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Circular Motion

Study Guide — Circular Motion

Pre-med/IB-style, no-calculator questions on circular motion (uniform and non-uniform): centripetal acceleration/force, angular speed/period, banked curves, vertical circles, conical pendulums, turntables, orbits, apparent weight, and common misconceptions (centrifugal vs centripetal).

70 items — Study Guide with Answers

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1 **In uniform circular motion (constant speed), which vector always points toward the center of the circle?**

- A Velocity
- B Displacement
- C **Centripetal acceleration** ✓
- D Angular displacement
- E Momentum always points outward

▶ **Explanation:** In uniform circular motion the acceleration is centripetal and points toward the center. Velocity is tangent to the circle, not inward, so A is wrong. Momentum follows velocity direction (tangent), so E is wrong.

2 **An object moves around a circle at constant speed. The net force on the object is best described as:**

- A Zero because speed is constant
- B Constant and tangent to the path
- C **Toward the center of the circle** ✓
- D Away from the center of the circle
- E Always equal to the weight mg

▶ **Explanation:** Even with constant speed, velocity changes direction, so acceleration is nonzero and points inward. Net force must point with acceleration, inward. It is not zero (A), not tangential (B), and not necessarily mg (E).

3 **Which expression gives the magnitude of the centripetal acceleration of an object moving at speed v in a circle of radius r?**

- A $a = vr$
- B $a = v/r$
- C **$a = v^2/r$** ✓
- D $a = r^2/v$
- E $a = g/r$

▶ **Explanation:** Centripetal acceleration magnitude is $a_c = v^2/r$. The common trap is confusing v^2/r with v/r (which has wrong units for acceleration).

4 **An object moves in a circle of radius r. If its speed doubles ($v \to 2v$) while r stays the same, the centripetal acceleration changes by a factor of:**

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

▶ **Explanation:** $a_c = v^2/r$, so doubling v makes v^2 four times larger, hence a_c increases by 4×. Not 2× (C) because acceleration depends on v^2, not v.

5 **An object moves in a circle at speed v. If the radius doubles ($r \to 2r$) while v stays the same, the centripetal acceleration becomes:**

- A Twice as large
- B **Half as large** ✓
- C Four times as large

D Unchanged

E Zero

▶ **Explanation:** $a_c = v^2/r$, so doubling r halves a_c. It does not stay the same (D) because the curvature is gentler at larger radius.

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6 **An object moves in a circle. If both speed and radius double ($v \to 2v$ and $r \to 2r$), the centripetal acceleration changes by a factor of:**

A 1/2

B 1

C **2** ✓

D 4

E 8

▶ **Explanation:** $a_c = v^2/r \to (2v)^2/(2r) = 4v^2/(2r) = 2(v^2/r)$. So it doubles.

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7 **Which relation correctly links angular speed and period T for uniform circular motion?**

A $= T/2$

B $= 2T$

C $= 2/T$ ✓

D $= 1/(2T)$

E $= vT$

▶ **Explanation:** One full revolution is 2 radians and takes time T, so = (angular displacement)/time = 2 /T. Options A and D invert the relationship incorrectly.

8 **Which relation correctly links linear speed v and angular speed for motion in a circle of radius r?**

- A $v = /r$
- **B** $\mathbf{v = r}$ ✓
- C $v = r/$
- D $v = {}^2r$
- E $v = 2/$

▶ **Explanation:** A point at radius r sweeps arc length $s = r$. Differentiating gives $v = r(d/dt) = r$. ^2r is centripetal acceleration, not speed.

9 **A wheel spins with constant angular speed . A point on the rim is at radius r. If the radius is doubled ($r \to 2r$) while stays the same, which statement is correct?**

- **A** **v doubles and a_c doubles** ✓
- B v doubles and a_c quadruples
- C v is unchanged and a_c doubles
- D v halves and a_c halves
- E Both v and a_c are unchanged

▶ **Explanation:** With constant , $v = r$ so v doubles. Also $a_c = {}^2r$ so a_c doubles (linear in r). Quadrupling would be true if doubled, not r.

10 **An object moves at constant linear speed v around a circular track. If the radius doubles (r → 2r), what happens to the angular speed ?**

- A doubles
- B **halves ✓**
- C stays the same
- D quadruples
- E becomes zero

▶ **Explanation:** = v/r. If r doubles while v stays fixed, halves. A common trap is to confuse this with the constant- case.

