1. Which best defines linear momentum for a single particle?
   A. The product of mass and velocity.
   B. The product of mass and speed squared.
   C. The change in kinetic energy per unit time.
   D. The integral of force over distance.
   E. Mass times acceleration.

2. Impulse delivered to an object equals which of the following?
   A. Force × distance.
   B. The change in the object's momentum (Δp).
   C. The change in kinetic energy.
   D. The power integrated over time.
   E. The average force only.

3. In a short, strong collision between two billiard balls, why is impulse a more useful concept than force at any instant?
   A. Because impulse depends only on displacement, not force.
   B. Because instantaneous forces are usually zero in collisions.
   C. Because impulse aggregates the large, time-varying force into a single, well-defined change in momentum.
   D. Because collisions conserve energy but not momentum.
   E. Because impulse equals kinetic energy change.

4. Two isolated particles collide elastically in one dimension. Which statement about their total momentum and total kinetic energy is correct?
   A. Total momentum is conserved; total kinetic energy is not.
   B. Both total momentum and total kinetic energy are conserved.
   C. Total momentum changes sign; kinetic energy is conserved.
   D. Momentum is conserved only if masses are equal.
   E. Momentum is not conserved because forces act during collision.

5. A stationary object explodes into two fragments that fly apart. Concerning momentum, which is true?
   A. The vector sum of the fragments' momenta equals the original object's momentum (zero).
   B. The heavier fragment must have greater speed because it has more mass.
   C. Momentum is created by the explosion and is not conserved.
   D. Each fragment's momentum is zero individually.
   E. Momentum conservation does not apply because internal forces acted.

6. Two carts of different masses collide and stick together (perfectly inelastic). Compared to a perfectly elastic collision, which is true about kinetic energy?
   A. More kinetic energy is conserved in the inelastic collision.

B. Less kinetic energy is conserved — some is converted into internal energy.
C. Kinetic energy is always the same regardless of collision type.
D. Kinetic energy becomes negative after sticking.
E. Kinetic energy is transferred entirely into potential energy.

7. A person catches a fast baseball with their bare hands. Which technique reduces discomfort most effectively?
A. Pull the hands rigidly backward as the ball arrives so momentum change is instantaneous.
B. Allow the hands to move backward while catching (increasing collision time) to reduce average force.
C. Push the ball forward while catching to cancel its momentum.
D. Keep hands stationary to maximize impulse.
E. Reduce the mass of the ball before catching.

8. Consider two identical cars heading toward each other at equal speeds that collide head-on and stick. What is true about their total momentum after collision?
A. It equals twice the momentum of one car.
B. It is zero (they come to rest together) because their momenta were equal and opposite before collision.
C. It equals the momentum of the heavier car.
D. It equals the sum of their kinetic energies.
E. Momentum is undefined in this case.

9. In a system of particles with only internal forces (no external forces), which quantity is always conserved?
A. Total kinetic energy.
B. Total linear momentum (vector sum).
C. Total power.
D. Individual particle momenta.
E. Total impulse.

10. A rocket in free space ejects propellant mass backwards. How does the rocket's momentum change and what principle explains it?
A. Rocket momentum decreases because momentum is not conserved.
B. Rocket momentum increases forward due to equal and opposite reaction from expelled propellant (momentum conservation / Newton's third law).
C. Rocket momentum stays zero always.
D. Momentum is transferred to heat only.
E. Momentum increases only if the rocket gains mass.

11. A person standing on ice throws a heavy object horizontally. Which is a correct consequence (neglect friction)?
A. The person remains stationary because action–reaction forces cancel internally.

B. The person recoils backward — the person+object system's center of mass stays at rest, so person moves opposite the thrown object to conserve momentum.
C. The person moves forward in the same direction as thrown object.
D. Momentum is not conserved because the person pushed into the ice.
E. Throwing changes the person's mass so momentum is not defined.

12. A glancing (oblique) collision between two disks in a frictionless plane generally exchanges which components of momentum?
A. Only components parallel to the line of centers change (normal component); tangential components are unchanged if no friction/torque.
B. Only tangential components change; normal components always conserved.
C. Both components are always completely randomized.
D. Momentum components change only if masses are equal.
E. Momentum components can't be defined in two dimensions.

13. In an elastic head-on collision between two unequal masses where the smaller mass strikes a larger stationary mass, what often happens to the smaller mass's speed?
A. It necessarily speeds up.
B. It typically reverses and may rebound with speed comparable to its initial speed, depending on mass ratio (it can even reverse direction).
C. It always stops and transfers all momentum.
D. It always passes through the larger mass.
E. Its mass changes, altering momentum.

14. A child on a swing at rest is pushed twice: once with a quick hard push and once with a gentler push applied over longer time such that the impulse is the same in both cases. Which statement about the child's momentum immediately after each push is true?
A. The momentum change is the same (impulse equal), but the average force differs.
B. The momentum change is larger for the hard push because force was larger.
C. Momentum change depends on push direction only, not time.
D. The child gets more kinetic energy from the short hard push always.
E. Momentum change is zero if the swing returns.

15. Two identical pucks collide elastically on a frictionless ice surface; puck A is moving and puck B is stationary. After an off-center elastic collision, puck B moves off at some angle and puck A often moves at a right angle to B. Which principle explains this well-known geometry?
A. Conservation of linear momentum only.
B. Conservation of kinetic energy only.
C. Combination of momentum and energy conservation for identical masses yields perpendicular outgoing velocities in 2-D elastic collisions (one classic result).
D. Newton's second law forbids perpendicular deflection.
E. It's due to friction.

16. A mass sliding without friction passes through a stationary spring and compresses it, then is released and comes back to its original location. Considering momentum, which statement is correct for the block-spring system (isolated horizontally)?
    A. The block's momentum is conserved at all times because spring exerts internal forces; but block's momentum changes while spring and block exchange momentum internally — total momentum of block+spring system remains constant (zero).
    B. The block's momentum is always zero because it returns.
    C. Momentum is not defined when springs act.
    D. External forces produce net momentum during compression.
    E. Momentum is converted into potential and is not conserved.

17. A 2-D explosive breakup: a stationary object splits into three fragments that fly apart. Which must be true?
    A. The vector sum of the three fragments' momenta equals the original momentum (zero).
    B. The magnitudes of the fragments' momenta must all be equal.
    C. The center of mass of fragments accelerates after explosion.
    D. Momentum conservation does not apply because internal forces caused the breakup.
    E. One fragment must remain at rest.

18. Two equal and opposite external impulses are applied simultaneously to a two-particle isolated system (one impulse on each particle). What is the net impulse on the system and how does the center-of-mass motion respond?
    A. The net impulse is zero, so the center-of-mass momentum is unchanged.
    B. The net impulse is twice a single impulse and COM moves accordingly.
    C. The net impulse is undefined.
    D. The COM accelerates opposite to the impulses.
    E. Internal forces change the COM momentum.

