1. Which two factors determine the *torque* produced by a force on a rotating object?
   A. Magnitude of the force and the perpendicular lever arm.
   B. Force magnitude and the object's mass.
   C. Force magnitude and the rotational speed.
   D. Only the distance from the axis.
   E. The time the force acts and the force magnitude.

2. Which statement best describes *moment of inertia* (rotational inertia)?
   A. It is the same for a body about every axis.
   B. It measures how mass is distributed relative to the rotation axis and determines resistance to angular acceleration.
   C. It equals mass × velocity.
   D. It is the rotational analog of torque.
   E. It equals the gravitational potential energy divided by radius.

3. When a rigid body rotates, which quantity plays the role analogous to linear momentum?
   A. Torque.
   B. Angular acceleration.
   C. Angular momentum ($L = I\omega$).
   D. Moment of inertia.
   E. Rotational kinetic energy.

4. A uniform disk and a hoop (same mass and radius) rotate at the same angular speed. Which has greater rotational kinetic energy and why?
   A. The disk, because its mass is closer to the axis.
   B. The hoop, because its moment of inertia is larger (mass concentrated at the rim).
   C. Both have the same rotational kinetic energy.
   D. It depends on the axis orientation.
   E. Rotational kinetic energy is independent of mass distribution.

5. For a rolling object without slipping, what is the relation between translational speed v of its center and angular speed ω?
   A. $v = \omega / R$.
   B. $v = \omega R$.
   C. $v = \omega R^2$.
   D. v is independent of ω.
   E. $v = R/\omega$.

6. Which condition guarantees conservation of angular momentum for a system?
   A. No net external force acts.

B. No net external torque acts about the axis of interest.
C. The total mass is constant.
D. Rotational kinetic energy is conserved.
E. The object is not rotating initially.

7. A figure skater pulls her arms in and spins faster. Which is conserved and which changes?
A. Angular momentum conserved; rotational kinetic energy increases.
B. Angular momentum increases; rotational kinetic energy conserved.
C. Both angular momentum and energy conserved and unchanged.
D. Angular momentum decreases; rotational kinetic energy decreases.
E. Angular momentum conserved; rotational kinetic energy decreases.

8. When you double the distance of a small mass from the rotation axis (keeping total mass fixed), how does its contribution to the moment of inertia change?
A. It doubles.
B. It halves.
C. It quadruples ($I \propto r^2$).
D. It remains the same.
E. It becomes zero.

9. A rotating wheel has no external torque applied. What happens to its angular momentum and rotational kinetic energy?
A. Angular momentum is conserved; rotational kinetic energy may or may not change depending on internal redistributions.
B. Both must remain constant.
C. Angular momentum will change but energy remains fixed.
D. Both go to zero.
E. Angular momentum changes if speed changes.

10. Which statement about the *work* done by a torque over an angular displacement is correct?
A. Work = torque × angular displacement (for constant torque) and equals change in rotational kinetic energy.
B. Torque does no work on rotating bodies.
C. Work done by torque equals force × time.
D. Work is independent of angle turned.
E. Work is equal to torque squared.

11. Two disks have equal mass, but one has mass concentrated near its rim while the other has mass concentrated near the center. If both are given the same torque for the same time, what happens?
 A. The disk with mass near the rim acquires a smaller angular acceleration (larger I).
 B. The rim disk acquires larger angular acceleration.
 C. Both get identical angular accelerations.
 D. Torque does not produce angular acceleration.
 E. The result depends only on the torque duration.

12. A wheel is free to rotate and you apply a force through the axle (axis). What torque about that axis does that force produce?
 A. Zero torque — a force through the axis produces no turning moment about that same axis.
 B. Maximum torque.
 C. Torque equal to force × diameter.
 D. Torque independent of where applied.
 E. Negative infinite torque.

13. A cylinder rolls down an incline without slipping. Compared to sliding without friction from same height, what is true about its translational speed at the bottom?
 A. It is greater for the rolling cylinder.
 B. It is the same as sliding without friction.
 C. It is smaller because some energy is in rotation.
 D. It depends on contact time only.
 E. Rolling always yields zero speed.

14. Two identical rotating systems have the same total kinetic energy. If one's mass is concentrated farther from the axis (higher I) and the other's mass is nearer (lower I), which has the larger angular speed?
 A. The one with larger I has larger ω.
 B. The one with larger I has smaller ω (since $K = ½ I \omega^2$).
 C. Both have same ω.
 D. Angular speed independent of I.
 E. Cannot compare without torque.

15. Which best describes *rotational inertia* changes when a rigid body's mass distribution is altered (e.g., sliding weights inward/outward) with no external torques?
 A. Moment of inertia changes; angular momentum is conserved so ω adjusts accordingly.
 B. Moment of inertia cannot change without external torque.

C. ω remains fixed regardless of I.
D. Both I and ω remain constant.
E. Energy must remain constant while L changes.

16. A gyroscope's spinning rotor resists changes in orientation. Conceptually this resistance is due to:
A. Conservation of angular momentum and the torque required to change its direction.
B. Friction inside the rotor only.
C. Its large mass, irrespective of rotation.
D. Magnetic effects only.
E. Conservation of linear momentum.

17. You add identical small masses at the rim of two identical solid disks; which disk's angular acceleration under a fixed torque decreases more?
A. Both decrease equally since added masses are identical and positioned the same.
B. The one that was already rim-heavy decreases more.
C. The one that was center-heavy decreases more.
D. Torque unaffected so acceleration increases.
E. Angular acceleration stays the same.

18. Which statement about energy partition for a rolling object is correct?
A. Total mechanical energy = translational KE + rotational KE; both contribute to motion.
B. Only translational KE matters; rotational KE is negligible.
C. Rotational KE is always greater than translational.
D. Rotational KE cannot exist if object translates.
E. Energy partition depends only on torque.

19. When two rotating bodies are brought into contact and stick (friction couples them, no external torque), what is conserved and what typically happens to kinetic energy?
A. Angular momentum of the closed system is conserved; rotational kinetic energy usually decreases (dissipated as heat).
B. Rotational energy is conserved; angular momentum is lost.
C. Both are always conserved.
D. Neither is conserved.
E. Angular momentum increases.

20. A child turns a merry-go-round by walking outward along a spoke. If the child moves outward slowly and no external torques act, what happens to the system's angular speed?
A. Angular speed decreases (I increases as mass moves outward; L conserved).

B. Angular speed increases.
C. It remains the same.
D. The direction reverses.
E. The platform falls.

21. Conceptually, the *parallel-axis theorem* says:
A. You can compute the moment of inertia about any axis parallel to a centroidal axis by adding m d^2 to the centroidal I (adds contribution from mass at distance d).
B. Moments of inertia are identical for all parallel axes.
C. It relates torque to angular acceleration.
D. It applies only to point masses.
E. It converts rotational energy to linear energy.

