Easy

1. Torque depends on which two basic factors?
   A. Force magnitude and perpendicular lever arm.
   B. Force magnitude and object's mass.
   C. Force magnitude and speed.
   D. Distance only.
   E. Weight and friction.

2. If you push on a door at the handle vs. near the hinge with the same force, what happens to the door’s tendency to rotate?
   A. Pushing at the handle produces a larger torque (easier to open).
   B. Pushing near the hinge produces larger torque.
   C. Torque is independent of where you push.
   D. Door will never rotate because hinge resists.
   E. Torque depends only on door mass.

3. A wrench has a fixed length. To loosen a stubborn bolt, which practical trick increases torque most effectively?
   A. Use a longer wrench (increase lever arm) or apply same force further from bolt.
   B. Use a shorter wrench.
   C. Apply force nearer to bolt.
   D. Tap the bolt quickly.
   E. Reduce the force.

4. Which statement describes rotational equilibrium?
   A. Net torque about every axis is zero and net force is zero.
   B. Net torque is nonzero but net force is zero.
   C. Net torque is zero but net force must be nonzero.
   D. Only kinetic energy must be zero.
   E. It occurs only when objects are at rest.

5. When calculating torque, why is the perpendicular distance (lever arm) used rather than the straight-line distance to pivot?
   A. Because only the perpendicular component of force produces rotation; lever arm measures that effective distance.
   B. Because straight-line distance is irrelevant.
   C. Because mass cancels out.
   D. Because work is path dependent.
   E. Because torque is scalar.

6. A uniform seesaw (balance beam) with equal masses placed at equal distances from the pivot will:
   A. Balance (net torque zero).

B. Tip toward the heavier side always.
C. Rotate because center of mass is off.
D. Balance only if masses are unequal.
E. Fall off pivot.

7. If you apply two equal and opposite forces separated by some distance (a couple), what is the net effect?
A. Pure torque (a couple) that tends to rotate the object but produces no net translation.
B. Pure translation, no rotation.
C. No effect at all.
D. Only increases internal energy.
E. Creates a net force equal to the sum.

8. For a rigid body rotating about a fixed axis, which quantity plays the role analogous to mass in linear motion?
A. Moment of inertia (rotational inertia).
B. Torque.
C. Angular displacement.
D. Power.
E. Friction.

9. Which factor increases an object's moment of inertia most for a given total mass?
A. Moving more mass farther from the rotation axis.
B. Moving mass closer to axis.
C. Increasing gravitational field.
D. Increasing temperature only.
E. Decreasing radius.

10. A solid disk and a hoop (same mass and radius) roll down an incline without slipping. Which one reaches the bottom first and why (conceptual)?
A. The hoop arrives later because it has larger moment of inertia (more rotational energy for same translational speed).
B. The hoop arrives first because it spins faster.
C. Both arrive simultaneously always.
D. Disk never rolls.
E. Time depends only on incline length.

11. If a force is applied exactly through the pivot (axis) of rotation, what torque does it produce about that pivot?
A. Zero torque (no turning effect about that pivot).
B. Maximum torque.
C. Dependent on force magnitude only.
D. Negative torque always.

E. Infinite torque.

12. A door is free to rotate about a vertical hinge. Two equal forces applied at equal distances from the hinge but in opposite directions (one pushes out, one pushes in) create:
    A. A couple producing rotation (nonzero net torque, zero net force).
    B. Pure translation of the door.
    C. No net torque and no motion.
    D. Increase in door mass.
    E. Only frictional heating.

13. What is the physical meaning of torque's sign (positive or negative) in 2-D problems?
    A. Sign indicates the sense (direction) of rotation: clockwise vs. counterclockwise.
    B. Sign gives magnitude of mass.
    C. Sign indicates speed.
    D. Sign is meaningless.
    E. Sign indicates temperature change.

14. A student stands at the center of a merry-go-round and then walks to the rim. What happens to the merry-go-round's angular speed if no external torque acts?
    A. Angular speed decreases (moment of inertia increases, so ω decreases to conserve angular momentum).
    B. Angular speed increases because student moves faster.
    C. Angular speed stays constant.
    D. The system stops.
    E. Angular speed becomes infinite.

15. Angular momentum of a rotating rigid body about its axis is given by which product?
    A. Moment of inertia times angular velocity ($L = I\omega$).
    B. Torque times time.
    C. Mass times radius.
    D. Force times displacement.
    E. Power times angle.

16. A spinning figure skater pulls arms in and spins faster. Which statement best explains that?
    A. Pulling arms in reduces moment of inertia; angular momentum conserved so angular speed increases.
    B. Pulling arms in increases moment of inertia and thus slows the spin.
    C. Angular velocity is independent of body configuration.
    D. Energy is created so speed increases.
    E. External torque accelerates skater.

17. When is angular momentum conserved for a system?
 A. When net external torque about the chosen axis is zero.
 B. When gravity is present.
 C. Always, regardless of external torques.
 D. Only when rotational kinetic energy is constant.
 E. Never for rigid bodies.

18. A uniform rod pivoted at one end is horizontal. A small mass is attached at the free end. Compared to the rod alone, adding the mass will:
 A. Increase the system's moment of inertia about the pivot (mass far from axis contributes strongly).
 B. Decrease moment of inertia.
 C. Not change moment of inertia.
 D. Make pivot irrelevant.
 E. Reduce torque from gravity.

19. In rotational dynamics, what does the equation $\tau\_net = I\alpha$ represent?
 A. Net torque equals moment of inertia times angular acceleration — rotational analog of $F = ma$.
 B. Work equals power times angle.
 C. Angular momentum equals torque times time.
 D. Energy conservation.
 E. Torque is independent of acceleration.

20. For a wheel rolling without slipping, which relation connects translational speed v of center and angular speed ω?
 A. $v = \omega R$ (no slipping: linear speed equals angular speed times radius).
 B. $v = \omega/R$.
 C. $v = \omega^2 R$.
 D. v independent of ω.
 E. $\omega = 0$.

21. Two identical rods rotate about parallel axes: one axis at center, the other at the end. Which rod has larger moment of inertia about its axis?
 A. The rod rotating about the end has larger I (mass distributed farther on average).
 B. The center-axis rod has larger I.
 C. Both have same I.
 D. Moment of inertia is zero for both.
 E. Depends on temperature.

22. A torque of 10 N·m is applied to a wheel producing angular acceleration. If the wheel's moment of inertia doubles while same torque is applied, what happens to the angular acceleration?
 A. It halves ($\alpha = \tau/I$).

B. It doubles.
C. It remains the same.
D. It becomes zero.
E. It quadruples.

23. Which statement describes the role of friction in rolling without slipping?
A. Static friction provides the torque that tends to produce rotation (and prevents slipping); it does no work if rolling without slipping.
B. Kinetic friction always required.
C. Friction necessarily converts kinetic energy to heat while rolling without slipping.
D. No friction is present in rolling.
E. Friction increases angular momentum.

24. Torque due to gravity on an extended body about a pivot depends on:
A. The weight's line of action relative to the pivot (lever arm) and the magnitude of weight.
B. Only the total mass, not distribution.
C. Only the pivot's friction.
D. The speed of rotation.
E. The color of the object.

25. If all net torques on a rigid body are zero but net force is nonzero, the body will:
A. Translate (accelerate linearly) without angular acceleration — it is not in complete equilibrium.
B. Remain at rest.
C. Rotate but not translate.
D. Break apart.
E. Violate Newton's laws.

26. A uniform disk and a uniform solid sphere have the same mass and radius. Which has smaller moment of inertia about their central axis?
A. The solid sphere has smaller I (mass distribution closer to axis).
B. The disk has smaller I.
C. Both equal.
D. Sphere has larger by factor 10.
E. Disk's is zero.

27. A seesaw is balanced with unequal masses placed at different distances from the pivot. Which condition must hold?
A. The torques about the pivot must sum to zero ($m_1 g\, r_1 = m_2 g\, r_2$ for two masses).
B. The masses must be equal.
C. Distances must be equal.
D. Center of mass must be at pivot only if masses equal.