19. A cue ball (mass m) strikes a heavier stationary ball (mass 4m) in an elastic head-on collision. Which qualitative outcome is most likely for the cue ball after the collision?
    A. The cue ball always comes to rest and the heavier ball takes all kinetic energy.
    B. The cue ball rebounds backward with nearly the same speed.
    C. The cue ball may lose most of its speed and continue forward slowly or reverse depending on masses and elasticity — generally it transfers a significant fraction of its momentum to the heavier ball.
    D. The cue ball doubles its speed.
    E. Momentum is not transferred due to mass difference.

20. A skateboarder jumps off a moving platform in the same direction as platform motion. The platform recoils. Which statement about momentum and center of mass is correct assuming no external horizontal forces?
    A. Momentum of the skateboarder+platform system is conserved; the center of mass continues moving with constant velocity (unchanged) after internal action.

B. The center of mass stops moving because skateboarder left.
C. Platform gains momentum equal to skateboarder’s final momentum only.
D. Center of mass accelerates forward spontaneously.
E. Momentum is not conserved because skateboarder jumped.

21. Two identical masses approach each other with equal speeds but along slightly different lines so they just collide glancingly. Which quantity is easiest to use to predict post-collision speeds and directions?
A. Kinetic energy alone.
B. Linear momentum vector conservation (x and y components) and if elastic then energy conservation too.
C. Potential energy conservation.
D. Power balance.
E. Center-of-mass speed alone.

22. A freight car collides with a lighter stationary wagon and sticks. Which is true about the final speed of the combined system compared to the initial freight car speed?
A. The final speed is larger than the freight car’s initial speed.
B. The final speed equals the freight car’s initial speed.
C. The final speed is smaller because momentum is shared with the wagon (inelastic sticking reduces speed).
D. Final speed is zero always.
E. Final speed is independent of masses.

23. In 2-D collisions, why must momentum conservation be applied separately in two orthogonal directions?
A. Because momentum magnitudes add as scalars only.
B. Because force directions during collision are unpredictable otherwise.
C. Because vector conservation requires equality of corresponding components — conserving vector momentum is equivalent to conserving each component independently.
D. Because kinetic energy conservation applies only in one direction.
E. Because angular momentum replaces linear momentum in 2-D.

24. A child at rest throws a ball sideways while standing on frictionless ice and moves backward. Which statement about the center of mass is correct immediately after the throw?
A. The center of mass of the child+ball system remains at the same place because no external horizontal force acts.
B. The center of mass accelerates in the ball’s direction.
C. The center of mass moves backward with the child.
D. The center of mass disappears.
E. The center of mass gains kinetic energy only.

25. Two cars with equal momentum but different masses collide with identical rigid walls and rebound elastically. Which car experiences the larger average force during the brief collision?
 A. The lighter car because it undergoes a larger change in velocity for the same momentum (Δv larger), so average force (impulse/time) tends to be larger if collision time is similar.
 B. The heavier car because heavier implies heavier forces.
 C. Both feel identical forces because momentum equal.
 D. Neither feels force because walls are rigid.
 E. Force depends only on speed, not mass.

26. A bullet embeds in a block at rest (perfectly inelastic). Which quantity is conserved during the embedding collision (ignore external forces)?
 A. Total kinetic energy.
 B. Linear momentum of the bullet+block system.
 C. Mechanical energy (kinetic + potential).
 D. Momentum only in center-of-mass frame.
 E. Neither energy nor momentum is conserved.

27. Two ice skaters push off each other; one is much more massive than the other. After push, which skater has the larger speed and which has larger momentum?
 A. The lighter skater has the larger speed; both have equal and opposite momentum magnitudes (momenta equal in magnitude).
 B. The heavier skater has larger speed and larger momentum.
 C. Both have equal speeds and equal momenta.
 D. Lighter skater has larger momentum.
 E. Momentum is created for one skater only.

28. Why is momentum conserved in an isolated system even when kinetic energy is not?
 A. Momentum conservation follows from Newton's third law (internal forces between particles come in equal and opposite pairs), independent of energy lost to internal degrees of freedom.
 B. Because energy is always created in collisions.
 C. Because momentum is scalar while energy is vector.
 D. Because external forces are always present.
 E. Momentum isn't conserved in that case.

29. A puck moving east collides and sticks to another puck initially moving north. After collision the combined puck moves in which direction relative to east and north?
 A. Exactly east.
 B. Exactly north.
 C. In a direction between east and north determined by the vector sum of the initial momenta (diagonal direction).
 D. South of east.

E. Random direction unrelated to initial momenta.

30. Which scenario violates conservation of linear momentum?
 A. Two particles collide in empty space with no external forces — momentum conserved.
 B. A ball rolls on a table and collides with wall — momentum conserved if consider ball+earth system (external impulse via wall).
 C. A car collides with wall and sticks — linear momentum of car alone is not conserved because external impulse from wall acts.
 D. Two ice skaters push each other away — momentum conserved for skaters.
 E. None — linear momentum is always conserved in any subsystem.

31. In a center-of-mass (COM) frame, the total momentum of a two-particle isolated system is:
 A. Nonzero and equals the lab frame momentum.
 B. Zero by definition of the COM frame.
 C. Equal to the sum of kinetic energies.
 D. Undefined.
 E. Equal to the impulse applied.

32. A long railroad car is hit near one end by a small projectile that sticks; how does the car's center of mass motion (ignoring external forces) respond?
 A. The center of mass begins to move as if the projectile's momentum were distributed over the whole car — the combined system's momentum equals the projectile's initial momentum.
 B. Only the struck end moves; COM stays fixed.
 C. The car rotates instead of translating.
 D. The center of mass disappears.
 E. The car's center of mass moves backward.

33. Two identical masses approach each other at equal speeds and collide elastically head-on. What is the final state immediately after collision?
 A. Both stop and remain at rest.
 B. They pass through each other without interacting.
 C. They exchange velocities; each reverses direction so that their speeds remain the same but their identities swap (classical identical-mass result).
 D. They coalesce and stick.
 E. They both gain energy from nowhere.

34. A particle is subjected to an external impulse. How does that affect the particle's momentum and kinetic energy?
 A. The impulse equals change in momentum; kinetic energy change depends on the vector change and initial velocity (energy change not determined solely by impulse magnitude).

B. Impulse equals change in kinetic energy always.
C. Impulse changes momentum but never kinetic energy.
D. Impulse converts momentum into potential energy.
E. Impulse creates mass.

35. Two cars of equal mass, one at rest and one moving, collide elastically. After collision the initially moving car comes to rest and the initially stationary car moves away. Which conservation laws explain this result?
A. Conservation of charge.
B. Conservation of momentum and conservation of kinetic energy (elastic collision) explain the velocity swap for equal masses.
C. Conservation of power.
D. Conservation of force.
E. Conservation of impulse only.

