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## Circular Motion

### Exam — 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 — Printable Exam

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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



**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  $mg$



**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  $a = g/r$





4 An object moves in a circle of radius  $r$ . If its speed doubles ( $v \rightarrow 2v$ ) 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

5 An object moves in a circle at speed  $v$ . If the radius doubles ( $r \rightarrow 2r$ ) 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

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



- A  $1/2$
- B 1
- C 2
- D 4





E 8

7 Which relation correctly links angular speed  $\omega$  and period  $T$  for uniform circular motion?



A  $\omega = T/2$

B  $\omega = 2 T$

C  $\omega = 2 /T$

D  $\omega = 1/(2 T)$

E  $\omega = vT$

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



A  $v = \omega /r$

B  $v = \omega r$

C  $v = \omega /r$

D  $v = \omega^2 r$

E  $v = 2 \omega /r$

9 A wheel spins with constant angular speed  $\omega$ . A point on the rim is at radius  $r$ . If the radius is doubled ( $r \rightarrow 2r$ ) while  $\omega$  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

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



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

**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





**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



**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



**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





**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

**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  $g$

**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

**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

**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

**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

**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

**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





**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



**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  $v^2/r = g$
- C  $v^2/r = 2g$
- D  $v^2/r = g/2$
- E  $v^2/r = mg$



**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  $mg$

**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

**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

**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

**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

**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





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



**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



**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





**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  $0^\circ$  always
- E It becomes  $90^\circ$  always

**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

**36** A coin rests on a horizontal turntable rotating at angular speed  $\omega$ . 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

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  $\mu_s N$
- C Kinetic friction equals  $\mu_k N$  even before slipping
- D Normal force becomes zero
- E Centripetal acceleration becomes zero

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



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

39 For a coin on a horizontal turntable, the maximum angular speed before slipping satisfies  $\omega_{\max} \propto 1/\sqrt{r}$  (with  $\mu_s$  and  $g$  fixed). If the radius  $r$  doubles,  $\omega_{\max}$  changes by a factor of:





- A 2
- B  $\sqrt{2}$
- C  $1/2$
- D  $1/\sqrt{2}$
- E It stays the same

**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  $= vf$

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



- A  $T$  doubles and  $\omega$  halves
- B  $T$  halves and  $\omega$  doubles
- C  $T$  and  $\omega$  both double
- D  $T$  and  $\omega$  both halve
- E  $T$  stays the same and  $\omega$  doubles





**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



**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



**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





**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

**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  $mg = mv^2/r$

**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

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

**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





**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



**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



**52** A cyclist rides at constant speed  $v$ . On a curve of radius  $r_1$  they need friction to provide centripetal force. If they take a curve of smaller radius  $r_2 < r_1$  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

**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

**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

**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

**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  $v^2/r < g$
- B  $v^2/r = g$
- C  $v^2/r = 0$
- D  $v^2/r = 2g$  always
- E No condition is needed because water sticks to the bucket

**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





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

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

60 Two points on a rotating disk are at radii  $r$  and  $2r$  from the center. The disk rotates with angular speed  $\omega$ . 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





**61** Two points on a rotating disk are at radii  $r$  and  $2r$ . The disk rotates with angular speed  $\omega$ . 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

**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  $\omega$ . 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  $F = m \omega^2 r$  and increases with  $r$
- C They require the same force because  $\omega$  is the same
- D The rider at  $r$ , because centripetal acceleration decreases with  $r$  at fixed  $\omega$
- E Neither needs centripetal force because speed is constant

**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

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

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

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

**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

**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  $v$





**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



**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  $T$







| #  | Ans | Answer Text   |
|----|-----|---|
|    | C   |   |
| 2  | C   | Toward the center of the circle   |
|    | C   |   |
| 4  | D   | 4   |
|    | B   |   |
| 6  | C   | 2   |
|    | C   |   |
| 8  | B   | $v = r$   |
|    | A   |   |
| 10 | B   | halves  |
|    | C   |   |
| 12 | A   | Constant  |
|    | C   |   |
| 14 | B   | Tangential acceleration   |
|    | B   |   |
| 16 | D   | Approximately zero  |
|    | C   |   |
| 18 | B   | A fictitious (pseudo) force introduced when analyzing motion in a rotati...   |
|    | B   |   |
| 20 | C   | The horizontal component of the normal force                                  |
|    | B   |   |
| 22 | B   | Slide up the bank (toward the outer edge)                                     |
|    | C   |   |
| 24 | B   | $v^2/r = g$   |
|    | B   |   |
| 26 | C   | The seat must push up with more than $mg$ to provide upward centripetal ac... |
|    | B   |   |
| 28 | C   | It stays the same   |
|    | B   |   |
| 30 | C   | It must have a period equal to Earth's rotation and orbit in the equator...   |
|    | B   |   |
| 32 | C   | The normal force from the floor pushing inward                                |
|    | C   |   |
| 34 | B   | It increases (string becomes more horizontal)                                 |
|    | B   |   |
| 36 | C   | Static friction between coin and turntable                                    |
|    | B   |   |
| 38 | B   | $\sqrt{2}$  |