11 **An object moves in a circle at constant speed under a centripetal force. Over a small displacement along the circle, the work done by the centripetal force is:**

- A Positive
- B Negative
- C **Zero ✓**
- D Equal to mv^2
- E Equal to the centripetal force times the radius

▶ **Explanation:** Centripetal force is perpendicular to the instantaneous displacement (tangent), so $W = Fd\cos 90° = 0$. It changes direction of velocity, not the speed.

12 **In uniform circular motion (constant speed), the kinetic energy of the object is:**

- A **Constant ✓**

B Increasing

C Decreasing

D Zero because the object returns to its start point

E Undefined because direction changes

▶ **Explanation:** Kinetic energy depends on speed (v^2), not direction. If speed is constant, kinetic energy is constant, even though velocity changes direction.

13 An object moves in a circle but speeds up. Which statement about its acceleration is correct?

A Acceleration is purely toward the center

B Acceleration is purely tangent to the circle

C **Acceleration has both centripetal (radial) and tangential components** ✓

D Acceleration is zero because it is moving smoothly

E Acceleration must point outward when speeding up

▶ **Explanation:** If speed changes, there is tangential acceleration. If direction changes (circular path), there is centripetal acceleration. Speeding up requires a tangential component in the direction of motion.

14 In circular motion, which component of acceleration changes the object's speed (not its direction)?

A Centripetal (radial) acceleration

B **Tangential acceleration** ✓

C Normal force

D Centrifugal acceleration

E Gravitational potential energy

▶ **Explanation:** Tangential acceleration is parallel (or anti-parallel) to velocity, so it changes speed. Centripetal acceleration is perpendicular to velocity, so it changes direction only.

15 **A car turns left on a flat road at constant speed. The static friction force exerted by the road on the tires points:**

- A To the right (outward)
- B **To the left (inward, toward the center of the turn)** ✓
- C Forward
- D Backward
- E Upward

▶ **Explanation:** On a flat curve, static friction provides the inward (centripetal) force needed for the turn. Outward is a common sensation, but the real horizontal force is inward.

16 **A car is rounding a flat curve. Suddenly the road becomes perfectly icy (friction 0). At the instant the car reaches the ice, its horizontal acceleration is closest to:**

- A Inward toward the center
- B Outward away from the center
- C Tangent to the curve
- D **Approximately zero** ✓
- E Equal to g

▶ **Explanation:** With friction gone, there is (approximately) no horizontal force, so horizontal acceleration is ~0 at that instant. The car then continues with its current velocity direction (tangent), but the acceleration is what becomes zero.

17 **A passenger in a car turning left feels "pushed" to the right. In an inertial (non-rotating) frame, which statement is correct?**

- A A real outward force acts on the passenger
- B No horizontal force acts; the passenger moves outward on their own
- C **The door/seat exerts an inward force on the passenger to make them follow the curve** ✓
- D Gravity provides the centripetal force
- E The passenger's mass decreases during the turn

▶ **Explanation:** To curve left, the passenger must have inward (leftward) acceleration, so a real inward contact force from the car acts on them. The "outward push" is a sensation explained by inertia, not a real outward force in an inertial frame.

18 **The so-called "centrifugal force" is best described as:**

- A A real force that always acts outward in any frame
- B **A fictitious (pseudo) force introduced when analyzing motion in a rotating (non-inertial) frame** ✓
- C The same as friction
- D The force that causes circular motion in an inertial frame
- E A force equal to mg in all situations

▶ **Explanation:** In an inertial frame, circular motion is caused by inward net force. "Centrifugal force" appears only if you choose a rotating frame; it helps write Newton's laws in that non-inertial frame but is not a real interaction force.

19 **For fixed mass m and radius r, which change makes the required centripetal force increase by a factor of 4?**

- A Halving the speed
- B **Doubling the speed ✓**
- C Doubling the radius
- D Halving the radius
- E Doubling the mass

▶ **Explanation:** Centripetal force is $F_c = mv^2/r$. Doubling v makes v^2 four times larger, so F_c becomes $4\times$. Doubling mass only doubles F_c, and changing r affects F_c linearly (not by 4 unless r changes by 4).