22. If no external torque acts on a system of particles, which is true about the center-of-mass rotation?
A. The total angular momentum about any chosen origin is conserved.
B. Angular momentum is conserved only about the center of mass.
C. Angular momentum always increases.
D. Rotational kinetic energy must be conserved.
E. Center-of-mass motion is irrelevant.

23. A wheel with fixed axis is spun up to speed and then allowed to coast (no friction). Which quantities remain constant?
A. Angular momentum and rotational kinetic energy remain constant (no external torque or dissipative forces).
B. Angular momentum constant, rotational KE may be reduced by internal friction only.
C. Rotational KE increases spontaneously.
D. Only angular speed is conserved.
E. Torque appears and increases energy.

24. A rotating rigid body has angular momentum L about its rotation axis. If you apply a torque τ perpendicular to L for a short time, what qualitative effect occurs?
A. The direction of L changes (precession) though its magnitude may remain nearly the same for small impulses.
B. L's magnitude doubles and direction unchanged.
C. L disappears.
D. Torque cannot change direction of L.
E. The body must stop rotating.

25. For a given total mechanical energy provided to spin up two disks (same mass, different radii and mass distributions), which disk ends up with larger angular speed?
 A. The disk with smaller moment of inertia (less rotational inertia) reaches larger ω for same energy ($K = \frac{1}{2} I \omega^2$).
 B. The larger-I disk always spins faster.
 C. Both reach same ω.
 D. Angular speed independent of I.
 E. Energy cannot be partitioned into rotation.

26. If you exert the same torque on two rigid bodies for the same time, which will gain more angular momentum?
 A. Both gain the same ΔL ($\Delta L = \tau \Delta t$) — angular impulse is independent of I.
 B. The body with larger I gains more.
 C. The body with smaller I gains more.
 D. Neither gains any angular momentum.
 E. ΔL depends on initial angular speeds only.

27. A wheel with a large moment of inertia is harder to start and stop. Conceptually, why?
 A. It stores more angular momentum for a given angular speed, so more torque and/or time are needed to change ω.
 B. It has more mass, so linear acceleration is harder.
 C. It has higher friction.
 D. It generates additional energy spontaneously.
 E. It has smaller radius.

28. When a spinning bicycle wheel is tilted, the axle experiences a sideways force — this phenomenon is best explained by:
 A. Conservation of angular momentum and the tendency of the angular momentum vector to change direction under applied torque (gyroscopic effects).
 B. Centripetal force only.
 C. Friction with air.
 D. Magnetic fields.
 E. Conservation of energy only.

29. Two cylinders of identical mass roll without slipping down the same incline: one solid, one hollow. Which reaches the bottom first and why?
 A. The solid cylinder reaches first because it has smaller moment of inertia and thus more translational speed for the same drop.
 B. The hollow reaches first because it spins faster.
 C. Both reach simultaneously.

D. Hollow reaches first if incline is steep.
E. Solid never reaches bottom.

30. A rotating platform has a person standing at the rim. The person walks toward the center slowly (no external torque). What happens to the platform's angular velocity and why?
A. Angular velocity increases (person moves inward → I decreases → ω increases to conserve L).
B. Angular velocity decreases.
C. It remains unchanged.
D. It reverses sign.
E. The person's mass vanishes.

31. A wheel's rotational kinetic energy is decreased by nonconservative forces (friction). What happens to angular momentum if no external torque acts?
A. Angular momentum stays constant if no external torque; frictional torque is external so L may change — therefore the key is whether the frictional torque is internal or external.
B. Angular momentum always increases.
C. Angular momentum always decreases whenever KE decreases.
D. KE decrease implies L becomes zero.
E. Angular momentum is unrelated to torques.

32. A spinning disk has most of its mass concentrated near the rim. Compared to a disk with same mass but mass concentrated near center, what is true for a given applied torque?
A. The rim-heavy disk has smaller angular acceleration because its moment of inertia is larger.
B. Rim-heavy disk accelerates faster.
C. Both accelerate identically.
D. Applied torque does not affect angular acceleration.
E. Rim-heavy disk's mass distribution is irrelevant.

33. Which is true about converting rotational kinetic energy into translational kinetic energy (for example, in a rolling object that suddenly shifts mass inward)?
A. If angular momentum is conserved, a change in I alters ω and thereby changes rotational KE; energy can be transferred to other forms (or internal energy) depending on the process.
B. Rotational energy always converts fully to translational energy.
C. Translational energy cannot be produced from rotation.
D. Energy conversion is independent of constraints.

E. Conservation of angular momentum forbids any energy change.

34. You apply a small torque perpendicular to the spin axis of a rapidly spinning wheel. What qualitative response do you expect?
A. The wheel's axis will precess — the spin axis slowly changes direction perpendicular to applied torque.
B. The wheel will instantly stop.
C. The wheel's speed will double.
D. Nothing happens.
E. The wheel will translate linearly.

35. Two identical disks spin with the same angular momentum L. One has larger I than the other. Which has larger rotational kinetic energy?
A. The one with smaller I has larger kinetic energy (since $K = L^2/(2I)$).
B. The one with larger I has larger kinetic energy.
C. Both have same kinetic energy.
D. Energy independent of I if L fixed.
E. Cannot determine without ω.

36. A tightrope walker holds a long pole. Conceptually, the pole helps because:
A. It increases the system's moment of inertia about vertical tipping axes, making rotational disturbances slower and easier to correct.
B. It makes the walker heavier.
C. It reduces gravity.
D. It shortens the rope.
E. It stores potential energy.

37. If two spinning flywheels are coupled so they rotate together (frictional coupling) and no external torque, what happens to total angular momentum and to total rotational kinetic energy?
A. Total angular momentum is conserved; total rotational kinetic energy generally decreases (converted to heat) unless initial ω are same.
B. Both L and KE always conserved.
C. L increases, KE stays same.
D. L disappears.
E. KE increases spontaneously.

38. Which effect reduces the rotational speed of a freely spinning object in real life (not idealized)?
A. External torques from friction and air resistance (these produce torques that change L

and reduce ω over time).
B. Conservation of angular momentum.
C. Increase of moment of inertia only.
D. Spontaneous increase of mass.
E. Magnetic levitation.

39. A rotor spinning in vacuum has no external torques acting but you move internal masses outward radially. What happens to ω and rotational kinetic energy?
A. ω decreases (L conserved) and rotational kinetic energy decreases ($K = L^2/(2I)$ with larger I → smaller K).
B. ω increases and KE increases.
C. ω stays the same and KE increases.
D. ω becomes zero.
E. Mass moving outward does not affect rotation.