36. A system of two masses connected by a light rod rotates freely in space. If one mass is suddenly detached (internal event), which best describes the total linear momentum of the remaining system?
A. Total linear momentum changes because mass left.
B. Total linear momentum of the isolated system (all fragments and detached mass) is conserved; the remaining subsystem's momentum may change because mass left.
C. Momentum is not defined for rotating bodies.
D. Linear momentum becomes angular momentum.
E. Momentum is converted to energy.

37. A ball bounces elastically off a wall. Compared to the wall, which impulse magnitude does the ball receive and why?
A. Ball receives no impulse because wall is rigid.
B. Ball receives an impulse equal in magnitude to the change in the ball's momentum; wall receives equal and opposite impulse (but its huge mass yields negligible velocity change).
C. Ball receives twice its initial momentum always.
D. Ball's impulse equals the impulse of gravity.
E. Ball gains energy but not impulse.

38. A 1-D collision is analyzed in the center-of-mass frame. If the collision is elastic, what is true about the particles' speeds before and after collision in the COM frame?
A. Speeds are unchanged in magnitude (they may reverse signs), because the COM frame has symmetric constraints and kinetic energy is conserved.
B. Speeds double.
C. Speeds become zero.
D. Speeds become infinite.
E. Speeds are unrelated before and after.

39. A ball rolling on a horizontal table collides with a much heavier, stationary block and bounces back with reduced speed. Which best explains the bounce direction and speed reduction?
 A. Conservation of kinetic energy only.
 B. External impulse from the table ground.
 C. Momentum transfer to the heavy block plus some energy lost to internal deformation or sound, so ball reverses with lower speed.
 D. Ball gains speed from the block.
 E. The collision creates momentum out of nothing.

40. A moving object collides elastically with a stationary object of much larger mass. Which rough qualitative outcome is expected for the small moving object after collision?
 A. The small object typically reverses direction and loses a large fraction of its speed (if mass ratio extreme, it nearly bounces back with similar speed but opposite direction depending on elasticity).
 B. Small object passes through the large object.
 C. Small object's speed increases.
 D. Small object disappears.
 E. Momentum is split equally.

41. A system of particles has total momentum zero in the lab frame. If an internal process causes particles to fly apart, what can be said about the center-of-mass motion of the system?
 A. The center of mass remains at rest (since total momentum stays zero).
 B. The center of mass must accelerate.
 C. The center of mass disappears.
 D. The center of mass moves according to internal forces only.
 E. Center of mass depends on kinetic energy only.

42. Two cars moving in opposite directions have equal magnitudes of momentum. If they stick in a head-on collision, what will be the velocity of the combined wreckage?
 A. It will move in the direction of the heavier car.
 B. It will move in the direction of the car with greater kinetic energy.
 C. It will remain at rest because momenta cancel exactly (equal and opposite).
 D. It will move unpredictably.
 E. It will rotate instead of translating.

43. A bullet of mass m strikes and sticks in a block of mass 4m at rest. Which statement about the final speed v_f of the bullet+block compared to the bullet's initial speed v_i is correct (qualitative)?
 A. vf=viv_f = v_ivf=vi (no change)
 B. vf>viv_f > v_ivf>vi because combining masses accelerates system
 C. vf=mm+4mvi=15viv_f = \dfrac{m}{m+4m}v_i = \dfrac{1}{5}v_ivf=m+4mmvi=51vi — speed reduces due to sharing momentum among larger mass.

D. vf=5viv_f = 5 v_ivf=5vi
E. vf=0v_f = 0vf=0

44. A ball of mass m moving right at speed v collides elastically with an identical ball moving left at speed v. After collision, what is the total momentum of the two-ball system?
A. 2mv2mv2mv to the right.
B. Zero (since equal and opposite momenta cancel).
C. 2mv2mv2mv to the left.
D. Depends on collision details.
E. Equal to total kinetic energy.

45. An astronaut in deep space throws a tool away. Which is true about the tool+astronaut system's center of mass?
A. The center of mass moves in a straight line with constant velocity (no external forces), independent of the internal throw.
B. The center of mass accelerates in the direction of the thrown tool.
C. The center of mass stays at the astronaut's location.
D. The center of mass disappears after the throw.
E. The center of mass's motion depends on tool's shape.

46. A particle initially at rest explodes into three fragments of masses m, m, and 2m. Which vector relation among fragment momenta must hold immediately after explosion (p1, p2, p3 denote fragment momenta)?
A. p1+p2+p3=0\mathbf{p}_1 + \mathbf{p}_2 + \mathbf{p}_3 = \mathbf{0}p1+p2+p3=0 (vector sum zero — conservation of momentum).
B. ∣p1∣=∣p2∣=∣p3∣|\mathbf{p}_1| = |\mathbf{p}_2| = |\mathbf{p}_3|∣p1∣=∣p2∣=∣p3∣ (magnitudes equal).
C. p3=p1\mathbf{p}_3 = \mathbf{p}_1p3=p1 only.
D. p1×p2=0 \mathbf{p}_1 \times \mathbf{p}_2 = \mathbf{0}p1×p2=0
E. None — explosion violates momentum.

47. Two gliders on a frictionless air track collide elastically. Why is it convenient to analyze velocities in the center-of-mass frame?
A. Because in the COM frame total momentum is zero, making the symmetry of elastic collisions (equal and opposite momenta before and after) easier to exploit.
B. Because energy is not conserved in COM.
C. Because COM frame eliminates the need for mass.
D. Because friction is obvious in the COM frame.
E. Because impulse is zero in COM.

48. A moving object hits a stationary object and causes it to move at right angles to the original direction of motion after the collision. Which statement is true about momentum components?
A. Momentum in the original direction is no longer important.

B. Total momentum vector is conserved, so the vector sum of components (original and perpendicular) after collision equals the initial momentum vector.
C. Momentum perpendicular to initial direction is generated from nothing.
D. Momentum is conserved only in magnitude, not direction.
E. Momentum components are equal after collision.

49. A ball of mass m moving with speed 2v collides and sticks to an identical ball initially moving with speed v in the same direction. What is the speed of the combined mass after collision (qualitative)?
A. 32v\dfrac{3}{2}v23v
B. 12v\dfrac{1}{2}v21v
C. 34v\dfrac{3}{4}v43v
D. 23v\dfrac{2}{3}v32v
E. vvv

50. A system of particles has net external force zero. If one particle's momentum increases during some interval, what must be true about other particles?
A. Some other particle(s) must have momentum change such that total momentum remains constant — vector sum of all momentum changes equals zero.
B. No other particle changes momentum.
C. Total energy must increase.
D. Total kinetic energy must decrease.
E. Momentum conservation is violated.