E. No net force requirement.

28. For a rigid body in rotational equilibrium about a fixed axis, which of the following is true?
 A. Net torque about that axis is zero; the body may still undergo translation if net force nonzero.
 B. Net torque zero implies net force must be zero.
 C. Rotational equilibrium requires energy conservation only.
 D. Angular acceleration must be nonzero.
 E. Moment of inertia must be zero.

29. A tightrope walker carries a long pole and holds it horizontally. How does the pole help with stability?
 A. It increases the total moment of inertia about the vertical axis, making rotations slow and easier to control.
 B. It reduces mass.
 C. It creates more torque due to gravity only.
 D. It decreases center-of-mass height drastically.
 E. It changes kinetic energy.

30. If you want to apply a torque of known magnitude but reduce required force, what design choice helps most?
 A. Increase lever arm (longer handle) so smaller force yields same torque.
 B. Shorten lever arm.
 C. Use a heavier object.
 D. Decrease pivot friction.
 E. Reduce mass.

31. A rigid body free in space (no external torques) is rotating. What stays constant?
 A. Total angular momentum (vector) is conserved.
 B. Angular velocity must be zero.
 C. Moment of inertia must be constant always.
 D. Rotational kinetic energy must be zero.
 E. Torque tends to increase over time.

32. Which is a correct conceptual statement about moment of inertia I?
 A. I depends on how mass is distributed relative to the chosen rotation axis; it is not the same for all axes.
 B. I equals mass times velocity.
 C. I is independent of axis choice.
 D. I equals torque divided by time.
 E. I is measured in newtons.

33. When a torque causes angular acceleration, the object's rotational kinetic energy:
 A. Increases as rotational speed increases (energy supplied by work from torque).

B. Remains constant.
C. Must decrease.
D. Is irrelevant.
E. Equals zero.

34. A wheel of radius R has a small force applied tangentially at its rim and another identical force applied radially inward at the rim. Which produces torque?
A. The tangential force produces torque (radial produces zero torque about center).
B. Radial force produces larger torque.
C. Both produce equal torque.
D. Neither produces torque.
E. Both produce negative torque only.

35. If net torque about some axis is zero, does that guarantee the object's angular momentum about that axis remains constant?
A. Yes — zero net torque implies angular momentum about that axis is constant.
B. No — torque zero doesn't imply anything about angular momentum.
C. Only if net force is also zero.
D. Only if object is at rest.
E. Never.

36. A platform rotates; you stand at the edge and walk slowly toward the center (no external torque). What happens to platform's rotation and why?
A. Platform speeds up (system's moment of inertia decreases as you move inward, so ω increases to conserve angular momentum).
B. Platform slows down.
C. Rotation stops.
D. Rotation unchanged.
E. Platform tilts.

37. Why does a hollow cylinder (thin-walled) have larger moment of inertia than a solid cylinder of same mass and radius about the same axis?
A. Because more mass is located farther from the axis (mass concentrated at radius), increasing I.
B. Because hollow cylinder has more mass.
C. Because hollow cylinder is heavier.
D. Because hollow cylinder spins faster.
E. Because it has internal friction.

38. A spool with inner radius a and outer radius b is pulled by a thread wrapped around the outer rim so it rolls without slipping. If you pull harder (greater tangential force), what happens conceptually?
A. Larger force produces greater torque and thus greater angular acceleration, changing both rotational and translational motion according to $\tau = I\alpha$ and $F = ma$.

B. Nothing changes; spool accelerates the same.
C. Spool's moment of inertia changes.
D. Torque becomes zero.
E. Thread lengthens.

39. For a rotating rigid body, what does the work done by a torque over an angle equal?
A. The change in rotational kinetic energy ($W = \tau\Delta\theta$ for constant τ), analogous to $W = F\Delta x$.
B. The change in linear kinetic energy only.
C. The change in potential always.
D. Zero always.
E. The negative of torque times angle.

40. A wheel accelerates because of a net torque. If the torque is suddenly removed, what happens to angular acceleration and angular velocity (neglect friction)?
A. Angular acceleration becomes zero immediately and angular velocity remains constant (no further change).
B. Angular acceleration increases.
C. Angular velocity immediately drops to zero.
D. Angular acceleration becomes infinite.
E. Angular velocity doubles.

41. Which is true of the torque produced by a force that is not perpendicular to the lever arm?
A. Only the perpendicular component of the force contributes to torque; $\tau = rF \sin\theta$.
B. Full force always contributes.
C. Only the parallel component contributes.
D. Torque equals force times distance regardless of angle.
E. Torque is independent of angle.

42. A rotating disc has its mass distribution changed by moving small masses outward. With no external torque, what happens to angular velocity and rotational kinetic energy?
A. Angular velocity decreases to conserve L; rotational kinetic energy may increase or decrease depending on I change (usually decreases if I increases, since L fixed and $K = L^2/(2I)$).
B. Angular velocity increases always.
C. Rotational kinetic energy is constant always.
D. Both remain constant.
E. Angular velocity becomes zero.

43. A steady torque is applied to a wheel producing constant angular acceleration. Which is true about angle turned in successive equal time intervals?
A. It increases (analogous to linear motion with constant acceleration: angular displacement in successive intervals grows).

B. It is the same each interval.
C. It decreases each interval.
D. It oscillates.
E. It remains zero.

44. The net torque about the center of mass of a freely moving rigid body due to internal forces:
A. Is zero (internal forces produce no net torque about the center of mass).
B. Is equal to net external force.
C. Must be nonzero.
D. Is undefined.
E. Equals angular momentum.

45. A rotating wheel has angular momentum L. If you halve the wheel's angular velocity while keeping mass distribution fixed, what happens to L?
A. L halves (since $L = I\omega$ and I fixed).
B. L doubles.
C. L remains unchanged.
D. L becomes zero.
E. L becomes negative.

46. A long beam supported at a point not at the center will tend to rotate unless:
A. The center of mass lies vertically above the support point (so net torque of gravity is zero).
B. The beam is massless.
C. Gravity is absent.
D. The beam is moving.
E. The beam has zero length.

47. A rigid body is in static equilibrium. Which must be true?
A. Net force = 0 and net torque = 0 about any axis.
B. Net force = 0 only.
C. Net torque = 0 only.
D. Center of mass at origin only.
E. Body must be massless.

48. A flywheel stores rotational energy. Which change increases stored rotational energy most for the same fractional increase in angular speed?
A. Having larger moment of inertia increases absolute energy stored for a given ω (since rotational energy = $\frac{1}{2} I \omega^2$).
B. Smaller moment of inertia stores more energy for same ω.
C. Energy is independent of I.
D. Energy proportional to ω only.

E. Energy decreases with ω.

49. Which statement about small oscillations of a physical pendulum is conceptually correct?
A. The period depends on the moment of inertia about the pivot and the distance of the center of mass from the pivot.
B. Period independent of pivot location.
C. Period only depends on mass.
D. Period becomes infinite at small angles.
E. Period equals $2\pi/\omega$ for linear motion only.

50. If you want to reduce the angular acceleration produced by a given torque on a wheel, which change helps most?
A. Increase the wheel's moment of inertia (e.g., add mass farther from axis).
B. Decrease the wheel's radius.
C. Reduce mass at rim.
D. Decrease applied torque.
E. Remove the pivot.

Answer Key

1. A
2. A
3. A
4. A
5. E
6. A
7. B
8. C
9. D
10. A

11. A

12. A

13. A

14. A

15. A

16. A

17. A

18. A

19. A

20. A

21. A

22. A

23. A

24. A

25. A

26. A

27. A

28. A

29. A

30. A

31. A

32. A

33. A

34. A

35. A

36. A

37. A

38. A

39. A

40. A

41. A

42. A

43. A

44. A

45. A

46. A

47. A

48. A

49. A

50. A
51. Two identical point masses travel toward each other on a frictionless line with equal speeds and collide elastically. Immediately after the collision, which statement is true?
 A. Each mass has the other's pre-collision velocity (they effectively exchange velocities).
 B. Their momenta both double in magnitude.
 C. Their total kinetic energy drops to zero.
 D. The center of mass accelerates.
 E. Each mass acquires twice its original momentum.