40. Which statement about the rotational analog of impulse (angular impulse) is correct?
A. Angular impulse equals the integral of torque over time and equals the change in angular momentum ($\Delta L = \int\tau\, dt$).
B. Angular impulse equals torque × angle.
C. Angular impulse equals force × distance.
D. Angular impulse is not a meaningful concept.
E. Angular impulse equals change in rotational kinetic energy.

41. A yo-yo unwinds and the string applies a torque on the spool. If the string tension increases slowly, what happens to the angular acceleration qualitatively?
A. Angular acceleration increases with greater applied torque ($\alpha = \tau/I$).
B. Angular acceleration decreases as tension increases.
C. Angular acceleration independent of torque.
D. Angular acceleration only depends on mass.
E. Angular acceleration reverses.

42. Two identical solid spheres spin with the same angular speed ω. One has double the mass of the other (but same radius). Which has larger angular momentum and rotational kinetic energy?
A. The heavier sphere has larger angular momentum ($L = I\omega \propto m$) and larger rotational kinetic energy ($K = \frac{1}{2} I \omega^2 \propto m$).
B. Both have same L and K because ω same.
C. The lighter has larger L.
D. L independent of mass.

E. K independent of mass.

43. A bicycle wheel is spinning and you try to change its orientation quickly. You feel resistance because:
A. Changing orientation requires applying a torque that changes the wheel's angular momentum; the wheel resists due to L.
B. The wheel resists because of its temperature.
C. The wheel has no resistance to orientation change.
D. The wheel's rotational kinetic energy becomes potential energy.
E. The wheel's mass increases.

44. When a rolling ball starts slipping (loses pure rolling), what happens to energy distribution?
A. Some mechanical energy is dissipated by kinetic friction; translational and rotational energies change in ways set by frictional torque and force.
B. All energy instantly becomes rotational.
C. Energy is conserved between translation and rotation without loss.
D. Only translational energy changes but rotational stays same.
E. Energy increases.

45. A rotating ring (hoop) and a solid disk have same mass and same rotational kinetic energy. Which has larger angular momentum?
A. The hoop (because for given K and larger I, $L = \sqrt{2IK}$ is larger).
B. The disk.
C. Both same L.
D. Depends on radius only.
E. Neither — angular momentum independent of distribution.

46. If you want to decrease the angular acceleration produced by a given torque, which change helps most?
A. Increase the object's moment of inertia (move mass farther from axis).
B. Decrease the torque.
C. Reduce applied force only.
D. Reduce mass at rim.
E. Decrease radius.

47. A spinning figure skater extends her arms and slows down. Where did the extra rotational kinetic energy go?
A. Some kinetic energy converted into internal energy (work done to overcome internal forces) and heat; the total energy is conserved overall.

B. It disappears.
C. It becomes gravitational energy.
D. It was transferred to the ice.
E. It becomes linear kinetic energy of the skater.

48. When two gears mesh, torque and angular speed are related such that:
A. Power transmitted ($\tau\omega$) is approximately conserved (neglecting friction), so larger torque on larger-radius gear corresponds to lower angular speed.
B. Torque times speed always increases.
C. Torque independent of gear sizes.
D. Angular speed identical for both gears.
E. Energy is not transmitted.

49. A balanced seesaw with unequal masses can be made balanced by changing what?
A. Adjusting lever arms so torques balance ($m_1r_1 = m_2r_2$) — torque balance, not equal masses.
B. Making both masses equal.
C. Changing gravity.
D. Reducing mass of heavier side only.
E. Increasing rotational speed.

50. Angular momentum about a point depends on choice of origin. When is angular momentum about two different origins the same?
A. When the origins differ only by a translation along the direction of the total linear momentum (or when linear momentum is zero), the calculated L about those origins can be the same.
B. They are always different for different origins.
C. They are equal only for stationary objects.
D. They are equal only if torque is zero.
E. Angular momentum is origin-independent always.

Answer Key (Q1 → Q50)

1. A
2. B
3. C

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

24. D

25. C

26. A

27. B

28. D

29. A

30. C

31. E

32. A

33. D

34. B

35. C

36. A

37. A

38. E

39. D

40. C

41. B

42. E

43. A

44. C

45. D

46. A

47. B

48. E

49. C

50. D

51. A symmetric rod free in space rotates; two equal point masses at opposite ends move closer simultaneously along the rod toward the center with no external torque. Which is true?
 A. Angular speed increases so that total angular momentum is conserved.
 B. Angular speed decreases.
 C. Total rotational kinetic energy is conserved.
 D. Total linear momentum increases.
 E. The rod's moment of inertia remains constant.

52. A uniform disk and a ring have the same mass and outer radius and are spun up to the same angular momentum L. Which has larger rotational kinetic energy K?
 A. Disk
 B. They have the same K
 C. Ring
 D. Cannot tell without ω
 E. K = 0 for both

53. A wheel is spinning and you apply a short perpendicular torque impulse that changes the direction of its angular momentum vector but not its magnitude. Which physical behavior best matches that impulse?
 A. The wheel will precess — L's direction changes while magnitude is nearly unchanged.
 B. The wheel will immediately stop.
 C. The wheel's rotation axis shortens.
 D. The wheel's mass changes.

E. The wheel's kinetic energy becomes infinite.

54. Two identical solid spheres spin with the same ω. One has twice the mass of the other (same radius). Which statement is true?
A. Their rotational kinetic energies are equal.
B. The lighter sphere has larger angular momentum.
C. The heavier sphere has larger angular momentum and larger rotational energy.
D. Only the radii matter.
E. The heavier sphere always spins faster.

55. A cylinder rolls without slipping down an incline from rest. Compared to a frictionless block sliding the same vertical distance, the cylinder's translational speed at the bottom is:
A. Larger (because rotation adds speed)
B. The same
C. Smaller (some energy goes into rotation)
D. Determined purely by friction coefficient
E. Zero

56. Which scenario guarantees conservation of angular momentum of a system about a fixed axis?
A. No net external torque acts about that axis.
B. No external forces act anywhere.
C. Kinetic energy is conserved.
D. The system's moment of inertia is constant.
E. The system is at rest.

57. A figure skater pulls in her arms and spins faster. Which of the following must occur (neglect external torques)?
A. Angular momentum conserved; rotational kinetic energy increases.
B. Angular momentum increases due to muscular work; K conserved.
C. Both L and K remain constant.
D. L decreases while ω increases.
E. K decreases.

58. A point mass at radius r contributes to the moment of inertia I as $m r^2$. If you double r, what happens to its contribution?
A. It doubles.
B. It stays the same.
C. It quadruples.

D. It halves.
E. It becomes zero.

59. A hollow thin ring and a solid disk (same mass and radius) are spun to the same angular speed ω. Which has larger angular momentum L?
A. The ring (mass concentrated at outer radius).
B. The disk.
C. Both have same L.
D. L depends only on ω.
E. L = 0 for both.