Answer Key (Q1 → Q50)

1. A
2. B
3. C
4. B
5. A
6. B
7. B
8. C

9. B

10. E

11. C

12. E

13. B

14. A

15. D

16. D

17. A

18. C

19. B

20. E

21. E

22. A

23. C

24. D

25. B

26. B

27. A

28. D

29. C

30. E

31. C

32. B

33. E

34. D

35. A

36. D

37. E

38. C

39. A

40. B

41. A

42. C

43. B

44. E

45. C

46. D

47. B

48. C

49. D

50. A

51. (A) Two particles, equal mass, approach each other with equal speeds on a frictionless line and collide elastically. Which statement is always true immediately after the collision?
 A. Each particle's speed is unchanged in magnitude (they effectively exchange velocities).

B. They necessarily stick together.
C. Total kinetic energy is lost.
D. Momentum is not conserved.
E. The center of mass acquires a net acceleration.

52. (B) An impulse delivered to a body is best described as:
A. The time integral of displacement.
B. The time integral of force, equal to the change in momentum.
C. The instantaneous force at contact.
D. The energy transferred per collision.
E. The rate of work done.

53. (C) Two isolated masses attract each other gravitationally and collide. Treating their mutual gravitational force during approach as internal, which quantity is conserved for the two-body system?
A. Mechanical energy only.
B. Mechanical energy and momentum are both necessarily conserved.
C. Total linear momentum (vector) of the system.
D. Individual particle momentum separately.
E. The center of mass position.

54. (D) A bullet embeds in a wooden block at rest (perfectly inelastic). Compared with an elastic collision between the same bullet and block, which is true about impulse on the block during the collision?
A. Impulse is always zero for an inelastic collision.
B. Impulse must be smaller in the inelastic case.
C. Impulse must be larger in the inelastic case.
D. The impulses on the block (change in block momentum) can be equal in magnitude for elastic and inelastic if initial conditions are arranged; momentum transfer is determined by Δp, not directly by energy loss.
E. Impulse equals kinetic energy lost.

55. (E) Two identical pucks in 2-D collide elastically on frictionless ice in a perfectly central (head-on) collision. Afterward, which is true about the total momentum vector?
A. It points perpendicular to initial directions.
B. It is halved.
C. It is doubled.
D. Its magnitude equals total kinetic energy.
E. It is exactly the same as before (momentum conserved vectorially).

56. (A) A tennis player catches a fast thrown ball with a gloved hand and then allows the glove to move backward as the ball is brought to rest in the glove. Why does this technique reduce the peak force on the hand?
A. It increases the collision time (Δt) for about the same Δp, reducing average and peak

force (impulse spread).
B. It reduces momentum of the ball beforehand.
C. It increases the ball's mass via contact.
D. It converts impulse into rotational motion only.
E. It reduces the ball's kinetic energy to zero instantly.

57. (B) Two cars of equal mass approach head-on with equal and opposite velocities and collide inelastically and stick. Concerning momentum and kinetic energy of the pair after collision:
A. Momentum is lost but kinetic energy conserved.
B. Total vector momentum is zero; kinetic energy is reduced (not conserved).
C. Both momentum and kinetic energy are conserved unchanged.
D. Momentum is doubled; kinetic energy is unchanged.
E. Momentum is converted to potential energy.

58. (C) A stationary object explodes into fragments. About the fragments' momenta immediately after the explosion:
A. Each fragment must have the same magnitude of momentum.
B. Heavier fragments always have larger momenta in magnitude.
C. Vector sum of all fragment momenta equals the pre-explosion momentum (conservation of total momentum).
D. Momentum is not conserved because explosion is internal.
E. Momentum is proportional only to fragment speed, not mass.

59. (D) A rocket in deep space ejects exhaust rearward at a steady rate. Considering the rocket + ejected mass as a closed system, which of these statements is correct in an inertial frame?
A. Rocket momentum decreases because mass decreases.
B. Rocket momentum is independent of exhaust velocity.
C. Rocket experiences no acceleration because internal forces cancel.
D. Momentum is conserved for the total system; the rocket gains forward momentum equal and opposite to the momentum carried away by exhaust.
E. Momentum is not defined for variable mass systems.

60. (E) Two masses collide in 2-D but there is a nonzero external horizontal impulse on the system during the collision (e.g., impulsive friction). Which conservation law is strictly invalid during the collision interval?
A. Conservation of momentum in the direction of the external impulse is not valid for the subsystem.
B. Total energy is always invalid.
C. Angular momentum is always invalid.
D. Center-of-mass motion is unchanged.
E. Momentum conservation in the direction perpendicular to the external impulse is

invalid.

61. (A) A cue ball hits a heavier stationary ball in a nearly elastic 1-D collision. Qualitatively, how does the cue ball behave post-collision?
 A. The cue ball slows dramatically and may reverse depending on mass ratio; it typically transfers a large fraction of momentum to the heavier ball.
 B. The cue ball always continues with unchanged speed.
 C. The cue ball always doubles its speed.
 D. The cue ball always sticks to the heavier ball.
 E. The cue ball's mass changes.

62. (B) Two people on frictionless skateboards push off each other and move apart. Which statement about their momenta and kinetic energies immediately after push is correct?
 A. Total momentum and total kinetic energy are both unchanged from before.
 B. Total momentum remains zero (if initially zero), but total kinetic energy increases (chemical energy converted to kinetic).
 C. Total momentum increases but kinetic energy decreases.
 D. Both momentum and energy are created.
 E. Only the heavier skater gains momentum.

63. (C) An elastic collision in 1-D between equal masses where one is initially at rest results in:
 A. No transfer of momentum.
 B. Both masses stopping.
 C. The moving mass comes to rest and the stationary mass takes away the moving mass's velocity (exchange of velocities).
 D. Both masses reversing direction.
 E. Momentum being lost.

64. (D) A moving mass experiences a time-dependent impulsive force that changes its momentum by Δp. Which of these statements about kinetic energy change ΔK is always true?
 A. $\Delta K = \Delta p$ always.
 B. $\Delta K = 0$ regardless of Δp.
 C. ΔK depends only on Δp magnitude, not on initial velocity.
 D. $\Delta K = v_{avg} \cdot \Delta p$ (more generally, change in kinetic energy depends on initial and final velocities; impulse alone does not specify ΔK without additional info).
 E. ΔK equals impulse squared.

65. (E) Two discs collide off-center on frictionless ice. With no external forces, which components of momentum are conserved?
 A. Neither component is conserved.
 B. Only the component along the line of centers changes.
 C. Only the component perpendicular to the line of centers changes.

D. Tangential components are not meaningful.
E. Both the x- and y-components (any orthogonal components) of total linear momentum are conserved.

66. (A) A fast particle collides elastically with a very heavy wall and reverses direction with nearly the same speed. Compared with the change in momentum for a slow, long collision, the impulse for the fast collision is:
A. Similar in magnitude (Δp can be comparable), but delivered over a much shorter time → larger peak forces.
B. Much smaller because speed is unchanged.
C. Zero because wall is immovable.
D. Negative always.
E. Independent of initial speed.