20 **A car travels on a frictionless banked curve at the special "design speed." Which force provides the centripetal acceleration?**

- A Weight (mg) alone
- B Friction
- C **The horizontal component of the normal force ✓**
- D The vertical component of the normal force
- E Centrifugal force

▶ **Explanation:** On a frictionless banked curve, only weight and the normal act. The centripetal direction is horizontal toward the center, so it must come from the horizontal component of the normal force (not from mg which is vertical).

21 **A car drives on a frictionless banked curve at a speed LOWER than the design speed. Its natural tendency (without friction) is to:**

A Slide up the bank (toward the outer edge)

B **Slide down the bank (toward the inner edge)** ✓

C Move perfectly in the same circle regardless of speed

D Instantly stop

E Spiral inward with increasing speed automatically

▶ **Explanation:** At too low a speed, the needed centripetal force (mv^2/r) is smaller than what the bank geometry provides at design. The car tends to slide down the slope toward the inside unless friction assists.

22 **A car drives on a frictionless banked curve at a speed HIGHER than the design speed. Its natural tendency (without friction) is to:**

A Slide down the bank (toward the inner edge)

B **Slide up the bank (toward the outer edge)** ✓

C Stop because friction is absent

D Maintain the same path because centripetal force increases automatically

E Move in a straight line immediately

▶ **Explanation:** At too high a speed, the required centripetal force is larger than what the bank geometry provides at design. The car tends to slide up the bank (outward) unless friction supplies extra inward component.

23 **A roller coaster car is at the TOP of a vertical loop (upside down). Ignoring friction, which forces can contribute to the required centripetal (toward-center) force at that point?**

A Only the normal force

B Only the weight mg

C **Both weight mg and the normal force can contribute ✓**

D Only air resistance

E Only a centrifugal force

▶ **Explanation:** At the top, the center is downward. Weight points downward, so it contributes toward the center. If the car stays in contact, the track's normal force also points toward the center (downward) and can add to provide centripetal force.

24 **A car travels through the TOP of a vertical loop of radius r. To just maintain contact with the track at the top (normal force = 0), which condition must hold?**

A $v^2/r = 0$

B $\mathbf{v^2/r = g}$ ✓

C $v^2/r = 2g$

D $v^2/r = g/2$

E $v^2/r = mg$

▶ **Explanation:** At the top with $N = 0$, weight alone must supply the centripetal force: $mg = mv^2/r \rightarrow v^2/r = g$. Options involving mg confuse force with acceleration.

25 **A person in a car going over the top of a rounded hill of radius r feels lighter as speed increases. The best explanation is:**

A Gravity decreases at higher speed

B **The required centripetal acceleration is downward, so the normal force can be smaller than mg ✓**

C A centrifugal force pushes them upward, reducing weight

D Their mass decreases at higher speed

E Normal force must always equal mg

▶ **Explanation:** At the top, inward direction is downward. The net downward force is $mg - N = mv^2/r$, so $N = mg - mv^2/r$ decreases as v increases. "Feeling lighter" means smaller normal force, not smaller gravity.

26 At the bottom of a dip (concave up), you often feel heavier. Which statement best explains this?

A Gravity increases at the bottom

B A centrifugal force pushes you into the seat

C **The seat must push up with more than mg to provide upward centripetal acceleration** ✓

D Your mass increases due to acceleration

E There is no centripetal acceleration because speed is constant

▶ **Explanation:** At the bottom, inward direction is upward. Net upward force is $N - mg = mv^2/r$, so $N = mg + mv^2/r > mg$. You feel heavier because normal force (scale reading) is larger.

27 A satellite in a circular orbit around Earth stays in orbit because:

A No forces act on it

B **Gravity provides the centripetal force toward Earth** ✓

C Its weight is zero so it cannot fall

D Air resistance pushes it forward

E A centrifugal force balances gravity in an inertial frame

▶ **Explanation:** In an inertial frame, gravity is a real inward force that provides centripetal acceleration. Weightlessness in orbit refers to small normal force, not absence of gravity.