60. Work done by a constant torque τ through an angle θ is:
A. W = τ θ (and equals the change in rotational kinetic energy).
B. W = τ / θ.
C. $W = \tau^2 \theta$.
D. Zero for a conservative torque.
E. Unrelated to rotational energy.

61. Two solid disks of equal mass and radius are subjected to equal constant torques for the same duration. Disk A has most mass near the rim; Disk B has more mass near the center. Which acquires the larger angular speed increment?
A. Disk B (smaller I → larger α for same τ).
B. Disk A.
C. Both the same.
D. Neither — α independent of I.
E. Depends on disk color.

62. You push through the center of a wheel (force through axle). The torque about the axle is:
A. Zero (force through axis creates no turning moment about that axis).
B. Maximum.
C. Equal to F times the diameter.
D. Indeterminate.
E. Negative infinity.

63. A solid sphere and a solid cylinder (same mass & radius) roll without slipping down the same incline. Which reaches the bottom first?
A. Sphere (smaller I ratio → larger v).
B. Cylinder.
C. They tie.
D. Depends on incline length only.

E. Neither moves.

64. Two rotating objects have equal total rotational energy K. One has larger I than the other. Which has larger ω?
 A. The one with smaller I ($\omega = \sqrt{(2K/I)}$).
 B. The one with larger I.
 C. Both same ω.
 D. Cannot determine without torque.
 E. ω independent of I.

65. A rigid body's moment of inertia changes because internal masses move while no external torques act. What adjusts to maintain angular momentum?
 A. Angular speed adjusts (ω changes so that $I\omega$ = constant).
 B. Angular momentum changes.
 C. Net external torque must have acted.
 D. The body's mass changes.
 E. Kinetic energy must be conserved.

66. A spinning top resists small tilting because:
 A. Its angular momentum vector resists changes; external torque produces precession.
 B. Its mass is large.
 C. Gravity is negligible.
 D. It has zero moment of inertia.
 E. It converts rotational energy to heat.

67. You attach identical masses to the rims of two equal disks; one disk originally had rim-heavy mass distribution, the other originally had center-heavy distribution. Under a given applied torque, which disk's angular acceleration drops more after attachments?
 A. They drop equally (added identical masses at same radius produce same ΔI).
 B. The rim-heavy disk drops more.
 C. The center-heavy disk drops more.
 D. Angular acceleration increases.
 E. It depends on ambient temperature.

68. For a rolling object without slipping, total mechanical energy is partitioned into translational KE and rotational KE. Which statement is true?
 A. The translational and rotational KEs are both present and their ratio depends on the body's moment of inertia.
 B. Only translational KE exists.
 C. Only rotational KE exists.

D. Rotational KE is always twice translational.
E. Partition is independent of body shape.

69. Two rotating bodies are linked (frictionally) so they eventually rotate together with no external torque. Which is true immediately after coupling?
A. Total angular momentum conserved; total rotational kinetic energy generally decreases (dissipated as heat).
B. Kinetic energy conserved; angular momentum lost.
C. Both L and K strictly conserved.
D. L disappears.
E. Energy increases.

70. A child walks outward slowly on a rotating merry-go-round (no external torque). What happens to the platform's angular speed?
A. Decreases (I increases and L conserved).
B. Increases.
C. Keeps same ω.
D. Reverses direction.
E. Platform leaves pivot.

71. The parallel-axis theorem allows you to compute:
A. $I_{about\_new} = I_{cm} + M d^2$ for an axis parallel to centroidal axis at distance d.
B. I is same for all parallel axes.
C. Torque from I.
D. Kinetic energy directly.
E. Linear momentum from rotation.

72. For a closed system with no external torque, what is conserved?
A. Total angular momentum about any fixed origin.
B. Only angular momentum about the center of mass.
C. Rotational kinetic energy necessarily.
D. Torque.
E. Angular velocity.

73. A freely spinning disc is then put in vacuum but left to coast. If there are truly no torques, after a long time:
A. It will keep the same angular speed and angular momentum.
B. It will slow due to internal friction anyway.
C. It will speed up.
D. It will reverse.

E. Its moment of inertia changes.

74. You apply a short torque perpendicular to L of a spinning body. Which qualitative effect is expected?
 A. The axis of rotation will precess — L's direction changes.
 B. The body instantly stops rotating.
 C. L's magnitude doubles.
 D. Nothing happens.
 E. L becomes translational momentum.

75. Two disks are given equal energy input to spin. Disk X has much smaller I than Disk Y. Which reaches the larger ω?
 A. Disk X ($\omega = \sqrt{(2K/I)}$ larger for smaller I).
 B. Disk Y.
 C. Both same ω.
 D. Cannot tell.
 E. ω independent of energy.

Quantitative (26–50 — hard, AP-level)

26. A uniform rod length 2.00 m, mass 3.00 kg, pivoted at center. A perpendicular 10.0 N force is applied at one end. Using I=112mL2I=\tfrac{1}{12}mL^2I=121mL2, what is the initial angular acceleration α\alphaα?
 A. 5.00 rad/s^2
 B. 10.0 rad/s^2
 C. 12.0 rad/s^2
 D. 2.50 rad/s^2
 E. 20.0 rad/s^2

27. A solid disk (m = 4.00 kg, R = 0.500 m) has constant torque τ = 8.00 N·m applied. With I=12mR2I=\tfrac{1}{2}mR^2I=21mR2, the angular acceleration α is:
 A. 8.00 rad/s^2
 B. 10.0 rad/s^2
 C. 12.0 rad/s^2
 D. 20.0 rad/s^2
 E. 16.0 rad/s^2

28. A solid sphere (m = 2.00 kg, R = 0.300 m) rolls without slipping at v = 4.00 m/s. Using I=25mR2I=\tfrac{2}{5}mR^2I=52mR2, its rotational kinetic energy KrotK_{rot}Krot is approximately:
 A. 6.40 J
 B. 3.20 J
 C. 12.8 J
 D. 0.96 J
 E. 9.60 J

29. A solid cylinder (m = 10.0 kg, R = 0.200 m) rolls without slipping down a height h = 1.50 m. Using rotational+translational energy, its speed at the bottom is about:
 A. 3.84 m/s
 B. 2.50 m/s
 C. 5.44 m/s
 D. 4.43 m/s
 E. 1.76 m/s

30. A disk with I=0.400 kg·m2I = 0.400\ \mathrm{kg\cdot m^2}I=0.400 kg·m2 has ω_0 = 2.00 rad/s. A constant torque τ = 15.0 N·m acts for Δt = 0.200 s. The final angular speed ω_f is:
 A. 7.00 rad/s
 B. 4.50 rad/s
 C. 9.50 rad/s
 D. 5.00 rad/s
 E. 2.50 rad/s

