experiences a small amount of atmospheric drag over time and gradually spirals to a lower circular orbit. After it has settled into a lower circular orbit, its orbital speed compared to before is:**

- A Smaller, because drag slows everything
- B The same
- C **Larger, because circular orbit speed increases at smaller radius (v $1/\sqrt{r}$)** ✓
- D Zero, because it eventually stops
- E Negative (reverses direction)

▶ **Explanation:** In a circular orbit, $v = \sqrt{(GM/r)}$, so smaller r requires larger speed. Drag removes energy and angular momentum, causing the orbit to shrink; in the new smaller circular orbit, the required orbital speed is higher (even though drag initially reduces speed at the moment it acts).

58 **Tides on Earth are primarily caused by:**

- A Earth's rotation creating extra gravity
- B **The difference (gradient) in gravitational pull across Earth's diameter ✓**
- C The Moon's magnetic field
- D Air pressure changes from day to night
- E Friction between Earth and space

▶ **Explanation:** Tides come from differential gravity: the side of Earth closer to the Moon is pulled slightly more strongly than the far side, producing stretching and tidal bulges.

59 **The Moon raises stronger tides on Earth than the Sun mainly because:**

- A The Moon is more massive than the Sun
- B **Tidal effects depend strongly on distance; the Moon is much closer even though it is less massive ✓**
- C The Sun's gravity does not reach Earth
- D The Moon rotates faster than the Sun
- E The Sun has no gravitational field in space

▶ **Explanation:** Tides depend on how quickly gravitational force changes with distance (a gradient effect), which is very sensitive to distance. The Moon is far closer than the Sun, so its differential pull across Earth is larger.

60 **If you wanted an Earth satellite with the shortest possible orbital period (ignoring atmospheric drag limits), you would choose:**

- A. A very high orbit, because the path is smoother
- B. **A very low orbit close to Earth** ✓
- C. A geostationary orbit
- D. A polar orbit must always have the shortest period
- E. Orbit period does not depend on radius

▶ **Explanation:** Orbital period increases with orbital radius (Kepler's third law). Lower orbits have shorter periods (they move faster and have smaller circumference).

61 **Which statement is true about gravitational force compared with electric force (in basic physics models)?**

- A. Gravitational forces can be repulsive, but electric forces cannot
- B. **Gravitational force is always attractive between masses; electric force can be attractive or repulsive** ✓
- C. Both forces are always repulsive
- D. Electric force is always weaker than gravity
- E. Gravity depends on charge, not mass

▶ **Explanation:** In Newtonian physics, mass is always positive, so gravity between masses is always attractive. Electric forces depend on the signs of charges, so they can attract or repel.

62 **A spacecraft moves closer to a planet (r decreases). What happens to the gravitational potential energy $U = -GMm/r$?**

- A. U increases (becomes less negative)
- B. **U decreases (becomes more negative)** ✓
- C. U stays constant because gravity is conservative

D U becomes zero

E U becomes positive

▶ **Explanation:** Because $U = -GMm/r$, decreasing r makes the magnitude GMm/r larger, so U becomes more negative (decreases). Conservativeness means you can define U, not that U is constant.

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63 If an object is launched from a planet's surface with speed greater than escape speed (ignoring air resistance), which statement is correct?

A It will rise to a maximum height and then return

B **It will move away forever, reaching infinity with nonzero speed** ✓

C It will enter a circular orbit automatically

D Gravity becomes zero immediately so it stops accelerating

E It must move in a straight line with constant speed right away

▶ **Explanation:** Speeds above escape give positive total mechanical energy (unbound trajectory), so the object can reach infinity with leftover speed. Gravity still acts and continues to slow it, but not enough to stop it.

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64 A projectile is launched from very far away toward a planet. Neglecting atmosphere, which statement is correct about its speed as it falls inward?

A It slows down because gravity is attractive

B **It speeds up because gravitational potential energy decreases and converts to kinetic energy** ✓

C Its speed stays constant because gravity is conservative

D It can only move if a rocket engine pushes it

E It speeds up only if it is heavy

▶ **Explanation:** Gravity does positive work when displacement is inward, converting potential energy into kinetic energy. Conservativeness means total mechanical energy is conserved (without losses).

65 Hypothetical planet: its mass stays the same, but its radius is compressed to half its original value. The surface gravitational field strength g changes by a factor of:

- A 1/2
- B 2
- C **4** ✓
- D 1/4
- E Unchanged

▶ **Explanation:** Surface $g = GM/R^2$. If $R \to R/2$, then $g \to GM/(R/2)^2 = GM/(R^2/4) = 4GM/R^2$, so it quadruples.

66 Two planets have the same surface gravitational field strength g, but planet A has a larger radius than planet B. Which statement must be true?

- A Planet A has smaller mass
- B **Planet A has larger mass (because M must scale with R^2 to keep g constant)** ✓
- C They must have equal mass
- D Planet A must have lower density
- E It is impossible for two planets to have the same g

▶ **Explanation:** Since $g = GM/R^2$, if g is the same and R is larger, then M must also be larger in proportion to R^2. Density could vary either way, so D is not guaranteed.

67 **A student says: "If the gravitational field at a point is zero, then a test mass placed there has zero gravitational potential energy." Which response is best?**

- A Correct, because zero field means zero energy
- B **Incorrect: potential energy depends on potential, and potential can be nonzero even where field is zero** ✓
- C Correct only if the test mass is 1 kg
- D Correct only if there is exactly one mass present
- E Incorrect because potential energy must always be positive

▶ **Explanation:** Field is a vector (related to the slope/gradient of potential). You can have zero field where forces cancel, but the scalar potential (and thus potential energy) can still be nonzero (often negative).

68 **A spacecraft moves from point A to point B in space where gravity is the only force. If gravitational potential energy increases ($\Delta U > 0$), then the work done by gravity is:**

- A Positive
- B **Negative** ✓
- C Zero
- D Always equal to mg
- E Always equal to the change in momentum

▶ **Explanation:** For gravity (conservative), $W_{gravity} = -\Delta U$. So if $\Delta U > 0$ (moving "up" in the gravitational sense), gravity does negative work (it removes kinetic energy unless energy is added by something else).

69 **A small object is released from rest at distance r from a planet and falls inward. If it reaches distance r/2 (ignoring atmosphere), which statement is correct about its gravitational potential energy change?**

- A U increases because it moved closer
- B **U decreases (becomes more negative) because 1/r increased** ✓
- C U stays the same because only kinetic energy changes
- D U becomes zero at r/2
- E U becomes positive at r/2

▶ **Explanation:** $U = -GMm/r$. Going from r to r/2 increases 1/r, making U more negative, so U decreases. The lost potential energy becomes kinetic energy.

70 **Why is Earth's gravitational pull on the Moon not causing the Moon to crash straight into Earth?**

- A Because gravity does not act in space
- B **Because the Moon's sideways (tangential) velocity makes it continuously fall around Earth, creating an orbit** ✓
- C Because the Moon has no mass
- D Because centrifugal force perfectly cancels gravity in an inertial frame
- E Because Earth repels the Moon gravitationally

▶ **Explanation:** Orbit is continuous free fall: gravity pulls the Moon inward, changing its velocity direction, while its tangential speed keeps it moving sideways so it keeps "missing" Earth. Gravity is the centripetal cause, not something canceled in an inertial frame.