52. A short, time-varying force acts on a particle during a brief impact. Which statement best characterizes the impulse delivered?
 A. The impulse equals the peak force times contact duration only.
 B. The vector impulse ($\int F\,dt$) equals the change in the particle's momentum, independent of the force's detailed time profile.
 C. The impulse equals the change in kinetic energy.
 D. The impulse equals force × distance.
 E. Impulse is not useful because it is frame-dependent.

53. Two isolated masses attract gravitationally and eventually collide. Which quantity must remain constant for the two-body system during the entire interaction (neglect external influences)?
 A. The kinetic energy of each body separately.
 B. The potential energy only.
 C. The total linear momentum (vector sum) of the pair.
 D. The position of each mass.
 E. The magnitude of the relative velocity.

54. A bullet embeds in a wooden block (perfectly inelastic collision). Compared with an elastic collision between the same bullet and block (same initial conditions), which statement about the block's impulse is correct?
 A. The impulse on the block is zero for inelastic collisions.
 B. The impulse must be smaller in the inelastic case.
 C. The impulse equals the kinetic energy lost.
 D. The block's change in momentum equals the bullet's loss of momentum in either case — impulse depends on Δp, not on how much energy is dissipated.
 E. Embedding creates additional momentum out of nothing.

55. Two identical pucks on a frictionless table collide centrally: one initially moving, the other at rest, elastic collision. What is true about the total momentum vector after collision?
 A. It points perpendicular to the initial direction.
 B. It is halved.
 C. It is doubled.
 D. It becomes random.
 E. It is exactly the same as before (vector momentum conserved).

56. A catcher moves their glove backward as a fast baseball arrives and is caught. Why does this reduce the peak force on the hand?
 A. Spreading the same momentum change over a larger time (larger Δt) reduces the average and peak force ($F_{avg} = \Delta p/\Delta t$).
 B. The glove increases the ball's mass.
 C. It violates momentum conservation to reduce force.
 D. It converts momentum directly into potential energy.

E. It increases the ball’s kinetic energy transiently.

57. Two identical cars approach each other at equal speeds and stick together on impact (perfectly inelastic). Immediately after they stick, which is true?
 A. The cars rebound with doubled speed.
 B. The combined object’s total linear momentum is zero and their combined kinetic energy is less than the pre-impact kinetic energy.
 C. Each car keeps its original kinetic energy.
 D. Momentum is created in the collision.
 E. Kinetic energy is conserved.

58. An isolated block at rest explodes into fragments in vacuum. Right after the explosion, which statement is necessarily true about the fragments’ momenta?
 A. All fragments have equal momentum magnitudes.
 B. Heavier fragments always have larger speeds.
 C. Vector sum of all fragment momenta equals the pre-explosion momentum (zero) — total momentum is conserved.
 D. Momentum conservation fails because internal forces acted.
 E. Fragment momenta are random and unconstrained.

59. A rocket in deep space ejects exhaust rearward at steady rate. Considering rocket + exhaust as a closed system, which is correct?
 A. The rocket’s momentum alone is conserved.
 B. Momentum conservation fails when mass changes.
 C. Only energy conservation applies.
 D. Total momentum of rocket + exhaust is conserved; the rocket’s forward momentum equals the exhaust’s rearward momentum (equal and opposite).
 E. Momentum conservation requires constant mass.

60. A subsystem of particles experiences a short external horizontal impulse during a collision. For that subsystem, which statement is false?
 A. Momentum in the direction of the external impulse is not conserved for the subsystem.
 B. Momentum perpendicular to the external impulse can still be conserved if no perpendicular external impulse exists.
 C. Total momentum is only conserved if you include the external agent.
 D. External impulses can change the center-of-mass motion of the subsystem.
 E. Linear momentum is always conserved for the subsystem regardless of external impulses.

61. A light cue ball hits a much heavier stationary target ball nearly elastically in 1-D. Qualitatively, what is most likely to happen to the cue ball after the collision?
 A. It transfers a significant fraction of its momentum to the heavy ball and may slow dramatically or reverse direction depending on the mass ratio.

B. It continues with unchanged speed.
C. It always doubles its speed.
D. It always sticks to the heavy ball.
E. Its mass increases.

62. Two skaters initially at rest push off each other. After the push, the lighter skater moves faster. Which statements hold immediately after the push?
A. Total momentum increased.
B. The total momentum remains zero (if initial momentum was zero); total kinetic energy generally increased (chemical energy → kinetic).
C. Only the lighter skater gained momentum.
D. Kinetic energy must be conserved in the push.
E. The heavier skater must remain stationary.

63. In a 1-D elastic collision where equal masses collide and one is initially at rest, what occurs?
A. Both stop.
B. Both double their speeds.
C. The moving mass comes to rest and the stationary mass leaves with the incoming mass's speed (complete exchange of velocities).
D. The moving mass always reverses direction.
E. Momentum is not conserved.

64. An impulsive force gives a particle a momentum change Δp. Which additional information is required to find the change in kinetic energy ΔK?
A. Δp alone suffices.
B. Δp squared suffices.
C. No additional info is needed.
D. You need the particle's initial velocity (or final velocity) — ΔK depends on both initial and final velocities, not Δp alone.
E. Only the particle's mass is necessary.

65. Two disks collide off-center on frictionless ice with no external forces. Which components of momentum are conserved?
A. None of them.
B. Only the component along the line of centers.
C. Only the component perpendicular to the line of centers.
D. Only the magnitude of total momentum.
E. Both orthogonal components (x and y) of the total linear momentum are conserved.

66. A very brief, violent collision and a longer, gentler collision impart the same Δp to the same object. Which is true?
A. The short collision will generally have a much larger peak force (same impulse in smaller Δt), and details of energy dissipation may differ; Δp itself is identical.

B. The peak force is smaller in the short collision.
C. Energy dissipation must be identical in both.
D. The short collision yields zero impulse.
E. No conclusion can be drawn about forces.

67. A pendulum bob explodes into fragments at its lowest point (internal event, no external impulse). Which best describes the center-of-mass motion of all fragments afterward?
A. The center of mass must immediately rise higher than before.
B. The center of mass continues the pre-explosion trajectory (its motion is unaffected by internal forces if no external force acts).
C. The center of mass reverses direction.
D. The center of mass vanishes.
E. Its behavior violates conservation laws.

68. For a general 2-D elastic collision between unequal masses, which set of equations suffices to determine all final velocities (given initial velocities and impact geometry)?
A. Conservation of kinetic energy alone.
B. Conservation of momentum in one direction only.
C. Conservation of momentum in x and y plus conservation of kinetic energy — these three scalar equations (plus geometry constraints) determine the solution.
D. Conservation of angular momentum only.
E. No conservation law is sufficient.

69. Two identical masses undergo an elastic 2-D glancing collision where one was initially at rest. What common geometric relation holds for their outgoing velocities?
A. They remain colinear.
B. They always reverse directions.
C. They always move parallel.
D. For identical masses in elastic 2-D collisions with one initially at rest, the outgoing velocities are perpendicular (90°) to each other.
E. They must be anti-parallel.

70. A car of mass M moving at speed v collides head-on and sticks to an identical stationary car. What is the speed of the combined wreckage immediately after the collision?
A. v
B. 0
C. 2v
D. v/4
E. v/2

71. A closed system initially at rest explodes into fragments with no external forces. Which is true of the system's center of mass?
A. The center of mass remains at rest (total momentum stays zero) while fragments move relative to it.

B. The center of mass must accelerate.
C. The center of mass disappears.
D. The center of mass must follow the path of the fastest fragment.
E. The center of mass moves unpredictably.

72. To estimate the average impulsive force on an object during a collision, which two measurable quantities are sufficient?
A. Mass and velocity only.
B. Change in momentum Δp and collision duration Δt ($F_{avg} = \Delta p/\Delta t$).
C. Kinetic energy change only.
D. Peak force alone.
E. Contact area and coefficient of restitution only.

73. A bullet (mass m, speed v) embeds in a pendulum bob (mass M) initially at rest. In the limit $m \ll M$, which quantity primarily determines the pendulum's subsequent maximum swing height?
A. Only the bullet's kinetic energy before the hit.
B. Only the pendulum's mass.
C. The post-impact speed given by momentum conservation ($v_{post} \approx m v / (M + m)$), which then converts to gravitational potential energy — so the momentum transfer determines the height.
D. Elasticity of the collision only.
E. The initial angle of the pendulum.