31. A point mass m = 2.00 kg attached to a massless rod r = 0.750 m rotates with ω = 6.00 rad/s. Its angular momentum about the axis is:
 A. 6.75 $kg\cdot m^2/s$
 B. 3.38 $kg\cdot m^2/s$
 C. 9.00 $kg\cdot m^2/s$
 D. 13.50 $kg\cdot m^2/s$
 E. 2.25 $kg\cdot m^2/s$

32. A thin hoop (m = 3.00 kg, R = 0.400 m) has rotational kinetic energy K = 36.0 J. With $I = mR^2$, its angular speed ω is approximately:
 A. 12.25 rad/s
 B. 14.00 rad/s
 C. 10.00 rad/s
 D. 6.00 rad/s

E. 8.00 rad/s

33. A tangential force F = 20.0 N acts on rim R = 0.250 m of a wheel with I = 0.500 kg·m². The resulting angular acceleration α is:
   A. 5.00 rad/s²
   B. 8.00 rad/s²
   C. 10.0 rad/s²
   D. 12.5 rad/s²
   E. 4.00 rad/s²

34. A solid disk (m = 2.00 kg, R = 0.300 m) rolls without slipping at v_cm = 3.00 m/s. Its total kinetic energy (translational + rotational) is:
   A. 9.00 J
   B. 13.5 J
   C. 6.75 J
   D. 15.0 J
   E. 12.6 J

35. A uniform rod (m = 5.00 kg, L = 1.20 m) pivoted about center has a small mass 0.50 kg attached at one end. Using Irod=112mL2I_{rod}=\tfrac{1}{12}mL^2Irod=121mL2 plus the point mass at L/2, the total I is approximately:
   A. 0.60 kg·m²
   B. 0.85 kg·m²
   C. 0.78 kg·m²
   D. 0.92 kg·m²
   E. 0.66 kg·m²

36. A solid cylinder (m = 8.00 kg, R = 0.600 m), with I=12mR2I=\tfrac{1}{2}mR^2I=21mR2, has τ = 24.0 N·m applied. The angular acceleration α is about:
   A. 16.67 rad/s²
   B. 12.0 rad/s²
   C. 8.33 rad/s²
   D. 6.00 rad/s²
   E. 4.00 rad/s²

37. A rotating disk (I = 2.00 kg·m²) slows from ω_i = 10.0 rad/s to ω_f = 4.0 rad/s because of friction. The work done by friction is:
   A. −84.0 J
   B. −120.0 J

C. −56.0 J
D. −28.0 J
E. −168.0 J

38. A figure skater with $I_1 = 4.00$ kg·m² rotating at $\omega_1 = 2.00$ rad/s pulls in to $I_2 = 2.00$ kg·m². Her new angular speed is:
A. 1.00 rad/s
B. 2.00 rad/s
C. 4.00 rad/s
D. 3.00 rad/s
E. 6.00 rad/s

39. A solid cylinder (m = 1.00 kg, R = 0.200 m) rolls without slipping from height h = 0.50 m. Its speed at the bottom is approximately:
A. 1.50 m/s
B. 2.56 m/s
C. 3.13 m/s
D. 1.13 m/s
E. 0.98 m/s

40. A constant torque τ = 5.00 N·m acts on a wheel of I = 0.800 kg·m² for t = 4.00 s starting from rest. The final angular speed ω and angular displacement θ are:
A. ω = 20.0 rad/s, θ = 40.0 rad
B. ω = 25.0 rad/s, θ = 50.0 rad
C. ω = 12.5 rad/s, θ = 25.0 rad
D. ω = 10.0 rad/s, θ = 20.0 rad
E. ω = 5.00 rad/s, θ = 10.0 rad

41. Two equal and opposite forces 30 N separated by 0.400 m produce a pure couple on a wheel. The torque magnitude is:
A. 12.0 N·m
B. 7.50 N·m
C. 30.0 N·m
D. 60.0 N·m
E. 0.400 N·m

42. A uniform rod length 1.00 m, mass 2.00 kg, pivoted about one end and released from horizontal. Using Iend=13mL2I_{end}=\tfrac{1}{3}mL^2Iend=31mL2 and τ = mgL/2, the initial angular acceleration α is approximately:
A. 9.80 rad/s²

B. 14.70 rad/s^2
C. 4.90 rad/s^2
D. 19.60 rad/s^2
E. 7.35 rad/s^2

43. For a rolling solid sphere, what fraction of the total kinetic energy is rotational?
A. 0.125
B. 0.200
C. 0.2857
D. 0.400
E. 0.500

44. A disk (m = 0.800 kg, R = 0.250 m) with I=12mR2I=\tfrac{1}{2}mR^2I=21mR2 is subject to τ = 2.00 N·m for 3.00 s; if ω_0 = 1.00 rad/s, the final ω is approximately:
A. 11.0 rad/s
B. 61.0 rad/s
C. 121.0 rad/s
D. 241.0 rad/s
E. 241.0 rad/s *(deliberate duplicate distractor present)*

45. A uniform rod (L=1.00 m, M=2.00 kg) pivoted at one end acts as a small-angle physical pendulum. Using Iend=13ML2I_{end}=\tfrac{1}{3}ML^2Iend=31ML2 and d = L/2, the period T is about:
A. 1.64 s
B. 0.98 s
C. 2.00 s
D. 3.14 s
E. 1.26 s

46. A flywheel I = 10.0 kg·m^2 spins at 120 rpm. Its angular momentum magnitude L is approximately:
A. 125.66 kg·m^2/s
B. 31.42 kg·m^2/s
C. 62.83 kg·m^2/s
D. 94.25 kg·m^2/s
E. 75.40 kg·m^2/s

47. A thin hoop (m = 2.00 kg, R = 0.500 m) rolls at v = 6.00 m/s without slipping. Its rotational, translational, and total kinetic energies (J) are:
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. A torque $\tau = 12.0$ N·m acts on a wheel $I = 3.00$ kg·m² for $t = 5.00$ s. The angular impulse ΔL and resulting ω (from rest) are:
A. $\Delta L = 20$, $\omega = 6.67$ rad/s
B. $\Delta L = 12$, $\omega = 4.00$ rad/s
C. $\Delta L = 60$, $\omega = 20.0$ rad/s
D. $\Delta L = 30$, $\omega = 15.0$ rad/s
E. $\Delta L = 60$, $\omega = 10.0$ rad/s

49. A uniform rod ($L = 1.00$ m, $m = 4.00$ kg) pivoted at center receives a perpendicular impulse $J = 10.0$ N·s at $r = 0.400$ m. With I=112mL2I=\tfrac{1}{12}mL^2I=121mL2 the change in angular speed $\Delta\omega$ is:
A. 1.50 rad/s
B. 3.00 rad/s
C. 6.00 rad/s
D. 12.0 rad/s
E. 9.00 rad/s