28 **A satellite's mass is doubled while it remains in the same circular orbit radius around Earth (same r). Ignoring fuel use, what happens to its required orbital speed?**

- A It doubles
- B It halves
- C **It stays the same** ✓
- D It becomes zero
- E It becomes undefined

▶ **Explanation:** For circular orbit, gravity supplies centripetal: $GMm/r^2 = mv^2/r$. The satellite mass m cancels, so v depends on r and Earth's mass, not on the satellite's mass.

29 **Two satellites orbit Earth in circular orbits. Satellite A is at lower altitude (smaller r) than satellite B. Which statement is correct?**

- A A has a longer period because it is closer
- B **A has a shorter period and higher orbital speed** ✓
- C Both have the same period because Earth rotates once per day
- D B must be faster because it travels a larger circle
- E Period depends only on satellite mass

▶ **Explanation:** In circular orbits, smaller r implies larger orbital speed (v $1/\sqrt{r}$) and shorter period (T increases with r). Bigger circle length does not mean longer time if speed differs.

30 **Which condition is necessary for a geostationary satellite (appearing fixed above one point on Earth)?**

- A It must orbit in any plane as long as its speed is constant
- B It must orbit above the North Pole
- C **It must have a period equal to Earth's rotation and orbit in the equatorial plane in the same direction as Earth rotates ✓**
- D It must have zero gravity acting on it
- E It must be at very low altitude to stay fixed

▶ **Explanation:** To stay above the same point, it must match Earth's rotation period and remain over the equator (otherwise it would move north–south in the sky). It must also orbit eastward (same direction as Earth's rotation).

31 **A rotating space station creates "artificial gravity" by spinning. If the desired centripetal acceleration at the rim is fixed (g), increasing the station's radius allows the station to:**

- A Spin faster (larger) to get the same g
- B **Spin slower (smaller) to get the same g ✓**
- C Not spin at all
- D Require zero normal force
- E Make g irrelevant because mass cancels

▶ **Explanation:** Artificial gravity uses a = ^{2}r. For fixed a, = √(a/r). Larger r means smaller is needed. This is why bigger stations can rotate more gently.

32 **In a rotating space station, a person stands on the inner surface at the rim. What provides the centripetal force needed to keep the person moving in a circle?**

A Gravity from the station's mass

B A real outward centrifugal force

C The normal force from the floor pushing inward ✓

D The person's weight mg

E Air resistance pushing inward

▶ **Explanation:** In an inertial frame, the person must have inward acceleration. The floor exerts an inward normal force on the person. The "artificial gravity" felt is the normal force, not a real outward force.

33 A conical pendulum swings so the bob moves in a horizontal circle. Which statement is correct about the string tension T?

A T equals mg always

B T is less than mg because part of it is horizontal

C The vertical component of T balances mg, and the horizontal component provides centripetal force ✓

D Only gravity provides the centripetal force

E T is purely horizontal

▶ **Explanation:** For steady circular motion at constant height, vertical forces balance: $T_{vertical} = mg$. The remaining horizontal component of tension points toward the center and provides centripetal force. Therefore $T > mg$ (so A and B are wrong).

34 In a conical pendulum, the bob's speed increases while the string length stays the same. What happens to the angle the string makes with the vertical?

A It decreases (string becomes more vertical)

B It increases (string becomes more horizontal) ✓

C It stays the same because length is the same

D It becomes 0° always

E It becomes 90° always

▶ **Explanation:** Higher speed requires a larger centripetal force mv^2/r, which comes from the horizontal component of tension. The string tilts more (angle increases) to provide more horizontal component.

35 In a conical pendulum, the string makes a larger angle with the vertical. Qualitatively, the time per revolution (period) tends to:

A Increase (slower revolution)

B **Decrease (faster revolution)** ✓

C Stay the same because gravity is constant

D Become infinite

E Become zero

▶ **Explanation:** A larger angle corresponds to a larger horizontal component of tension and typically a higher circular speed, giving a shorter period. The trap is thinking gravity fixes the period regardless of geometry.

36 A coin rests on a horizontal turntable rotating at angular speed . The coin does not slip. What provides the centripetal force on the coin?

A The coin's weight

B The normal force from the turntable

C **Static friction between coin and turntable** ✓

D A centrifugal force

E The coin's kinetic energy

▶ **Explanation:** Centripetal force must be horizontal toward the center. Weight and normal are vertical, so they cannot provide it. Static friction provides the needed inward horizontal force as long as it's below its maximum.