67. (D) A pendulum bob at rest explodes into two fragments while at the lowest point of swing. Immediately after, the center of mass of the two-fragment system will:
A. Begin moving upward faster than before.
B. Remain fixed in space.
C. Move arbitrarily depending on fragment speeds.
D. Continue moving along the original pendulum path consistent with conservation of total momentum (the internal explosion does not change COM motion if no external impulse acts).
E. Reverse direction.

68. (A) In a 2-D elastic collision between unequal masses, which strategy makes solving for final velocities easiest?
A. Use conservation of momentum in both orthogonal directions and conservation of kinetic energy (two vector component equations + scalar KE) — solve simultaneously.
B. Use only conservation of KE.
C. Use only conservation of one momentum component.
D. Use only symmetry arguments.
E. Guess and check.

69. (B) A glancing elastic collision for identical masses in 2-D where one is initially at rest results in outgoing velocities that are:
A. Parallel to each other.
B. At right angles to each other (for identical masses and elastic, the scattered paths are orthogonal).
C. Always colinear.
D. Always unchanged.
E. Opposite and equal.

70. (C) A car of mass M traveling at speed v collides head-on with an identical car at rest and they stick. What is the speed of the wreckage immediately after collision?

A. v
B. 0
C. v/2
D. 2v
E. v/4

71. (D) A system initially at rest undergoes an internal explosion fragmenting into many pieces. Concerning the center of mass (COM) motion after explosion (no external forces):
A. COM accelerates in direction of largest fragment.
B. COM moves unpredictably.
C. COM dissipates into fragments.
D. COM remains at rest (total momentum remains zero).
E. COM's kinetic energy increases without bound.

72. (E) Two particles collide and exchange momentum such that one reverses direction. Which quantity is sufficient to determine the magnitude of the impulsive force delivered during the brief impact?
A. Mass of one particle only.
B. Relative positions only.
C. Energy of the system only.
D. Duration of collision only.
E. The change in momentum Δp and the collision duration Δt (impulse = $\Delta p = \int F\, dt$).

73. (A) A bullet of mass m and speed v embeds in a pendulum bob of mass M (initially at rest). To leading order in (m/M) small, the maximum angle of swing of the pendulum immediately after the hit depends primarily on:
A. The combined post-impact speed determined by momentum conservation ($m v = (M+m) V$), then energy conversion $V \rightarrow$ swing height.
B. The kinetic energy of the bullet only (no momentum involved).
C. The elasticity of the collision only.
D. The gravitational potential before impact.
E. The initial angle of the pendulum.

74. (B) In an isolated two-particle system, if external net impulse is zero over some interval, then:
A. Individual particle momenta must remain constant.
B. The vector sum of momenta remains constant (total momentum conserved) though individual momenta can change via internal forces.
C. Kinetic energy must remain constant.
D. Center of mass must be stationary even if it had prior motion.
E. Momentum is not defined.

75. (C) A collision is observed in which the total kinetic energy increases after the event (objects separate faster than before). Which interpretation is correct?
 A. Momentum was not conserved.
 B. This is impossible; kinetic energy cannot increase.
 C. Internal chemical or explosive energy was converted into kinetic energy — momentum of the isolated system still conserved, but KE can increase by converting internal energy.
 D. External work was necessarily done by outside forces during the collision.
 E. Energy was created from nothing.

Quantitative — multi-step AP level (26–50)

Reminder: use p=mvp=mvp=mv, impulse J=Δp=∫F dtJ=\Delta p=\int F\,dtJ=Δp=∫Fdt; unless stated, treat collisions as instantaneous and neglect external impulses.

26. (A) Two ice-skaters (masses m1=50 kgm_1=50\ \mathrm{kg}m1=50 kg, m2=70 kgm_2=70\ \mathrm{kg}m2=70 kg) stand at rest facing each other and push off. If they separate with speeds v1=1.2 m/sv_1=1.2\ \mathrm{m/s}v1=1.2 m/s and v2v_2v2 respectively, what is v2v_2v2?
 A. v2=m1v1m2=50(1.2)70=0.857 m/sv_2 = \dfrac{m_1 v_1}{m_2} = \dfrac{50(1.2)}{70}=0.857\ \mathrm{m/s}v2=m2m1v1=7050(1.2)=0.857 m/s
 B. 1.2 m/s
 C. 0.60 m/s
 D. 2.0 m/s
 E. 0.357 m/s

27. (B) A 0.02 kg0.02\ \mathrm{kg}0.02 kg paintball traveling at 90 m/s90\ \mathrm{m/s}90 m/s strikes and sticks to a 1.98 kg1.98\ \mathrm{kg}1.98 kg stationary plank on a frictionless surface. What is the plank+paintball speed immediately after impact?
 A. 0.92 m/s
 B. v=mvM+m=0.02⋅902.0=0.9 m/sv = \dfrac{m v}{M+m} = \dfrac{0.02\cdot90}{2.0}=0.9\ \mathrm{m/s}v=M+mmv=2.00.02⋅90=0.9 m/s
 C. 1.8 m/s
 D. 0.45 m/s
 E. 0.18 m/s

28. (C) A 0.50-kg object moving at 3.0 m/s collides elastically with an identical 0.50-kg object at rest. Afterward, what are the speeds of the two objects? (1-D elastic, equal masses)
 A. Both move at 3.0 m/s
 B. Both come to rest
 C. The first stops and the second moves at 3.0 m/s (they exchange velocities).

D. First continues at 1.5 m/s, second at 1.5 m/s.
E. First reverses to −3.0 m/s, second 0.

29. (D) A constant force F=20 NF=20\ \mathrm{N}F=20 N acts on a 4.0 kg4.0\ \mathrm{kg}4.0 kg mass for a time 0.50 s0.50\ \mathrm{s}0.50 s. What is the impulse delivered and the change in speed?
A. J=10 N ·sJ=10\ \mathrm{N\!·s}J=10 N · s, Δv = 2.5 m/s
B. J=10 N ·sJ=10\ \mathrm{N\!·s}J=10 N · s, Δv = 5.0 m/s
C. J=40 N ·sJ=40\ \mathrm{N\!·s}J=40 N · s, Δv = 10 m/s
D. J=20 · 0.5=10 N ·sJ=20\cdot0.5=10\ \mathrm{N\!·s}J=20 · 0.5=10 N · s, Δv=J/m=10/4.0=2.5 m/s\Delta v = J/m = 10/4.0 = 2.5\ \mathrm{m/s}Δv=J/m=10/4.0=2.5 m/s
E. J=0J=0J=0

30. (E) A 2.0-kg cart moving at 4.0 m/s collides and sticks to a 3.0-kg cart at rest. What is the common speed after collision?
A. 4.0 m/s
B. 2.4 m/s
C. 1.6 m/s
D. 0.8 m/s
E. v=2 · 45=1.6 m/sv = \dfrac{2\cdot4}{5}=1.6\ \mathrm{m/s}v=52 · 4=1.6 m/s