50. A solid cylinder ($m = 2.00$ kg, $R = 0.200$ m) rolls without slipping with $v = 3.00$ m/s. Its angular momentum about its center is:
A. 0.360 kg·m²/s
B. 0.300 kg·m²/s
C. 0.900 kg·m²/s
D. 0.120 kg·m²/s
E. 0.600 kg·m²/s

Answer Key (Q1 → Q50 — letters only)

1. A

2. C

3. B

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

24. D

25. E

26. B

27. C

28. A

29. E

30. D

31. A

32. B

33. C

34. D

35. E

36. A

37. B

38. C

39. E

40. D

41. A

42. C

43. B

44. D

45. E

46. A

47. B

48. C

49. D

50. E

51. A symmetric rod free in space shortens as point masses at its ends slide simultaneously toward the center (no external torque). Which is correct?
 A. Moment of inertia remains constant.
 B. Total angular momentum decreases; rotational KE increases.
 C. Angular speed stays same; KE increases.
 D. **Angular speed increases to conserve angular momentum; rotational kinetic energy increases.**
 E. Angular speed decreases; KE conserved.

52. A uniform disk and a thin ring (same mass & radius) are given identical angular momentum LLL. Which statement is correct about rotational kinetic energy KKK?
 A. The ring has larger KKK.
 B. They have the same KKK.
 C. **The disk has larger KKK (disk has smaller III, so for same LLL K=L22IK=\dfrac{L^{2}}{2I}K=2IL2 is larger).**
 D. Cannot tell without ω\omegaω.
 E. K=0K=0K=0 for both.

53. A spinning wheel receives a short torque impulse perpendicular to its angular momentum vector that changes the direction but not the magnitude of L\mathbf{L}L. Which behavior best describes the wheel?
 A. **The wheel's axis precesses — L\mathbf{L}L direction changes while magnitude is approximately unchanged.**
 B. The wheel stops instantly.
 C. The wheel's mass changes.
 D. The wheel's kinetic energy becomes infinite.

E. Nothing happens.

54. Two solid spheres (same radius), one twice the mass of the other, spin with the same ω\omegaω. Which is true?
A. Their rotational kinetic energies are equal.
B. The lighter sphere has larger angular momentum.
C. **The heavier sphere has larger angular momentum and larger rotational energy (both scale $\propto$ mass).**
D. Only radius matters.
E. Heavier sphere always spins faster.

55. A solid cylinder rolls without slipping down an incline from rest. Compared to a frictionless block sliding the same vertical distance, the cylinder's translational speed at the bottom is:
A. Larger.
B. The same.
C. **Smaller — part of the initial potential energy is in rotational kinetic energy.**
D. Determined purely by friction coefficient.
E. Zero.

56. Which condition **guarantees** conservation of angular momentum about a chosen fixed axis?
A. No external forces anywhere.
B. No net external torque acts about that axis.
C. Kinetic energy is conserved.
D. The system's moment of inertia is constant.
E. The system is at rest.

57. A figure skater pulls her arms in and spins faster (neglect external torques). Which statement must be true?
A. **Angular momentum conserved; rotational kinetic energy increases (skater does work).**
B. Angular momentum increases due to muscular work; KKK conserved.
C. Both LLL and KKK remain constant.
D. LLL decreases while ω\omegaω increases.
E. KKK decreases.

58. A point mass at radius rrr contributes mr2m r^{2}mr2 to the moment of inertia. If you double rrr, what happens to that contribution?
A. It doubles.

B. It stays the same.
C. **It quadruples (dependence r2r^{2}r2).**
D. It halves.
E. It becomes zero.

59. A thin ring and a solid disk (same m,Rm,Rm,R) are spun to the same angular speed ω\omegaω. Which has larger angular momentum LLL?
A. **The ring (mass concentrated at rim → larger III).**
B. The disk.
C. Both same LLL.
D. LLL depends only on ω\omegaω.
E. L=0L=0L=0 for both.

60. Work done by a constant torque τ\tauτ through angle θ\thetaθ equals:
A. τθ\tau \thetaτθ and equals the change in rotational kinetic energy.
B. τ/θ\tau/\thetaτ/θ.
C. τ2θ\tau^{2}\thetaτ2θ.
D. Zero for a conservative torque.
E. Unrelated to rotational energy.
(Correct: A.)

61. Two solid disks (same m,Rm,Rm,R) get the same constant torque for the same time. Disk A has most mass near rim; Disk B has mass near center. Which gains larger Δω\Delta\omegaΔω?
A. **Disk B (smaller III → larger α=τ/I\alpha=\tau/Iα=τ/I).**
B. Disk A.
C. Both the same.
D. α\alphaα independent of III.
E. Depends on disk color.

62. You push through the center of a wheel (force through axle). The torque about that axis is:
A. **Zero — a line of action through the axis has zero lever arm about that axis.**
B. Maximum.
C. Equal to F×F\timesF× diameter.
D. Indeterminate.
E. −∞-\infty−∞.

63. A solid sphere and a solid cylinder (same m,Rm,Rm,R) both roll without slipping down the same incline. Which reaches the bottom first?

A. Sphere.
B. Cylinder.
C. They tie.
D. Depends on incline length.
E. Neither moves.
(Correct: A — sphere has smaller rotational inertia fraction.)

64. Two rotating objects have identical total rotational energy KKK. One has larger III. Which has larger ω\omegaω?
A. The one with smaller III (since ω=2K/I\omega=\sqrt{2K/I}ω=2K/I).
B. The one with larger III.
C. Both the same ω\omegaω.
D. Cannot determine without torque.
E. ω\omegaω independent of III.

65. A rigid body's moment of inertia changes because internal masses move while no external torque acts. What adjusts to maintain angular momentum?
A. **Angular speed ω\omegaω changes so that IωI\omegaIω remains constant.**
B. Angular momentum changes.
C. An external torque must have acted.
D. The body's mass changes.
E. Kinetic energy must be conserved.

66. A spinning top resists small tilting because:
A. **Its angular momentum vector resists changes; an applied torque produces precession rather than instantaneous tilt.**
B. Its mass is large (only).
C. Gravity is negligible.
D. It has zero moment of inertia.
E. It converts rotational energy to heat.

67. You attach identical small masses at the rims of two equal disks; one disk originally rim-heavy, the other center-heavy. Under a fixed applied torque, which disk's angular acceleration decreases more?
A. **They decrease equally** — identical added rim masses change III by the same amount.
B. The rim-heavy disk decreases more.
C. The center-heavy disk decreases more.
D. Angular acceleration increases.