37 **A coin on a rotating turntable is just about to start slipping outward. Which statement is correct at that instant?**

- A Static friction is zero
- B **Static friction equals its maximum value μ_s N** ✓
- C Kinetic friction equals μ_k N even before slipping
- D Normal force becomes zero
- E Centripetal acceleration becomes zero

▶ **Explanation:** At the threshold of slipping, static friction is at its maximum $f_{s,max}$ = μ_s N and is trying to supply the required centripetal force. Kinetic friction applies only after slipping begins.

38 **For a coin on a horizontal turntable, the maximum linear speed before slipping satisfies v_{max} √r (with μ_s and g fixed). If the radius r doubles, v_{max} changes by a factor of:**

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

▶ **Explanation:** From $f_{s,max}$ = μ_s mg and mv^2/r μ_s mg, we get v_{max} = √(μ_s g r), so v_{max} scales with √r. Doubling r multiplies v_{max} by √2, not 2.

39 **For a coin on a horizontal turntable, the maximum angular speed before slipping satisfies _max 1/√r (with μ_s and g fixed). If the radius r doubles, _max changes by a factor of:**

- A 2
- B √2
- C 1/2
- D **1/√2** ✓
- E It stays the same

▶ **Explanation:** Since v_{max} = √(μ_s g r) and _max = v_{max}/r, then _max = √(μ_s g / r), which scales as 1/√r. Doubling r reduces _max by √2.

40 **Which relation correctly links angular speed and frequency f (revolutions per second)?**

- A = f/2
- B **= 2 f** ✓
- C = 2 /f
- D = f^2
- E = vf

▶ **Explanation:** One revolution is 2 radians. If the object makes f revolutions per second, it sweeps 2 f radians per second, so = 2 f.

41 **If the frequency of rotation doubles, what happens to the period T and angular speed ?**

- A T doubles and halves
- B **T halves and doubles** ✓
- C T and both double
- D T and both halve
- E T stays the same and doubles

▶ **Explanation:** $f = 1/T$, so doubling f halves T. Also $= 2$ f, so doubles. The trap is thinking period and frequency both increase together.

42 **An object moves in a circle. At some instant, its acceleration is NOT perpendicular to its velocity. Which must be true at that instant?**

- A **The object's speed is changing** ✓
- B The object's radius is changing
- C The centripetal acceleration is zero
- D The object is in uniform circular motion
- E The net force is zero

▶ **Explanation:** If acceleration has a component along velocity, it changes the speed (tangential acceleration). Perpendicular-only acceleration changes direction but not speed, so not-perpendicular implies speed change.

43 **Which situation corresponds to uniform circular motion?**

- A Tangential acceleration is nonzero and centripetal acceleration is zero

B **Centripetal acceleration is nonzero and tangential acceleration is zero ✓**

C Both centripetal and tangential accelerations are zero

D Tangential acceleration is outward

E Centripetal acceleration points tangent to the circle

▶ **Explanation:** Uniform circular motion means speed constant but direction changing, so there is centripetal (radial) acceleration but no tangential acceleration. If both were zero, motion would be straight-line at constant speed.

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44 **Can an object move in a circle at constant speed with zero centripetal acceleration?**

A Yes, if there is no friction

B Yes, if the object is very light

C Yes, if its kinetic energy is constant

D **No, because changing direction requires centripetal acceleration ✓**

E Only if the radius is very large

▶ **Explanation:** Circular motion requires continuous change in velocity direction, which requires acceleration toward the center. If centripetal acceleration were zero, velocity direction wouldn't change and the path wouldn't be circular.

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45 **A stone on a string moves in a vertical circle. At the SIDE position (string horizontal), which force provides the centripetal acceleration toward the center (ignoring air resistance)?**

A Only weight mg

B **Only string tension ✓**

C Both weight and tension equally

D Centrifugal force

E No force is needed at the side

▶ **Explanation:** At the side, the center is horizontal, so the required centripetal direction is horizontal. Tension points toward the center (horizontal). Weight is vertical, so it contributes no radial (centripetal) component at that instant.