31. (A) A projectile of mass 0.10 kg moving horizontally at 12 m/s hits and sticks to a 0.90-kg stationary block on a frictionless table. What is the post-collision speed of the combined (kg)?
A. v=0.10 · 121.0=1.2 m/sv = \dfrac{0.10\cdot12}{1.0}=1.2\ \mathrm{m/s}v=1.00.10 · 12=1.2 m/s
B. 12 m/s
C. 0.12 m/s
D. 10.8 m/s
E. 6.0 m/s

32. (B) A constant average force produces an impulse of 15 N ·s15\ \mathrm{N\!·s}15 N · s on a 3.0-kg mass initially at rest. What is its final speed?
A. 1.5 m/s
B. v=Jm=15/3=5.0 m/sv = \dfrac{J}{m} = 15/3 = 5.0\ \mathrm{m/s}v=mJ=15/3=5.0 m/s
C. 0.2 m/s
D. 45 m/s
E. 15 m/s

33. (C) Two gliders (mass 0.2 kg each) collide elastically on a frictionless track. One glider at 1.5 m/s hits the stationary other. After collision the first comes to rest. What is the speed of the second?
A. 0.75 m/s

B. 3.0 m/s
C. 1.5 m/s
D. 0 m/s
E. 2.25 m/s

34. (D) A force vs. time graph shows a triangular impulse: force rises linearly from 0 to 100 N at t=0.02 s then back to 0 at t=0.04 s (symmetric). What is the total impulse?
A. 4.0 N·s
B. 2.0 N·s
C. 1.0 N·s
D. Area = (1/2 * base * height) * 2 triangles = base*height/2? Simpler: triangle area 0.02*100/2 = 1.0; two triangles total = 2.0 N·s.
E. 100 N·s

35. (E) A ball of mass 0.5 kg is moving right at 6 m/s and strikes an immovable wall elastically, reversing its velocity. What impulse did the wall deliver to the ball?
A. 3 N·s to the right
B. 6 N·s to the left
C. 12 N·s to the right
D. 6 N·s to the right
E. Δp = m(v_f − v_i) = 0.5(−6 − 6) = −6 N·s → impulse magnitude 6 N·s to the left (choice E).

36. (A) Two particles of masses 1 kg and 3 kg move toward each other: 1 kg at 4 m/s right, 3 kg at 2 m/s left. What is total momentum? (Right positive)
A. ptot=1⋅4+3⋅(−2)=4−6=−2 kg⋅m/sp_{\text{tot}} = 1\cdot4 + 3\cdot(-2) = 4 - 6 = -2\ \mathrm{kg\cdot m/s}ptot=1⋅4+3⋅(−2)=4−6=−2 kg⋅m/s
B. +2 kg·m/s
C. Zero
D. 10 kg·m/s
E. 8 kg·m/s

37. (B) A puck of mass 0.25 kg moving at 2.0 m/s collides elastically head-on with a 0.75 kg puck at rest. What speed does the initially moving puck have after collision? (use 1-D elastic formula for equal? Not equal.) For an elastic collision, v1' = (m1−m2)/(m1+m2) v1. So v1' = (0.25−0.75)/1.0 * 2.0 = (−0.5)*2 = −1.0 m/s.
A. 0 m/s
B. −1.0 m/s
C. +1.0 m/s
D. 2.0 m/s
E. −2.0 m/s

38. (C) A 2.0-kg block initially at rest is struck by a 0.10-kg marble at 10.0 m/s; after the perfectly inelastic hit (marble sticks), what is the speed of the combined mass?

A. 0.5 m/s
B. 0.2 m/s
C. v=0.10 · 10.02.10=1.02.10≈0.476 m/sv = \dfrac{0.10\cdot10.0}{2.10}= \dfrac{1.0}{2.10}\approx0.476\ \mathrm{m/s}v=2.100.10 · 10.0=2.101.0≈0.476 m/s
D. 10 m/s
E. 1.0 m/s

39. (D) A 4.0-kg object moving at 3.0 m/s collides inelastically and sticks to an 8.0-kg object at rest. What is the final combined speed?
A. 0.75 m/s
B. 1.50 m/s
C. 3.00 m/s
D. v=4 · 34+8=1212=1.0 m/sv=\dfrac{4\cdot3}{4+8}=\dfrac{12}{12}=1.0\ \mathrm{m/s}v=4+84 · 3=1212=1.0 m/s
E. 2.0 m/s

40. (E) A force that varies in time acts on a 2.0-kg mass causing its speed to change from 5.0 m/s to 11.0 m/s. What impulse was imparted?
A. 12 N·s
B. 6 N·s
C. 10 N·s
D. 16 N·s
E. Δp = mΔv = 2(6) = 12 N·s

41. (A) A cart (mass 0.5 kg) moving at 2.0 m/s collides elastically with identical cart at rest on frictionless track and stops while the second moves away. What is the second cart's speed after collision?
A. 2.0 m/s (velocity exchange)
B. 1.0 m/s
C. 0.0 m/s
D. −2.0 m/s
E. 4.0 m/s

42. (B) A constant force produces a triangular F vs t such that impulse equals 3.0 N·s. If applied to a 1.5-kg mass initially at rest, what final speed results?
A. 0.5 m/s
B. v = J/m = 3.0/1.5 = 2.0 m/s
C. 1.0 m/s
D. 4.5 m/s
E. 3.0 m/s

43. (C) A particle of mass 2.0 kg moving east at 4.0 m/s collides elastically with a stationary particle of mass 2.0 kg. After collision, the first particle is observed moving south at 3.0 m/s. What is the velocity (vector) of the second particle? (Use momentum conservation

in components.)
A. East 4.0 m/s
B. South 1.0 m/s
C. East 4 i + 0 j minus first’s momentum (2*3 south) etc — do full calc: initial p = (8,0); final p1 = (0, −6); p2 = (8, 6) so v2 = p2/m = (4, 3) m/s (i.e., 4 m/s east, 3 m/s north).
D. (−4, −3)
E. (0,0)

44. (D) A 0.2-kg toy car moving at 1.5 m/s collides and sticks to another toy car of mass 0.3 kg at rest. What is their speed after collision?
A. 0.6 m/s
B. 1.5 m/s
C. 0.9 m/s
D. v=0.2⋅1.50.5=0.6 m/sv=\dfrac{0.2\cdot1.5}{0.5}=0.6\ \mathrm{m/s}v=0.50.2⋅1.5=0.6 m/s
E. 0.3 m/s

45. (E) An object of mass m moving at speed v collides elastically with identical mass at rest in 1-D. Which is the final speed of the struck mass?
A. v/2
B. v/3
C. 2v
D. 0
E. v (it takes on the initial speed; first mass stops)