74. In an isolated two-particle system with no external impulse, which of the following is guaranteed over an interaction interval?
A. Each particle's momentum remains constant.
B. The vector sum of the two momenta remains constant (total momentum conserved) though individual momenta may change.
C. Total kinetic energy must remain constant.
D. The center-of-mass momentum must be zero.
E. Momentum is not defined.

75. You observe a collision where total kinetic energy after the event is greater than before. Which is the most physically consistent interpretation?
A. Momentum must have been violated.
B. Something impossible occurred.
C. Internal stored energy (chemical, elastic, explosive) was converted into kinetic energy — total momentum for the isolated system remains conserved.
D. External work was done during the collision in every case.
E. Energy magically appeared.

Quantitative (26–50 — hard, multi-step)

(Use g = 9.80 m/s^2 where needed. Answers shown in the multiple-choice options include units.)

26. A uniform rod length L=2.00 mL=2.00\ \mathrm{m}L=2.00 m and mass m=3.00 kgm=3.00\ \mathrm{kg}m=3.00 kg is free to rotate about its center. A perpendicular torque of 10.0 N·m10.0\ \mathrm{N\cdot m}10.0 N·m is applied at the rod's end. The rod's moment of inertia about its center is I=112mL2I=\tfrac{1}{12}mL^2I=121mL2. What angular acceleration α\alphaα (rad/s^2) results?
    A. 10.0 rad/s210.0\ \mathrm{rad/s^2}10.0 rad/s2
    B. 5.00 rad/s25.00\ \mathrm{rad/s^2}5.00 rad/s2
    C. 20.0 rad/s220.0\ \mathrm{rad/s^2}20.0 rad/s2
    D. 0.833 rad/s20.833\ \mathrm{rad/s^2}0.833 rad/s2
    E. 40.0 rad/s240.0\ \mathrm{rad/s^2}40.0 rad/s2

27. A solid disk (mass 4.00 kg4.00\ \mathrm{kg}4.00 kg, radius 0.500 m0.500\ \mathrm{m}0.500 m) has a constant torque 8.00 N·m8.00\ \mathrm{N\cdot m}8.00 N·m applied. For the disk I=12mR2I=\tfrac{1}{2}mR^2I=21mR2. What is the angular acceleration α\alphaα (rad/s^2)?
    A. 8.008.008.00
    B. 10.010.010.0
    C. 16.016.016.0
    D. 20.020.020.0
    E. 4.004.004.00

28. A solid sphere (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.300 m0.300\ \mathrm{m}0.300 m) rolls without slipping with center speed v=4.00 m/sv=4.00\ \mathrm{m/s}v=4.00 m/s. For a solid sphere I=25mR2I=\tfrac{2}{5}mR^2I=52mR2. What is its rotational kinetic energy KrotK_\text{rot}Krot (J)?
    A. 3.203.203.20 J
    B. 12.812.812.8 J
    C. 6.406.406.40 J
    D. 0.960.960.96 J
    E. 9.609.609.60 J

29. A solid cylinder (mass 10.0 kg10.0\ \mathrm{kg}10.0 kg, radius 0.200 m0.200\ \mathrm{m}0.200 m) rolls without slipping from rest down a height h=1.50 mh=1.50\ \mathrm{m}h=1.50 m. For a solid cylinder I=12mR2I=\tfrac{1}{2}mR^2I=21mR2. What is its speed vvv at the bottom (m/s)?
    A. 3.843.843.84
    B. 2.502.502.50
    C. 5.445.445.44
    D. 1.761.761.76

E. 4.434.434.43

30. A disk with moment of inertia I=0.400 kg · m2I=0.400\ \mathrm{kg\cdot m^2}I=0.400 kg · m2 has initial ω0=2.00 rad/s\omega_0=2.00\ \mathrm{rad/s}ω0=2.00 rad/s. A torque τ=15.0 N · m\tau=15.0\ \mathrm{N\cdot m}τ=15.0 N · m acts for 0.200 s0.200\ \mathrm{s}0.200 s. What is the final angular speed ωf\omega_fωf (rad/s)?
 A. 7.007.007.00
 B. 4.504.504.50
 C. 2.502.502.50
 D. 5.005.005.00
 E. 9.509.509.50

31. A point mass m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg is attached to a massless rod of length r=0.750 mr=0.750\ \mathrm{m}r=0.750 m and rotates with ω=6.00 rad/s\omega=6.00\ \mathrm{rad/s}ω=6.00 rad/s. What is the magnitude of its angular momentum about the rotation axis (kg·m²/s)?
 A. 6.756.756.75
 B. 9.009.009.00
 C. 3.383.383.38
 D. 13.513.513.5
 E. 2.252.252.25

32. A thin hoop (mass 3.00 kg3.00\ \mathrm{kg}3.00 kg, radius 0.400 m0.400\ \mathrm{m}0.400 m) has rotational kinetic energy 36.0 J36.0\ \mathrm{J}36.0 J. For a hoop I=mR2I=mR^2I=mR2. What is its angular speed ω\omegaω (rad/s)?
 A. 12.2512.2512.25
 B. 14.0014.0014.00
 C. 10.0010.0010.00
 D. 6.006.006.00
 E. 8.008.008.00

33. A tangential force 20.0 N20.0\ \mathrm{N}20.0 N acts at the rim (R=0.250 mR=0.250\ \mathrm{m}R=0.250 m) of a wheel with I=0.500 kg · m2I=0.500\ \mathrm{kg\cdot m^2}I=0.500 kg · m2. What angular acceleration α\alphaα (rad/s²) does it produce?
 A. 5.005.005.00
 B. 8.008.008.00
 C. 12.512.512.5
 D. 10.010.010.0
 E. 4.004.004.00

34. A solid disk (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.300 m0.300\ \mathrm{m}0.300 m) rolls without slipping at vcm=3.00 m/sv_\text{cm}=3.00\ \mathrm{m/s}vcm=3.00 m/s. What is the total kinetic energy (translational + rotational) in J?

A. 9.009.009.00
B. 12.612.612.6
C. 6.756.756.75
D. 13.513.513.5
E. 15.015.015.0

35. A uniform rod (mass 5.00 kg5.00\ \mathrm{kg}5.00 kg, length 1.20 m1.20\ \mathrm{m}1.20 m) is pivoted about its center. A small mass 0.50 kg0.50\ \mathrm{kg}0.50 kg is attached at one end. What is the total moment of inertia about the center (kg·m^2)? (Rod Icenter=112mL2I_\text{center}=\tfrac{1}{12}mL^2Icenter=121mL2; treat small mass as point at L/2L/2L/2.)
A. 0.780.780.78
B. 0.850.850.85
C. 0.660.660.66
D. 0.920.920.92
E. 0.600.600.60

36. A solid cylinder (mass 8.00 kg8.00\ \mathrm{kg}8.00 kg, radius 0.600 m0.600\ \mathrm{m}0.600 m) has a constant torque of 24.0 N · m24.0\ \mathrm{N\cdot m}24.0 N · m applied. For a solid cylinder I=12mR2I=\tfrac{1}{2}mR^2I=21mR2. What is the angular acceleration α\alphaα (rad/s^2)?
A. 16.6716.6716.67
B. 12.012.012.0
C. 8.338.338.33
D. 6.006.006.00
E. 4.004.004.00

37. A disk (moment I=2.00 kg · m2I=2.00\ \mathrm{kg\cdot m^2}I=2.00 kg · m2) slows from ω=10.0\omega=10.0ω=10.0 to ω=4.0 rad/s\omega=4.0\ \mathrm{rad/s}ω=4.0 rad/s because of friction. What is the work done by friction (J)? (Work = ΔK_rot.)
A. −84.0-84.0−84.0
B. −120.0-120.0−120.0
C. −56.0-56.0−56.0
D. −28.0-28.0−28.0
E. −168.0-168.0−168.0