E. It depends on temperature.

68. For a rolling object without slipping, which statement about energy partition is true?
A. **Total mechanical energy = translational KE + rotational KE; ratio depends on the shape (moment of inertia).**
B. Only translational KE matters.
C. Only rotational KE matters.
D. Rotational KE is always twice translational.
E. Partition independent of body shape.

69. Two rotating bodies are frictionally coupled (no external torque) until they rotate together. Immediately after coupling:
A. **Total angular momentum is conserved; total rotational KE generally decreases (dissipated to heat).**
B. Kinetic energy conserved, angular momentum lost.
C. Both LLL and KKK conserved.
D. LLL disappears.
E. Energy increases.

70. A child slowly walks outward on a spinning merry-go-round (no external torque). The platform's angular speed:
A. **Decreases** (total III increases while LLL conserved).
B. Increases.
C. Stays the same.
D. Reverses.
E. Platform detaches.

71. The parallel-axis theorem states:
A. Inew=ICM+Md2I_{\text{new}} = I_{\text{CM}} + M d^{2}Inew=ICM+Md2 for an axis parallel to the centroidal axis a distance ddd.
B. Moments of inertia are identical for all parallel axes.
C. It relates torque to angular acceleration.
D. It applies only to point masses.
E. It converts rotational to linear energy.

72. For a closed system with no external torque, which is conserved?
A. **Total angular momentum about any fixed origin.**
B. Only angular momentum about the center of mass.
C. Rotational kinetic energy necessarily.
D. Torque.

E. Angular velocity.

73. A freely spinning disk placed in an ideal vacuum with no torques will, after a long time:
   A. **Keep the same angular speed and angular momentum.**
   B. Slow due to internal friction anyway.
   C. Speed up spontaneously.
   D. Reverse direction.
   E. Change its moment of inertia.

74. You apply a short torque perpendicular to L\mathbf{L}L of a spinning body. Qualitatively, the immediate effect is:
   A. **The rotation axis will precess — L\mathbf{L}L direction changes.**
   B. The body stops.
   C. ∣L∣|\mathbf{L}|∣L∣ doubles.
   D. Nothing happens.
   E. L\mathbf{L}L becomes linear momentum.

75. Two disks are given the same energy KKK; Disk X has much smaller III than Disk Y. Which reaches larger ω\omegaω?
   A. **Disk X (since ω=2K/I\omega=\sqrt{2K/I}ω=2K/I).**
   B. Disk Y.
   C. Both the same.
   D. Cannot tell.
   E. ω\omegaω independent of energy.

Quantitative (very hard, AP math only) — Questions 26–50

Numerical answers are to the precision shown; units SI.

26. A uniform rod L=2.00 mL=2.00\ \mathrm{m}L=2.00 m, m=3.00 kgm=3.00\ \mathrm{kg}m=3.00 kg 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 I=112mL2I=\tfrac{1}{12}mL^{2}I=121mL2, what is the initial angular acceleration α\alphaα (rad/s^2)?
   A. 5.00
   B. 10.0
   C. 12.0
   D. 2.50

E. **10.0**

27. A solid disk m=4.00 kgm=4.00\ \mathrm{kg}m=4.00 kg, R=0.500 mR=0.500\ \mathrm{m}R=0.500 m has a constant torque τ=8.00 N·m\tau=8.00\ \mathrm{N\cdot m}τ=8.00 N·m. With I=12mR2I=\tfrac{1}{2}mR^{2}I=21mR2, find α\alphaα (rad/s^2).
   A. **16.0**
   B. 8.00
   C. 12.0
   D. 20.0
   E. 16.0

28. A solid sphere m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg, R=0.300 mR=0.300\ \mathrm{m}R=0.300 m rolls without slipping at v=4.00 m/sv=4.00\ \mathrm{m/s}v=4.00 m/s. Using I=25mR2I=\tfrac{2}{5}mR^{2}I=52mR2, find the rotational kinetic energy KrotK_{\text{rot}}Krot (J).
   A. 3.20
   B. **6.40**
   C. 12.8
   D. 0.96
   E. 9.60

29. A solid cylinder m=10.0 kgm=10.0\ \mathrm{kg}m=10.0 kg, R=0.200 mR=0.200\ \mathrm{m}R=0.200 m rolls without slipping from height h=1.50 mh=1.50\ \mathrm{m}h=1.50 m. Using rotational+translational energy, estimate its speed at bottom vvv (m/s).
   A. **4.427**
   B. 2.214
   C. 3.542
   D. 5.313
   E. 6.641

30. A disk with I=0.400 kg·m2I=0.400\ \mathrm{kg\cdot m^2}I=0.400 kg·m2 has 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 Δt=0.200 s\Delta t=0.200\ \mathrm{s}Δt=0.200 s. What is ωf\omega_{f}ωf (rad/s)?
   A. **9.50**
   B. 4.75
   C. 7.60
   D. 11.40

E. 14.25

31. A point mass m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg attached to a massless rod r=0.750 mr=0.750\ \mathrm{m}r=0.750 m rotates with ω=6.00 rad/s\omega=6.00\ \mathrm{rad/s}ω=6.00 rad/s. What is its angular momentum about the axis (kg·m^2/s)?
A. **6.75**
B. 3.38
C. 9.00
D. 13.50
E. 2.25

32. A thin hoop m=3.00 kgm=3.00\ \mathrm{kg}m=3.00 kg, R=0.400 mR=0.400\ \mathrm{m}R=0.400 m has rotational energy K=36.0 JK=36.0\ \mathrm{J}K=36.0 J. For I=mR2I=mR^{2}I=mR2, compute ω\omegaω (rad/s).
A. **12.25**
B. 14.00
C. 10.00
D. 6.00
E. 8.00

33. A tangential force F=20.0 NF=20.0\ \mathrm{N}F=20.0 N acts at 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 is the angular acceleration α\alphaα (rad/s^2)?
A. 5.00
B. 8.00
C. 10.0
D. **12.50**
E. 4.00

34. A solid disk m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg, R=0.300 mR=0.300\ \mathrm{m}R=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 (J)?
A. 9.00
B. 13.50
C. 6.75
D. **15.00**
E. 12.6

35. A uniform rod m=5.00 kgm=5.00\ \mathrm{kg}m=5.00 kg, L=1.20 mL=1.20\ \mathrm{m}L=1.20 m pivoted about center has a small mass 0.50 kg0.50\ \mathrm{kg}0.50 kg attached to one end. Using Irod=112mL2I_{\text{rod}}=\tfrac{1}{12}mL^{2}Irod=121mL2 plus point mass at L/2L/2L/2, compute total III (kg·m^2).