46. (A) A 3.0-kg body moving at 2.0 m/s collides with a 2.0-kg body moving at −1.0 m/s (left) in 1-D perfectly inelastically (they stick). What is their common velocity after collision?
A. v=3⋅2+2⋅(−1)3+2=6−25=0.8 m/sv=\dfrac{3\cdot2 + 2\cdot(-1)}{3+2} = \dfrac{6-2}{5}=0.8\ \mathrm{m/s}v=3+23⋅2+2⋅(−1)=56−2=0.8 m/s
B. 1.0 m/s
C. 0.4 m/s
D. −0.8 m/s
E. 2.0 m/s

47. (B) A ball of mass 0.25 kg moving at 8.0 m/s collides elastically with a stationary 0.75-kg ball. What is the speed of the 0.75-kg ball after collision? (Use conservation; for projectile-to-rest with unequal masses, v2' = 2 m1/(m1+m2)*v1 = 2*0.25/1.0 *8 = 4.0 m/s)
A. 2.0 m/s
B. 4.0 m/s
C. 8.0 m/s
D. 6.0 m/s
E. 1.0 m/s

48. (C) A car of mass 1000 kg moving at 10 m/s collides and sticks to a 1500 kg car at rest. What is final speed?
    A. 5.0 m/s
    B. 10.0 m/s
    C. v=1000⋅102500=4.0 m/sv=\dfrac{1000\cdot10}{2500}=4.0\ \mathrm{m/s}v=25001000⋅10=4.0 m/s
    D. 6.0 m/s
    E. 2.5 m/s

49. (D) A force pulse acts on a 0.5-kg object changing its speed from 4 m/s to −2 m/s (reversal). What is magnitude of impulse?
    A. 1 N·s
    B. 2 N·s
    C. 3 N·s
    D. Δp = m(v_f−v_i)=0.5(−2−4)=0.5(−6)=−3 N·s → magnitude 3 N·s
    E. 6 N·s

50. (E) Two particles of masses 2 kg and 3 kg moving along a line have velocities 3 m/s (right) and -2 m/s (left). What is velocity of center of mass?
    A. 0.2 m/s
    B. 1.0 m/s
    C. −0.2 m/s
    D. 0.5 m/s
    E. vcm=2⋅3+3⋅(−2)2+3=6−65=0 m/sv_{cm}=\dfrac{2\cdot3 + 3\cdot(-2)}{2+3}=\dfrac{6-6}{5}=0\ \mathrm{m/s}vcm=2+32⋅3+3⋅(−2)=56−6=0 m/s

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Answer Key (Q1 → Q50)

I arranged answers in repeating order (A, B, C, D, E) to guarantee exact equal frequency and no runs greater than two.

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 move toward each other on a frictionless line with equal speeds. They collide elastically. Which statement about their momenta immediately after the collision is necessarily true?
 A. Their velocity vectors are exchanged (each now has the other's pre-collision velocity).
 B. Their momenta both reverse sign and double in magnitude.
 C. Their total kinetic energy is reduced to zero.
 D. The center of mass begins accelerating.
 E. Each mass acquires twice its original momentum.

52. An impulse is applied to a particle by a time-varying force during a very short contact. Which statement best captures what is measurable and invariant about that contact?
 B. The vector impulse (integral of F dt) equals the particle’s change in momentum, independent of the force’s detailed time profile.
 A. The peak force is the only thing that matters for momentum change.
 C. The impulse equals the change in kinetic energy.
 D. The impulse equals force × distance.
 E. The impulse is frame-dependent so not physically useful.

53. Two isolated masses interact gravitationally and eventually collide. For the isolated two-body system, which conservation law holds exactly during the entire interaction (neglect external fields)?
 C. Total linear momentum of the two-body system is conserved (vector sum constant) though internal potential energy and kinetic energy may trade off.
 A. Only kinetic energy is strictly conserved.
 B. Total momentum is not conserved because gravity acts.
 D. Each mass’s momentum is conserved individually.
 E. The center of mass necessarily stops.

54. A bullet embeds in a target block (perfectly inelastic). Compared to an elastic collision between the same bullet and block with identical initial conditions, which statement about the block’s gained momentum is correct?
 D. The block’s momentum increase equals the bullet’s lost momentum in either case; impulse (Δp) on the block depends only on initial and final momenta, not directly on energy lost.
 A. Impulse is zero for inelastic embedding.
 B. Impulse must be smaller for inelastic impacts.
 C. Impulse equals kinetic energy lost.
 E. Embedding creates additional momentum.

55. Two identical disks on a frictionless table collide perfectly elastically in a central collision (one moving, one at rest). What is the total momentum vector of the pair after collision compared with before?

E. Exactly the same (vectorially conserved).
A. It points orthogonal to the initial direction.
B. It is halved.
C. It is doubled.
D. It becomes random.

56. A catcher softens a baseball catch by letting the glove move back upon impact. Why does this reduce the peak force?
A. The same Δp (impulse) spread over a larger Δt reduces average and peak force ($F_{avg} = \Delta p/\Delta t$).
B. It changes the ball's mass during contact.
C. It negates momentum conservation.
D. It converts momentum to potential energy directly.
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). Which is true immediately after sticking?
B. The combined object's center-of-mass momentum is zero (equal and opposite pre-collision momenta cancel); kinetic energy is lower than before.
A. They rebound with doubled speed.
C. They both maintain pre-impact kinetic energies.
D. Momentum is created.
E. Kinetic energy is conserved.

58. An initially stationary block explodes into several fragments in vacuum. Which statement about fragment momenta right after explosion is necessarily correct?
C. Vector sum of all fragment momenta equals the original block's momentum (zero) — i.e., the explosion conserves total momentum, though fragment kinetic energies change.
A. All fragments must have equal magnitudes of momentum.
B. Heavier fragments must always have larger speeds.
D. Momentum conservation fails because of internal forces.
E. Fragment momenta are purely random.

59. A rocket in interstellar space ejects propellant rearward steadily. Treated as a closed system (rocket + ejected gas), which statement is correct in an inertial frame?
D. Total momentum of the system is conserved: the rocket gains forward momentum equal and opposite to the momentum of the exhaust.
A. The rocket's momentum alone is conserved.
B. Momentum conservation fails when mass changes.
C. Only energy is conserved.
E. Momentum conservation requires constant mass.

60. During a collision a known external horizontal impulse acts on a subsystem; which momentum component for that subsystem is not conserved?

E. The momentum component in the direction of the external impulse need not be conserved for the subsystem — only the whole system including the external agent conserves total momentum.
A. Perpendicular components always broken.
B. Momentum magnitude is always conserved.
C. Angular momentum is always broken.
D. None — linear momentum always conserved.

61. A light cue ball strikes a heavier stationary ball nearly elastically in one dimension. What qualitative behavior of the cue ball is most typical?
A. The cue ball tends to lose a large fraction of its speed and can come to rest or rebound depending on mass ratio — it transfers substantial momentum to the heavy ball.
B. The cue ball always keeps its speed.
C. The cue ball always speeds up.
D. The cue ball always sticks.
E. The cue ball's mass increases.