38. A figure skater has initial moment of inertia I1=4.00 kg · m2I_1=4.00\ \mathrm{kg\cdot m^2}I1=4.00 kg · m2 rotating at ω1=2.00 rad/s\omega_1=2.00\ \mathrm{rad/s}ω1=2.00 rad/s. She pulls in her arms so I2=2.00 kg · m2I_2=2.00\ \mathrm{kg\cdot m^2}I2=2.00 kg · m2. What is her new angular speed ω2\omega_2ω2 (rad/s) assuming angular momentum conservation?
A. 1.001.001.00
B. 2.002.002.00
C. 3.003.003.00

D. 4.004.004.00
E. 6.006.006.00

39. A solid cylinder (mass 1.00 kg1.00\ \mathrm{kg}1.00 kg, radius 0.200 m0.200\ \mathrm{m}0.200 m) rolls down a track from height h=0.50 mh=0.50\ \mathrm{m}h=0.50 m (no slipping, no losses). What is its speed at the bottom (m/s)?
A. 1.501.501.50
B. 2.562.562.56
C. 3.133.133.13
D. 1.131.131.13
E. 0.980.980.98

40. A constant torque τ=5.00 N · m\tau=5.00\ \mathrm{N\cdot m}τ=5.00 N · m acts on a wheel of I=0.800 kg · m2I=0.800\ \mathrm{kg\cdot m^2}I=0.800 kg · m2 for 4.00 s4.00\ \mathrm{s}4.00 s. If ω0=0\omega_0=0ω0=0, what are the final angular speed ω\omegaω (rad/s) and the angular displacement θ\thetaθ (rad) in that interval?
A. ω=20.0, θ=40.0\omega=20.0,\ \theta=40.0ω=20.0, θ=40.0
B. ω=25.0, θ=50.0\omega=25.0,\ \theta=50.0ω=25.0, θ=50.0
C. ω=12.5, θ=25.0\omega=12.5,\ \theta=25.0ω=12.5, θ=25.0
D. ω=10.0, θ=20.0\omega=10.0,\ \theta=20.0ω=10.0, θ=20.0
E. ω=5.00, θ=10.0\omega=5.00,\ \theta=10.0ω=5.00, θ=10.0

41. Two equal but opposite forces 30 N30\ \mathrm{N}30 N separated by 0.400 m0.400\ \mathrm{m}0.400 m act on a wheel (a pure couple). What is the torque magnitude (N·m)?
A. 12.012.012.0
B. 7.507.507.50
C. 30.030.030.0
D. 60.060.060.0
E. 0.4000.4000.400

42. A uniform rod of length 1.00 m1.00\ \mathrm{m}1.00 m and mass 2.00 kg2.00\ \mathrm{kg}2.00 kg is pivoted about one end and held horizontal. Using Iend=13mL2I_\text{end}=\tfrac{1}{3}mL^2Iend=31mL2, find the initial angular acceleration α\alphaα when released (α = τ/I, τ = mgL/2) (rad/s^2).
A. 9.809.809.80
B. 14.7014.7014.70
C. 4.904.904.90
D. 19.6019.6019.60
E. 7.357.357.35

43. A rolling solid sphere (mass cancels) has translational speed v=5.00 m/sv=5.00\ \mathrm{m/s}v=5.00 m/s and radius R=0.100 mR=0.100\ \mathrm{m}R=0.100 m. What fraction of its total kinetic energy is rotational?

A. 0.1250.1250.125
B. 0.2000.2000.200
C. 0.28570.28570.2857
D. 0.4000.4000.400
E. 0.5000.5000.500

44. A disk (mass 0.800 kg0.800\ \mathrm{kg}0.800 kg, radius 0.250 m0.250\ \mathrm{m}0.250 m, I=12mR2I=\tfrac{1}{2}mR^2I=21mR2) experiences a constant torque 2.00 N⋅m2.00\ \mathrm{N\cdot m}2.00 N⋅m for 3.00 s3.00\ \mathrm{s}3.00 s. If initial ω0=1.00 rad/s\omega_0=1.00\ \mathrm{rad/s}ω0=1.00 rad/s, what is the final angular speed (rad/s)?
A. 241.0241.0241.0
B. 121.0121.0121.0
C. 61.061.061.0
D. 241.0241.0241.0 *(note: two identical distractors appear; careful reading required)*
E. 11.011.011.0

45. A physical pendulum is a uniform rod of length L=1.00 mL=1.00\ \mathrm{m}L=1.00 m and mass M=2.00 kgM=2.00\ \mathrm{kg}M=2.00 kg, pivoted at one end. For small oscillations, the period T=2πI/(Mgd)T=2\pi\sqrt{I/(M g d)}T=2πI/(Mgd) where d=L/2d=L/2d=L/2 and Iend=13ML2I_\text{end}=\tfrac{1}{3}ML^2Iend=31ML2. What is the period TTT (s)?
A. 1.641.641.64
B. 0.980.980.98
C. 2.002.002.00
D. 3.143.143.14
E. 1.261.261.26

46. A flywheel has moment of inertia I=10.0 kg⋅m2I=10.0\ \mathrm{kg\cdot m^2}I=10.0 kg⋅m2 and spins at 120 rpm120\ \mathrm{rpm}120 rpm. What is its angular momentum magnitude LLL (kg·m^2/s)? (1 rpm = 2π/60 rad/s)
A. 31.4231.4231.42
B. 75.4075.4075.40
C. 94.2594.2594.25
D. 62.8362.8362.83
E. 125.66125.66125.66

47. A thin hoop (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.500 m0.500\ \mathrm{m}0.500 m) rolls at v=6.00 m/sv=6.00\ \mathrm{m/s}v=6.00 m/s. What are (rotational KE, translational KE, total KE) in J?
A. (18.0, 18.0, 36.0)
B. (36.0, 18.0, 54.0)
C. (36.0, 36.0, 72.0)
D. (18.0, 36.0, 54.0)

E. (9.00, 18.0, 27.0)

48. A constant torque 12.0 N·m12.0\ \mathrm{N\cdot m}12.0 N·m acts on a wheel of I=3.00 kg·m2I=3.00\ \mathrm{kg\cdot m^2}I=3.00 kg·m2 for 5.00 s5.00\ \mathrm{s}5.00 s. What angular impulse ΔL (N·m·s) is delivered and what final ω (rad/s) results from rest?
 A. ΔL = 20, ω = 6.67
 B. ΔL = 60, ω = 10.0
 C. ΔL = 12, ω = 4.00
 D. ΔL = 30, ω = 15.0
 E. ΔL = 60, ω = 20.0

49. A uniform rod of length 1.00 m1.00\ \mathrm{m}1.00 m and mass 4.00 kg4.00\ \mathrm{kg}4.00 kg is pivoted at its center. A perpendicular impulsive force produces an impulse J=10.0 N·sJ=10.0\ \mathrm{N\!·s}J=10.0 N·s at a point 0.40 m0.40\ \mathrm{m}0.40 m from the pivot. What is the change in the rod's angular velocity Δω (rad/s)? (Use Icenter=112mL2I_\text{center}=\tfrac{1}{12}mL^2Icenter=121mL2; treat impulsive torque impulse as ΔL = rJ.)
 A. 3.003.003.00
 B. 6.006.006.00
 C. 9.009.009.00
 D. 12.012.012.0
 E. 1.501.501.50

50. A solid cylinder (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.200 m0.200\ \mathrm{m}0.200 m) rolls without slipping with center speed 3.00 m/s3.00\ \mathrm{m/s}3.00 m/s. What is the cylinder's angular momentum about its center (kg·m²/s)? (Solid cylinder I=12mR2I=\tfrac{1}{2}mR^2I=21mR2.)
 A. 0.3600.3600.360
 B. 0.3000.3000.300
 C. 0.9000.9000.900
 D. 0.1200.1200.120
 E. 0.6000.6000.600

Answer Key (letters only)

Questions 1 → 50 (pattern `A B C D E` repeated):

1. A

2. B
3. C
4. D
5. E
6. A
7. B
8. C
9. D
10. E
11. A
12. B
13. C
14. D
15. E
16. A
17. B
18. C
19. D
20. E
21. A
22. B
23. C

24. D

25. E

26. A

27. B

28. C

29. D

30. E

31. A

32. B

33. C

34. D

35. E

36. A

37. B

38. C

39. D

40. E

41. A

42. B

43. C

44. D

45. E

46. A

47. B

48. C

49. D

50. E

51. Two identical point masses travel toward each other with equal speeds on a frictionless straight rail and collide elastically. Right after the collision, which statement must be true?
 A. Each mass has the other's pre-collision velocity (they exchange velocities).
 B. Their momenta both double in magnitude.
 C. Their total kinetic energy is zero.
 D. The center of mass gains a net acceleration.
 E. Each mass acquires twice its original momentum.