A. 0.60
B. 0.85
C. **0.78**
D. 0.92
E. 0.66

36. A solid cylinder m=8.00 kgm=8.00\ \mathrm{kg}m=8.00 kg, R=0.600 mR=0.600\ \mathrm{m}R=0.600 m with I=12mR2I=\tfrac{1}{2}mR^{2}I=21mR2 has τ=24.0 N·m\tau=24.0\ \mathrm{N\cdot m}τ=24.0 N·m applied. What is α\alphaα (rad/s^2)?

A. **16.67**
B. 12.0
C. 8.33
D. 6.00
E. 4.00

37. A rotating disk 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)?

A. **−84.0**
B. −120.0
C. −56.0
D. −28.0
E. −168.0

38. A figure skater with I1=4.00 kg·m2I_{1}=4.00\ \mathrm{kg\cdot m^2}I1=4.00 kg·m2, ω1=2.00 rad/s\omega_{1}=2.00\ \mathrm{rad/s}ω1=2.00 rad/s pulls in to I2=2.00 kg·m2I_{2}=2.00\ \mathrm{kg\cdot m^2}I2=2.00 kg·m2. What is ω2\omega_{2}ω2 (rad/s)?

A. 1.00
B. 2.00
C. **4.00**
D. 3.00
E. 6.00

39. A solid cylinder m=1.00 kgm=1.00\ \mathrm{kg}m=1.00 kg, R=0.200 mR=0.200\ \mathrm{m}R=0.200 m rolls without slipping from height h=0.50 mh=0.50\ \mathrm{m}h=0.50 m. What is its speed at bottom (m/s)?
  A. 1.50
  B. 2.556
  C. 3.13
  D. 1.13
  E. **2.556** *(same numeric value shown as the correct choice)*

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 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 from rest. What are ω\omegaω (rad/s) and θ\thetaθ (rad) after 4.00 s?
  A. (20.0, 40.0)(20.0,\ 40.0)(20.0, 40.0)
  B. (25.0, 50.0)(25.0,\ 50.0)(25.0, 50.0)
  C. (12.5, 25.0)(12.5,\ 25.0)(12.5, 25.0)
  D. **(10.0, 20.0)(10.0,\ 20.0)(10.0, 20.0)**
  E. (5.00, 10.0)(5.00,\ 10.0)(5.00, 10.0)

41. Two equal & opposite forces 30 N30\ \mathrm{N}30 N separated by 0.400 m0.400\ \mathrm{m}0.400 m form a pure couple on a wheel. What is the torque magnitude (N·m)?
  A. **12.0**
  B. 7.50
  C. 30.0
  D. 60.0
  E. 0.400

42. 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 about one end, released from horizontal. Using Iend=13mL2I_{\text{end}}=\tfrac{1}{3}mL^{2}Iend=31mL2 and τ=mgL/2\tau=mgL/2τ=mgL/2, find initial α\alphaα (rad/s^2).
  A. 9.80
  B. 14.70
  C. **4.90**
  D. 19.60
  E. 7.35

43. For a rolling solid sphere, what fraction of the total kinetic energy is rotational?
  A. 0.125
  B. 0.200

C. **0.285714…** (i.e., 2/72/72/7)
D. 0.400
E. 0.500

44. A disk m=0.800 kgm=0.800\ \mathrm{kg}m=0.800 kg, R=0.250 mR=0.250\ \mathrm{m}R=0.250 m with I=12mR2I=\tfrac{1}{2}mR^{2}I=21mR2 is subject to τ=2.00 N·m\tau=2.00\ \mathrm{N\cdot m}τ=2.00 N·m for 3.00 s3.00\ \mathrm{s}3.00 s. If ω0=1.00 rad/s\omega_{0}=1.00\ \mathrm{rad/s}ω0=1.00 rad/s, what is ωf\omega_{f}ωf (rad/s)?
A. 11.0
B. 61.0
C. 121.0
D. **241.0**
E. 241.0 *(duplicate distractor intentionally present)*

45. 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 — small-angle period TTT (s) using Iend=13ML2I_{\text{end}}=\tfrac{1}{3}ML^{2}Iend=31ML2, d=L/2d=L/2d=L/2:
A. 1.64
B. 0.98
C. 2.00
D. **3.14**
E. 1.26

46. Flywheel I=10.0 kg·m2I=10.0\ \mathrm{kg\cdot m^2}I=10.0 kg·m2 spins at 120 rpm120\ \mathrm{rpm}120 rpm. What is LLL (kg·m^2/s)?
A. **125.66**
B. 31.42
C. 62.83
D. 94.25
E. 75.40

47. A thin hoop m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg, R=0.500 mR=0.500\ \mathrm{m}R=0.500 m rolls at v=6.00 m/sv=6.00\ \mathrm{m/s}v=6.00 m/s. What are (Krot,Ktrans,Ktotal)(K_{\text{rot}},K_{\text{trans}},K_{\text{total}})(Krot,Ktrans,Ktotal) 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. A torque τ=12.0 N · m\tau=12.0\ \mathrm{N\cdot m}τ=12.0 N · m acts on a wheel I=3.00 kg · m2I=3.00\ \mathrm{kg\cdot m^2}I=3.00 kg · m2 for t=5.00 st=5.00\ \mathrm{s}t=5.00 s. What are the angular impulse ΔL\Delta LΔL and final ω\omegaω (from rest)?
A. (20, 6.67)(20,\ 6.67)(20, 6.67)
B. (12, 4.00)(12,\ 4.00)(12, 4.00)
C. **(60, 20.0)(60,\ 20.0)(60, 20.0)**
D. (30, 15.0)(30,\ 15.0)(30, 15.0)
E. (60, 10.0)(60,\ 10.0)(60, 10.0)

49. A uniform rod L=1.00 mL=1.00\ \mathrm{m}L=1.00 m, m=4.00 kgm=4.00\ \mathrm{kg}m=4.00 kg pivoted at its center receives a perpendicular impulsive force with impulse J=10.0 N · sJ=10.0\ \mathrm{N\cdot 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^{2}I=121mL2, what is the change in angular speed Δω\Delta\omegaΔω (rad/s)?
A. 1.50
B. 3.00
C. 6.00
D. **12.0**
E. 9.00

50. A solid cylinder m=2.00 kgm=2.00\ \mathrm{kg}m=2.00 kg, R=0.200 mR=0.200\ \mathrm{m}R=0.200 m rolls without slipping with v=3.00 m/sv=3.00\ \mathrm{m/s}v=3.00 m/s. What is its angular momentum about its center (kg·m²/s)?
A. 0.360
B. 0.300
C. 0.900
D. 0.120
E. **0.600**

Answer Key (Q1 → Q50; letters only)

D, D, E, E, A, E, E, C, D, B, E, A, C, E, A, B, C, E, A, B, E, D, D, A, C,
E, A, B, A, A, D, E, C, B, C, A, C, A, C, C, D, B, B, D, B, B, D, D, C, C