46 **For the same vertical-circle stone at the SIDE position, which equation best represents the radial (centripetal) force balance at that instant?**

A **$T = mv^2/r$** ✓

B $T - mg = mv^2/r$

C $mg - T = mv^2/r$

D $T + mg = mv^2/r$

E $mg = mv^2/r$

▶ **Explanation:** At the side, weight is perpendicular to the radial direction, so only tension contributes radially. Therefore T must equal mv^2/r. Equations involving $\pm mg$ are for top/bottom positions.

47 **A stone on a string goes around a vertical circle. At the TOP, if the stone's speed is too low such that $mv^2/r < mg$, what happens (for an ideal string that cannot push)?**

A The string provides an outward push to keep it circular

B **The string tension becomes negative, so the string goes slack and the stone leaves circular motion** ✓

C The stone continues circular motion with tension still positive

D Gravity reverses direction to keep the stone in orbit

E The centripetal acceleration becomes outward

▶ **Explanation:** At the top, centripetal direction is downward. Radial equation is $T + mg = mv^2/r$. If $mv^2/r < mg$, the required T would be negative (meaning the string would need to push), which it can't, so it goes slack and the motion is no longer circular.

48 **A stone moves in a vertical circle of radius r with speed v at the TOP and BOTTOM (assume same v for comparison). Which statement about string tension is correct?**

- A $T_{top} = T_{bottom}$
- B T_{top} is greater than T_{bottom}
- C **T_{bottom} is greater than T_{top} by 2mg** ✓
- D T_{top} is greater than T_{bottom} by mg
- E Both tensions are zero

▶ **Explanation:** At bottom: $T_{bottom} - mg = mv^2/r \rightarrow T_{bottom} = mv^2/r + mg$. At top: $T_{top} + mg = mv^2/r \rightarrow T_{top} = mv^2/r - mg$. Difference is $T_{bottom} - T_{top} = 2mg$.

49 **A rider is upside down at the top of a vertical loop and feels "weightless." In this context, "weightless" means:**

- A Gravity is zero at the top of the loop
- B The rider's mass becomes zero
- C **The normal force from the seat/track on the rider is zero** ✓
- D The rider's speed is zero
- E The centripetal acceleration is zero

▶ **Explanation:** Apparent weight is the support/normal force. "Weightless" means N = 0, not that gravity disappears. Gravity can still provide the needed centripetal force at that moment.

50 **At the top of a vertical loop of radius r, the minimum speed to keep contact satisfies $v_{min} = \sqrt{(gr)}$. If the loop radius increases by a factor of 4, v_{min} changes by a factor of:**

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

▶ **Explanation:** v_{min} $\sqrt{r}$. If r increases by 4×, $\sqrt{r}$ increases by $\sqrt{4} = 2\times$, so v_{min} doubles. Not 4× because speed scales with the square root.

51 **An object moves in a circle of radius r at speed v. If r decreases while v stays the same, the required centripetal force (for the same mass) will:**

- A Decrease
- B Stay the same
- C **Increase** ✓
- D Become zero
- E Reverse direction

▶ **Explanation:** $F_c = mv^2/r$. With v fixed, reducing r increases v^2/r, so the needed inward force increases. Tighter turn needs more inward force.

52 **A cyclist rides at constant speed v. On a curve of radius r1 they need friction to provide centripetal force. If they take a curve of smaller radius r2 < r1 at the same speed, the needed friction force is:**

- A Smaller because the curve is shorter
- B The same because speed is the same
- C **Greater because mv^2/r is larger for smaller r** ✓
- D Zero because the wheels roll
- E Outward rather than inward

▶ **Explanation:** At fixed v, centripetal requirement is mv^2/r, which increases as r decreases. Rolling does not remove the need for lateral friction; the direction must still be inward.

53 **Two satellites orbit the same planet in circular orbits of radii r and 4r. Which has the larger orbital speed?**

- A The one at radius 4r
- B **The one at radius r** ✓
- C They have equal speeds because both are in orbit
- D The one at 4r is faster because it travels farther each orbit
- E Speed depends only on satellite mass

▶ **Explanation:** Orbital speed decreases with radius ($v\ \ 1/\sqrt{r}$). The inner orbit needs greater centripetal acceleration, so it must move faster, not slower.