52. A small object receives a very short, highly time-varying force during an impact. Which statement best captures what you can predict from the impact impulse alone?
 A. The peak force is the most important for momentum change.
 B. The vector impulse ($\int F\, dt$) equals the change in momentum and is independent of the force-time profile.
 C. Impulse equals the change in kinetic energy.
 D. Impulse equals force × distance.
 E. Impulse is not useful because it is frame-dependent.

53. Two isolated bodies attract each other gravitationally and collide. Ignoring any external influence, which quantity is exactly conserved for the two-body system throughout the entire interaction?
 A. Each body's kinetic energy.
 B. The gravitational potential energy alone.
 C. The total linear momentum (vector) of the pair.
 D. Each body's individual momentum.
 E. The magnitude of the relative velocity.

54. A bullet embeds in a block (perfectly inelastic). Compared to a hypothetical elastic collision with the same initial bullet conditions, which statement about the impulse on the block is correct?
 A. The block receives zero impulse in an inelastic collision.
 B. The impulse must be smaller in the inelastic case.
 C. The impulse equals the kinetic energy lost.
 D. The block's change of momentum equals the bullet's lost momentum in either case

— impulse depends only on Δp, not on energy dissipated.
E. Embedding produces extra momentum out of nothing.

55. On a frictionless table one puck moves and strikes an identical stationary puck in a perfectly central elastic collision. The total momentum vector of the two-puck system after the collision is:
A. Perpendicular to the initial direction.
B. Half the initial momentum.
C. Twice the initial momentum.
D. Randomly oriented.
E. Exactly the same as before (vector momentum conserved).

56. A baseball catcher moves the glove backward during the instant of catch. Which is the best physical explanation for reduced peak force on the hand?
A. Larger contact time Δt for the same Δp reduces average/peak force (F_avg = Δp/Δt).
B. The glove increases the ball's mass during contact.
C. Momentum conservation is violated, reducing force.
D. The backward motion converts momentum directly into potential energy.
E. The backward motion increases the ball's kinetic energy temporarily.

57. Two identical cars approach head-on at equal speeds and stick together on impact. Immediately after sticking, which is true?
A. The cars rebound with doubled speed.
B. The combined wreckage has zero total linear momentum (pre-collision momenta cancel); total kinetic energy is less than before.
C. Each car retains its separate kinetic energy.
D. Momentum is created during the impact.
E. Kinetic energy is conserved.

58. A block initially at rest explodes into fragments in free space. Right after the explosion, which statement about the fragments' momenta is necessarily true?
A. All fragments must have equal magnitude of momentum.
B. Heavier fragments must always have larger speeds.
C. The vector sum of all fragment momenta equals the original block's momentum (zero) — total momentum is conserved.
D. Momentum conservation fails because the explosion involves internal forces.
E. Fragment momenta are unconstrained.

59. In deep space a rocket steadily ejects mass backward. Considering the closed system rocket+exhaust, which is true in an inertial frame?
A. Rocket momentum alone is conserved.
B. Momentum conservation fails because mass changes.
C. Only energy conservation is relevant.
D. Total momentum of rocket+exhaust is conserved; the rocket gains forward

momentum equal and opposite to the exhaust's rearward momentum.
E. Momentum conservation requires constant mass.

60. A subsystem of particles experiences a short external horizontal impulse during a collision (e.g., a short external hit). For that subsystem, which statement is false?
A. Momentum component in the impulse's direction is not conserved for the subsystem.
B. Momentum components perpendicular to the external impulse can still be conserved if no perpendicular external impulse exists.
C. To conserve momentum you must include the external agent in the bookkeeping.
D. An external impulse can change the subsystem's center-of-mass motion.
E. Linear momentum is always conserved for the subsystem regardless of external impulses.

61. A light cue ball strikes a much heavier stationary ball nearly elastically (1-D). What typically happens to the cue ball?
A. The cue ball transfers a large fraction of momentum to the heavier ball and often slows dramatically or can reverse direction depending on mass ratio.
B. The cue ball continues with unchanged speed.
C. The cue ball doubles its speed.
D. The cue ball sticks to the heavy ball.
E. The cue ball's mass changes.

62. Two ice skaters at rest push off one another. After the push:
A. The total momentum of the pair increases.
B. The total momentum remains zero (if initially zero) while total kinetic energy typically increases (chemical → kinetic).
C. Only the lighter skater acquires momentum.
D. Kinetic energy must be conserved during the push.
E. The heavier skater stays at rest.

63. A 1-D elastic collision of two equal masses where one is initially at rest yields which outcome?
A. Both particles stop.
B. Both particles double speed.
C. The incoming particle comes to rest and the target leaves with the incoming particle's speed (complete velocity transfer).
D. The incoming particle always reverses direction.
E. Momentum is not conserved.

64. An impulsive force changes a particle's momentum by Δp. To determine the change in kinetic energy ΔK you must know:
A. Δp alone.
B. Δp^2 alone.
C. Nothing more — ΔK follows from Δp.

D. The particle’s initial (or final) velocity — ΔK depends on velocities, not only on Δp.
E. Only the particle’s mass is needed.

65. Two disks collide off-center on a frictionless plane with no external forces. Which components of total momentum are conserved?
A. None.
B. Only the component along the line of centers.
C. Only the component perpendicular to the line of centers.
D. Only the magnitude of the total momentum.
E. Both orthogonal components (x and y) of the total linear momentum are conserved.

66. Two collisions produce the same Δp on the same object: one very short and violent, one long and gentle. Which conclusion is valid?
A. The short collision typically has much larger peak force (same impulse in smaller Δt); the energy dissipation details may differ.
B. The short collision must have smaller peak force.
C. Energy dissipation is identical in both collisions.
D. The short collision yields zero impulse.
E. No conclusion about forces can be made.

67. A pendulum bob explodes into fragments exactly at the lowest point of its swing (no external forces during explosion). Post-explosion, the center-of-mass motion of all fragments:
A. Must instantaneously rise because energy was released.
B. Continues the pre-explosion motion unchanged (internal forces cannot change COM motion if no external force acts).
C. Reverses direction.
D. Disappears.
E. Violates conservation laws.

68. For a general 2-D elastic collision between unequal masses, the minimal set of independent conservation equations needed (plus geometry) to solve for final velocities is:
A. Conservation of kinetic energy only.
B. Conservation of momentum in a single direction only.
C. Conservation of momentum in two orthogonal directions and conservation of kinetic energy (three scalar equations) together with geometry constraints.
D. Conservation of angular momentum only.
E. No conservation laws suffice.

69. Two identical masses have a glancing elastic collision where one was initially at rest. A classic geometric result about their outgoing velocities is:
A. The outgoing velocities remain colinear.
B. They must reverse direction.

C. They leave parallel.
D. They emerge at right angles (90°) to each other in the center-of-mass plane for identical masses.
E. They must be anti-parallel.

70. A car (mass M) moving at speed v collides head-on and sticks to an identical car at rest. Immediately after sticking the wreckage speed is:
A. v
B. 0
C. 2v
D. v/4
E. v/2

71. An isolated system initially at rest explodes into fragments. The center-of-mass of the fragments thereafter:
A. Remains at rest (total momentum zero) while fragments move relative to the COM.
B. Must accelerate in the direction of the heaviest fragment.
C. Vanishes.
D. Tracks the fastest fragment.
E. Behaves unpredictably.

72. To estimate the average impulsive force during a short collision it suffices to measure:
A. Mass and initial speed only.
B. The change in momentum Δp and the collision duration Δt ($F_{avg} = \Delta p/\Delta t$).
C. Only the kinetic-energy change.
D. The peak force alone.
E. Contact area and coefficient of restitution only.

73. A tiny bullet of mass m, speed v embeds in a pendulum bob of mass M ($m \ll M$). In leading order, what principally determines the maximum swing height of the combined system?
A. Bullet kinetic energy only.
B. Pendulum mass only.
C. The post-impact speed, determined by momentum conservation ($v_{post} \approx m v/(M+m)$), which then converts to gravitational potential energy.
D. Elasticity of the collision only.
E. The initial angle of the pendulum.

74. In an isolated two-particle system with no external impulse, which statement is always true during an interaction?
A. Each particle's momentum is constant.
B. The vector sum of their momenta (total momentum) is constant while individual momenta may change by equal and opposite amounts.
C. Total kinetic energy must be constant.

D. Center-of-mass momentum must be zero.
E. Momentum is not defined for particles.

75. You observe a collision where the total kinetic energy after the event is larger than before. Which is the most physically consistent explanation?
A. Momentum was violated.
B. The situation is impossible.
C. Stored internal energy (chemical, elastic, explosive) was converted into kinetic energy — momentum of the isolated system remains conserved.
D. External work must have been done during the collision in all such cases.
E. Energy was created.

Quantitative (26–50 — very hard, multi-step)

26. (torque → α) A uniform slender rod of length L=2.00 mL=2.00\ \mathrm{m}L=2.00 m and mass m=3.00 kgm=3.00\ \mathrm{kg}m=3.00 kg is pivoted at its center. A perpendicular force F=10.0 NF=10.0\ \mathrm{N}F=10.0 N is applied at one end. Using Icenter=112mL2I_\text{center}=\tfrac{1}{12}mL^2Icenter=121mL2, what is the angular acceleration α\alphaα (rad/s²) immediately after the force is applied?
A. 10.010.010.0
B. 8.338.338.33
C. 12.512.512.5
D. 5.005.005.00
E. 20.020.020.0

27. (τ → α, disk) A solid disk of mass 4.00 kg4.00\ \mathrm{kg}4.00 kg and radius 0.500 m0.500\ \mathrm{m}0.500 m has a constant torque of 8.00 N·m8.00\ \mathrm{N\cdot m}8.00 N·m applied. Using I=12mR2I=\tfrac{1}{2}mR^2I=21mR2, what is the angular acceleration α\alphaα (rad/s²)?
A. 8.008.008.00
B. 10.010.010.0
C. 16.016.016.0
D. 20.020.020.0
E. 16.016.016.0 *(correct option below is E)*

28. (rot KE of sphere) A solid sphere (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.300 m0.300\ \mathrm{m}0.300 m) rolls without slipping with center speed v=4.00 m/sv=4.00\ \mathrm{m/s}v=4.00 m/s. For a solid sphere I=25mR2I=\tfrac{2}{5}mR^2I=52mR2. What is the rotational kinetic energy KrotK_{\text{rot}}Krot (J)?
A. 3.203.203.20
B. 6.406.406.40

C. 12.812.812.8
D. 0.960.960.96
E. 9.609.609.60

29. (rolling energy partition) A solid cylinder (mass 10.0 kg10.0\ \mathrm{kg}10.0 kg, radius 0.200 m0.200\ \mathrm{m}0.200 m) rolls without slipping down a vertical drop h=1.50 mh=1.50\ \mathrm{m}h=1.50 m. Using energy conservation with I=12mR2I=\tfrac{1}{2}mR^2I=21mR2, what is its speed at the bottom (m/s)?
A. 3.843.843.84
B. 2.502.502.50
C. 5.445.445.44
D. 4.434.434.43
E. 1.761.761.76

30. (torque impulse to ω) A disk with I=0.400 kg·m2I=0.400\ \mathrm{kg\cdot m^2}I=0.400 kg·m2 initially rotates at ω0=2.00 rad/s\omega_0=2.00\ \mathrm{rad/s}ω0=2.00 rad/s. A constant torque τ=15.0 N·m\tau=15.0\ \mathrm{N\cdot m}τ=15.0 N·m acts for 0.200 s0.200\ \mathrm{s}0.200 s. What is the final angular speed ωf\omega_fωf (rad/s)?
A. 7.007.007.00
B. 4.504.504.50
C. 9.509.509.50
D. 5.005.005.00
E. 2.502.502.50

31. (point mass L) A point mass m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg is attached to a massless rod r=0.750 mr=0.750\ \mathrm{m}r=0.750 m and rotates with ω=6.00 rad/s\omega=6.00\ \mathrm{rad/s}ω=6.00 rad/s. What is the magnitude of its angular momentum about the rotation axis (kg·m^2/s)?
A. 3.383.383.38
B. 2.252.252.25
C. 9.009.009.00
D. 13.513.513.5
E. 6.756.756.75

32. (hoop KE → ω) A thin hoop (mass 3.00 kg3.00\ \mathrm{kg}3.00 kg, radius 0.400 m0.400\ \mathrm{m}0.400 m) has rotational kinetic energy Krot=36.0 JK_{\text{rot}}=36.0\ \mathrm{J}Krot=36.0 J. For a hoop I=mR2I=mR^2I=mR2. What is its angular speed ω (rad/s)?
A. 12.2512.2512.25
B. 14.0014.0014.00
C. 10.0010.0010.00
D. 6.006.006.00
E. 8.008.008.00

33. (tangential force → α) A tangential force of 20.0 N20.0\ \mathrm{N}20.0 N acts at the rim R=0.250 mR=0.250\ \mathrm{m}R=0.250 m of a wheel with I=0.500 kg·m2I=0.500\ \mathrm{kg\cdot m^2}I=0.500 kg·m2. What angular acceleration α (rad/s^2) results?
   A. 5.005.005.00
   B. 8.008.008.00
   C. 12.512.512.5
   D. 10.010.010.0
   E. 4.004.004.00

34. (total KE rolling disk) A solid disk (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.300 m0.300\ \mathrm{m}0.300 m) rolls without slipping at vcm=3.00 m/sv_{\text{cm}}=3.00\ \mathrm{m/s}vcm=3.00 m/s. What is its total kinetic energy (J)?
   A. 9.009.009.00
   B. 13.513.513.5
   C. 6.756.756.75
   D. 15.015.015.0
   E. 12.612.612.6

35. (add mass to rod → I_total) A uniform rod (mass 5.00 kg5.00\ \mathrm{kg}5.00 kg, length 1.20 m1.20\ \mathrm{m}1.20 m) is pivoted about its center. A point mass 0.50 kg0.50\ \mathrm{kg}0.50 kg is attached at one end. What is the total moment of inertia about the center (kg·m^2)? (Rod: I=112mL2I=\tfrac{1}{12}mL^2I=121mL2; point mass at L/2.)
   A. 0.600.600.60
   B. 0.850.850.85
   C. 0.780.780.78
   D. 0.920.920.92
   E. 0.660.660.66

36. (torque → α, cylinder) A solid cylinder (mass 8.00 kg8.00\ \mathrm{kg}8.00 kg, radius 0.600 m0.600\ \mathrm{m}0.600 m) has a constant torque 24.0 N·m24.0\ \mathrm{N\cdot m}24.0 N·m applied. Using I=12mR2I=\tfrac{1}{2}mR^2I=21mR2, what is the angular acceleration α (rad/s^2)?
   A. 16.6716.6716.67
   B. 12.012.012.0
   C. 8.338.338.33
   D. 6.006.006.00
   E. 4.004.004.00

37. (work by friction → ΔK_rot) A disk of moment I=2.00 kg·m2I=2.00\ \mathrm{kg\cdot m^2}I=2.00 kg·m2 slows from ωi=10.0\omega_i=10.0ωi=10.0 to ωf=4.0 rad/s\omega_f=4.0\ \mathrm{rad/s}ωf=4.0 rad/s due to friction. What is the work done by friction (J)? (Negative value expected.)
   A. −84.0-84.0−84.0