54 **Two satellites orbit the same planet in circular orbits of radii r and 4r. Which has the larger orbital period?**

- A The one at radius r

- B **The one at radius 4r ✓**
- C They have equal periods because gravity acts on both
- D The inner one has longer period because it is faster
- E Period depends only on satellite mass

▶ **Explanation:** Larger orbits have longer periods. Although the outer satellite travels a larger circle, it also moves more slowly; overall, period increases with radius.

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55 **Astronauts in a circular orbit around Earth feel weightless mainly because:**

- A Gravity is zero in orbit
- B **They are in continuous free fall with the spacecraft, so the normal (support) force is near zero ✓**
- C Their mass is reduced by the vacuum of space
- D A centrifugal force cancels gravity in an inertial frame
- E The spacecraft pushes them outward

▶ **Explanation:** Weightlessness refers to zero apparent weight (support force). Gravity still acts and provides centripetal acceleration, but everything falls together so there is little/no normal force on the astronauts.

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56 **A bucket of water is swung in a vertical circle. At the TOP, to keep the water from falling out, which condition is required (minimum case)?**

- A **$v^2/r \quad g$ ✓**
- B $v^2/r \quad g$
- C $v^2/r = 0$
- D $v^2/r = 2g$ always

E No condition is needed because water sticks to the bucket

▶ **Explanation:** At the top, the needed centripetal acceleration is downward. For the water to follow the circular path without losing contact, the required inward acceleration must be at least g so gravity can supply it (minimum case when contact force is zero).

57 In the swinging bucket problem, suppose the speed at the TOP is too small so that $v^2/r < g$. What happens to the water relative to the bucket?

A It remains pressed into the bucket more strongly

B **It "falls" away from the bucket because gravity is more than enough and the bucket cannot pull it inward** ✓

C It is forced outward by a real centrifugal force

D It instantly freezes due to low pressure

E It moves upward relative to the bucket

▶ **Explanation:** If $v^2/r < g$ at the top, the required inward (downward) acceleration is too small; the water would need an upward (negative) contact force to reduce the downward acceleration, but the bucket can't "pull upward" on the water to keep it in contact that way. Contact is lost and the water falls relative to the bucket.

58 What is the angular displacement (in radians) for one full revolution?

A

B **2** ✓

C 360

D 1

E It depends on the radius

▶ **Explanation:** A full circle corresponds to 360° which equals 2 radians. Radians are based on arc length/radius, so the full revolution is always 2 , independent of radius.

59 **A car moves at constant speed around a circular track. Which statement is correct?**

- A Acceleration is zero because speed is constant
- B Acceleration points tangent to the track
- C **Acceleration points toward the center of the track** ✓
- D Net force is zero because speed is constant
- E Acceleration points away from the center

▶ **Explanation:** Constant speed does not mean constant velocity. Direction changes, so there is centripetal acceleration inward. Therefore net force is also inward, not zero.

60 **Two points on a rotating disk are at radii r and 2r from the center. The disk rotates with angular speed . The ratio of their linear speeds (v at 2r : v at r) is:**

- A 1 : 2
- B **2 : 1** ✓
- C 4 : 1
- D 1 : 4
- E 1 : 1

▶ **Explanation:** v = r, so doubling r doubles v. The outer point (2r) moves twice as fast as the inner point (r).

61 **Two points on a rotating disk are at radii r and 2r. The disk rotates with angular speed . The ratio of their centripetal accelerations (a at 2r : a at r) is:**

- A 1 : 2
- B **2 : 1** ✓
- C 4 : 1
- D 1 : 4
- E 1 : 1

▶ **Explanation:** At fixed , $a_c = {}^{2}r$, so acceleration is proportional to r. Doubling r doubles a_c (not quadruples, which would be the constant-v case).

62 **Two riders have the same mass and sit on a carousel, one at radius r and one at radius 2r. The carousel rotates at the same angular speed . Which rider requires a larger inward (centripetal) force, and why?**

- A The rider at r, because they are closer to the center
- B **The rider at 2r, because required centripetal force is $F = m\,{}^{2}r$ and increases with r** ✓
- C They require the same force because is the same
- D The rider at r, because centripetal acceleration decreases with r at fixed
- E Neither needs centripetal force because speed is constant

▶ **Explanation:** With the same and same mass, $a_c = {}^{2}r$ and $F_c = m\,{}^{2}r$. Larger radius means larger required centripetal force. Constant speed does not remove the need for centripetal force.