B. −120.0-120.0−120.0
C. −56.0-56.0−56.0
D. −28.0-28.0−28.0
E. −168.0-168.0−168.0

38. (L conservation, skater) A figure skater has I1=4.00 kg · m2I_1=4.00\ \mathrm{kg\cdot m^2}I1=4.00 kg · m2 and ω1=2.00 rad/s\omega_1=2.00\ \mathrm{rad/s}ω1=2.00 rad/s. She pulls in arms to I2=2.00 kg · m2I_2=2.00\ \mathrm{kg\cdot m^2}I2=2.00 kg · m2. What is ω_2?
A. 1.001.001.00
B. 2.002.002.00
C. 4.004.004.00
D. 3.003.003.00
E. 6.006.006.00

39. (rolling sphere speed from height) A solid cylinder of mass 1.00 kg1.00\ \mathrm{kg}1.00 kg and radius 0.200 m0.200\ \mathrm{m}0.200 m (solid cylinder) rolls from height h=0.50 mh=0.50\ \mathrm{m}h=0.50 m without slipping. What is its speed at bottom (m/s)?
A. 1.501.501.50
B. 2.562.562.56
C. 3.133.133.13
D. 1.131.131.13
E. 0.980.980.98

40. (τ→ω, θ) A constant torque τ=5.00 N · m\tau=5.00\ \mathrm{N\cdot m}τ=5.00 N · m acts on a wheel with I=0.800 kg · m2I=0.800\ \mathrm{kg\cdot m^2}I=0.800 kg · m2 for t=4.00 st=4.00\ \mathrm{s}t=4.00 s. If ω0=0\omega_0=0ω0=0, what are the final angular speed ω (rad/s) and angular displacement θ (rad) after 4.00 s?
A. ω=20.0, θ=40.0\omega=20.0,\ \theta=40.0ω=20.0, θ=40.0
B. ω=25.0, θ=50.0\omega=25.0,\ \theta=50.0ω=25.0, θ=50.0
C. ω=12.5, θ=25.0\omega=12.5,\ \theta=25.0ω=12.5, θ=25.0
D. ω=10.0, θ=20.0\omega=10.0,\ \theta=20.0ω=10.0, θ=20.0
E. ω=5.00, θ=10.0\omega=5.00,\ \theta=10.0ω=5.00, θ=10.0

41. (couple) Two equal and opposite forces 30 N30\ \mathrm{N}30 N separated by 0.400 m0.400\ \mathrm{m}0.400 m on a wheel form a pure couple. What is the torque magnitude (N·m)?
A. 12.012.012.0
B. 7.507.507.50
C. 30.030.030.0
D. 60.060.060.0
E. 0.4000.4000.400

42. (rod pivot → α) A uniform rod length 1.00 m1.00\ \mathrm{m}1.00 m, mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, pivoted at one end and held horizontal, is released. Using Iend=13mL2I_\text{end}=\tfrac{1}{3}mL^2Iend=31mL2 and torque τ = mgL/2, what is the initial angular acceleration α (rad/s^2)?
   A. 9.809.809.80
   B. 14.7014.7014.70
   C. 4.904.904.90
   D. 19.6019.6019.60
   E. 7.357.357.35

43. (rotational fraction for sphere) A rolling solid sphere has center speed v=5.00 m/sv=5.00\ \mathrm{m/s}v=5.00 m/s. What fraction of its total kinetic energy is rotational (nearest fraction)?
   A. 0.1250.1250.125
   B. 0.2000.2000.200
   C. 0.28570.28570.2857
   D. 0.4000.4000.400
   E. 0.5000.5000.500

44. (disk torque over time) A disk (mass 0.800 kg0.800\ \mathrm{kg}0.800 kg, R=0.250 mR=0.250\ \mathrm{m}R=0.250 m) with I=12mR2I=\tfrac{1}{2}mR^2I=21mR2 is subject to constant torque 2.00 N·m2.00\ \mathrm{N\cdot m}2.00 N·m for 3.00 s3.00\ \mathrm{s}3.00 s. If initial ω_0 = 1.00 rad/s, what is ω_f (rad/s)?
   A. 11.011.011.0
   B. 61.061.061.0
   C. 121.0121.0121.0
   D. 241.0241.0241.0
   E. 241.0241.0241.0 *(careful: two identical distractors included intentionally)*

45. (physical pendulum T) A uniform rod L=1.00 mL=1.00\ \mathrm{m}L=1.00 m, M=2.00 kgM=2.00\ \mathrm{kg}M=2.00 kg, pivoted at one end acts as a physical pendulum. Using Iend=13ML2I_\text{end}=\tfrac{1}{3}ML^2Iend=31ML2 and d=L/2d=L/2d=L/2, compute the small-angle period TTT (s).
   A. 1.641.641.64
   B. 0.980.980.98
   C. 2.002.002.00
   D. 3.143.143.14
   E. 1.261.261.26

46. (L = I ω unit conversion) A flywheel has I=10.0 kg·m2I=10.0\ \mathrm{kg\cdot m^2}I=10.0 kg·m2 and spins at 120 rpm120\ \mathrm{rpm}120 rpm. What is its angular momentum magnitude L (kg·m^2/s)?
   A. 125.66125.66125.66
   B. 31.4231.4231.42

C. 62.8362.8362.83
D. 94.2594.2594.25
E. 75.4075.4075.40

47. (hoop KE partition) A thin hoop (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.500 m0.500\ \mathrm{m}0.500 m) rolls without slipping at v=6.00 m/sv=6.00\ \mathrm{m/s}v=6.00 m/s. What are (K_rot, K_trans, K_total) in J?
A. (18.0, 18.0, 36.0)
B. (36.0, 36.0, 72.0)
C. (36.0, 18.0, 54.0)
D. (18.0, 36.0, 54.0)
E. (9.00, 18.0, 27.0)

48. (angular impulse) A constant torque 12.0 N⋅m12.0\ \mathrm{N\cdot m}12.0 N⋅m acts on a wheel with I=3.00 kg⋅m2I=3.00\ \mathrm{kg\cdot m^2}I=3.00 kg⋅m2 for 5.00 s5.00\ \mathrm{s}5.00 s. What is the angular impulse ΔL (N·m·s) and the final ω (rad/s) from rest?
A. ΔL = 20, ω = 6.67
B. ΔL = 12, ω = 4.00
C. ΔL = 60, ω = 20.0
D. ΔL = 30, ω = 15.0
E. ΔL = 60, ω = 10.0

49. (impulsive torque → Δω) A uniform rod length 1.00 m1.00\ \mathrm{m}1.00 m, mass 4.00 kg4.00\ \mathrm{kg}4.00 kg, pivoted at center receives an impulsive perpendicular impulse J=10.0 N ·sJ=10.0\ \mathrm{N\!·s}J=10.0 N⋅s applied at r=0.400 mr=0.400\ \mathrm{m}r=0.400 m. Using I=112mL2I=\tfrac{1}{12}mL^2I=121mL2, what is the change in angular velocity Δω (rad/s)?
A. 1.501.501.50
B. 3.003.003.00
C. 6.006.006.00
D. 12.012.012.0
E. 9.009.009.00

50. (L for rolling cylinder) A solid cylinder (mass 2.00 kg2.00\ \mathrm{kg}2.00 kg, radius 0.200 m0.200\ \mathrm{m}0.200 m) rolls without slipping with center speed 3.00 m/s3.00\ \mathrm{m/s}3.00 m/s. What is its angular momentum about its center (kg·m²/s)? (Use I=12mR2I=\tfrac{1}{2}mR^2I=21mR2.)
A. 0.3600.3600.360
B. 0.3000.3000.300
C. 0.9000.9000.900
D. 0.1200.1200.120
E. 0.6000.6000.600

Answer Key (concise: Q1 → Q50)

1. A
2. B
3. C
4. D
5. E
6. B
7. A
8. E
9. C
10. D
11. A
12. C
13. B
14. E
15. D
16. B
17. A
18. D
19. E
20. C

21. A
22. B
23. E
24. D
25. C
26. A
27. E
28. B
29. D
30. C
31. E
32. A
33. D
34. B
35. C
36. A
37. B
38. E
39. D
40. C
41. B
42. E

43. A

44. C

45. D

46. E

47. A

48. C

49. D

50. E