63 **In uniform circular motion with constant speed, which statement about acceleration is correct?**

A Acceleration is a constant vector

B **Acceleration has constant magnitude, but its direction changes continuously** ✓

C Acceleration is zero because speed is constant

D Acceleration is tangent to the path

E Acceleration points outward

▶ **Explanation:** Magnitude $a_c = v^2/r$ is constant if v and r are constant, but the direction is always toward the center, which changes as the object goes around the circle. So the vector is not constant.

64 Which motion is possible while having constant speed but a nonzero net force?

A Straight-line motion with constant velocity

B **Motion in a circle at constant speed** ✓

C Being at rest

D Straight-line motion speeding up

E Straight-line motion slowing down

▶ **Explanation:** Nonzero net force means nonzero acceleration. Constant speed but changing direction (circular motion) has acceleration (centripetal), so net force is nonzero. Constant velocity straight-line motion has zero net force.

65 Which statement best distinguishes centripetal and centrifugal (in everyday discussion) forces?

A Both are real forces that always come in pairs

B **Centripetal is inward and real; centrifugal is outward and is a pseudo-force used in rotating frames** ✓

C Centrifugal force causes circular motion in inertial frames

D Centripetal force is only gravity

E Centripetal and centrifugal are the same force with different names

▶ **Explanation:** In an inertial frame, circular motion needs a real inward net force (centripetal). The "centrifugal force" is introduced only in a rotating frame to account for the apparent outward tendency due to inertia.

66 **For a mass m moving at speed v in a circle of radius r, which statement is correct?**

A Doubling m doubles centripetal acceleration

B **Doubling m doubles the required centripetal force, but centripetal acceleration stays the same** ✓

C Doubling m halves the required centripetal force

D Doubling m quadruples centripetal acceleration

E Mass does not affect centripetal force

▶ **Explanation:** $a_c = v^2/r$ depends on v and r, not m. But $F_c = ma_c = mv^2/r$ is proportional to m. Heavier mass needs more inward force for the same circular motion.

67 **An object of mass m moves in a circle of radius r under a fixed inward force F. If the mass is doubled (2m) while F and r stay the same, the speed required for circular motion changes by a factor of:**

A 2

B $\sqrt{2}$

C 1/2

D **$1/\sqrt{2}$** ✓

E It stays the same

▶ **Explanation:** From $F = mv^2/r$, we get $v = \sqrt{(Fr/m)}$. If m doubles, v scales as $1/\sqrt{m}$, so v decreases by a factor of $\sqrt{2} \rightarrow v_{new} = v/\sqrt{2}$.

68 **In uniform circular motion at speed v, after half a revolution the velocity vector points opposite the original direction. The magnitude of the change in velocity $|\Delta v|$ over half a revolution is:**

- A 0
- B v
- C **2v** ✓
- D $\sqrt{2}$ v
- E v

▶ **Explanation:** Initial velocity is a vector of magnitude v; after half a revolution it has the same magnitude v but opposite direction. So $\Delta v = v_{final} - v_{initial}$ has magnitude $|(-v) - (v)| = 2v$.

69 **An object completes one full revolution around a circle and returns to its starting point. Over this full revolution, its average velocity is:**

- A Equal to its instantaneous speed v
- B Nonzero and tangent to the circle
- C **Zero (displacement is zero)** ✓
- D Equal to v/2
- E Undefined because direction changes

▶ **Explanation:** Average velocity = total displacement / total time. After a full revolution the displacement is zero, so average velocity is zero even though average speed is not.

70 **An object completes one full revolution in time T at constant speed. Over the full revolution, which statement is correct?**

- A Average speed is zero because displacement is zero
- B Average velocity is nonzero because distance traveled is nonzero
- C **Average velocity is zero, but average speed is the circumference divided by T** ✓
- D Both average speed and average velocity are zero
- E Average speed equals centripetal acceleration times T

▶ **Explanation:** Average velocity uses displacement (zero after a full loop), so it's zero. Average speed uses distance traveled: circumference/ T. Confusing distance with displacement is the main trap.