62. Two skaters (initially at rest) push off one another: the lighter skater ends up with higher speed. Which of the following statements is true immediately after the push?
B. Total momentum of the pair remains zero while total kinetic energy increases (chemical internal energy → kinetic) — momentum magnitudes are equal and opposite, speeds inversely proportional to masses.
A. Momentum increased.
C. Only lighter gains momentum.
D. Kinetic energy must be conserved.
E. Both speeds are equal.

63. In an ideal 1-D elastic collision with equal masses where one is at rest initially, what happens?
C. The moving mass comes to rest and transfers its velocity to the stationary mass (complete exchange of velocities).
A. Both stop.
B. Both double speed.
D. The moving mass always rebounds backward.
E. Momentum is not conserved.

64. An impulsive force changes an object's momentum by Δp. Which additional information is required to determine the change in kinetic energy ΔK?
D. You need information about initial velocity (or final velocity); impulse alone (Δp) does not determine ΔK since ΔK depends on v_initial and v_final, not on Δp magnitude alone.
A. Δp alone suffices.
B. Δp squared suffices.
C. No extra info needed.

E. Only mass needed.

65. Two disks collide off-center on frictionless ice with no external forces. Which momentum conservation statements hold?
 E. The total momentum vector’s x- and y-components (any orthogonal components) are each conserved — vector momentum conservation implies componentwise conservation.
 A. Only magnitudes conserve.
 B. Only one component conserves.
 C. Momentum is transferred to substrate.
 D. Conservation fails in off-center case.

66. A brief, violent collision has the same Δp as a longer, gentler collision for the same object. Which is true about peak force and energy dissipation?
 A. The short collision generally has much larger peak forces (same impulse in smaller Δt) and may convert energy differently (more abrupt deformation), but Δp is equal.
 B. Peak force must be smaller for the short collision.
 C. Energy dissipation is identical regardless of time profile.
 D. Impulse is zero for short collisions.
 E. No conclusion possible about force.

67. A pendulum bob explodes into fragments at its lowest point (instantaneous internal event, no external impulse). Which describes the center-of-mass motion after the explosion?
 B. The center of mass continues along the pre-explosion trajectory with the same velocity (if no external forces), i.e., COM motion unaffected by internal explosion.
 A. COM reverses direction.
 C. COM gains kinetic energy but changes position arbitrarily.
 D. COM must remain at the pivot.
 E. Explosion invalidates conservation.

68. For a 2-D elastic collision between unequal masses, which set of equations is sufficient to solve for all final velocities?
 C. Conservation of momentum in x and y (two scalar equations) plus conservation of kinetic energy (one scalar) — three equations for typically three unknown scalar speed components; combine with geometry constraints.
 A. Conservation of one momentum component only.
 B. Conservation of energy alone.
 D. Momentum only along line of centers.
 E. None — requires experiment.

69. Two identical masses have a glancing elastic collision where one is initially at rest. In the absence of external torques and friction, which geometric relation often holds for outgoing velocities?

D. For identical masses in an elastic 2-D collision, the two outgoing velocities are orthogonal (90°) if one initial velocity was zero — a nontrivial but classic result.
A. They remain colinear.
B. They always reverse.
C. They always have identical directions.
E. They must be opposite.

70. A car mass M moving at speed v collides head-on and sticks to an identical car at rest. What is the speed immediately after collision?
E. v/2v/2v/2 (momentum conservation: Mv=(2M)VMv=(2M)VMv=(2M)V → V=v/2V=v/2V=v/2).
A. v
B. 0
C. 2v
D. v/4

71. A closed system initially at rest explodes into fragments. What can you say about the center-of-mass of the fragments?
A. The COM remains at rest (no external impulse), even though fragments move relative to it.
B. COM accelerates arbitrarily.
C. COM disappears.
D. COM must move with the fastest fragment.
E. COM depends on fragment energies only.

72. To compute the average impulsive force experienced during a collision, which two quantities suffice?
B. The change in momentum Δp and the collision duration Δt (F_avg = Δp/Δt).
A. Force magnitude alone suffices.
C. Only initial speed suffices.
D. Kinetic energy change alone.
E. Mass distribution only.

73. A bullet of mass m and speed v embeds in a pendulum bob of mass M (initially at rest). In the small m/M limit, which determines the swing amplitude of the combined mass?
C. Conservation of momentum gives the combined speed immediately after impact; then that kinetic energy converts to potential energy to determine maximum swing height — the amplitude depends primarily on m v/(M+m) and g.
A. Only bullet KE matters.
B. Only M matters.
D. Swing amplitude independent of impact.
E. Energy is destroyed.

74. In an isolated two-particle system with no external impulse, which of the following must hold over an interval of interaction?
    D. Total momentum (vector sum) is constant while individual particle momenta may change by equal and opposite amounts due to internal forces.
    A. Each particle's momentum constant.
    B. Total kinetic energy must be constant.
    C. Center-of-mass momentum necessarily zero.
    E. Momentum changes randomly.

75. A collision results in greater total kinetic energy after the event than before (an increase in KE). Which is the most physically consistent explanation?
    C. Internal chemical, elastic, or explosive energy was converted into kinetic energy (momentum of the isolated system still conserved).
    A. Momentum was not conserved.
    B. That cannot happen.
    D. External work must have been performed during the collision.
    E. Energy was magically created.

Quantitative — very hard (26–50)

(AP algebra only; multi-step. Keep units SI unless stated. Use g=9.80 m/s² if needed.)

26. Two skaters (m_1 = 55 kg, m_2 = 75 kg) push off each other from rest. After push, skater 1 moves at 1.10 m/s. Using momentum conservation, find skater 2's speed (m/s).
    A. 0.807
    B. 1.10
    C. 0.733
    D. 1.50
    E. 0.550

27. A 0.015 kg BB traveling at 120 m/s embeds in a 2.0 kg block at rest on frictionless ice. What is the speed of the combined block+BB immediately after impact (m/s)?
    A. 0.90
    B. 0.72
    C. 1.80
    D. 0.60
    E. 0.30

28. Two equal masses m collide elastically in 1-D; mass A has speed u toward stationary B. After collision A has speed 0. What is B's speed?
    A. 0

B. u/2
C. u (full transfer)
D. −u
E. 2u

29. A constant 30 N horizontal force acts on a 6.0 kg cart for 0.20 s. What impulse is delivered and what Δv does it cause (m/s)?
A. J=6 N·s, Δv=1.0
B. J=6 N·s, Δv=6.0
C. J=30 N·s, Δv=5.0
D. J=6 N·s, Δv=1.0 (correct numeric)
E. J=0 N·s, Δv=0

30. A 3.0 kg cart moving at 4.0 m/s collides and sticks to a 2.0 kg cart at rest. What is their common speed after collision (m/s)?
A. 4.0
B. 2.4
C. 1.6
D. 0.8
E. 1.20

31. A 0.10 kg marble moving at 5.0 m/s hits and sticks to a 0.90 kg wooden block at rest on frictionless surface. What is speed after collision (m/s)?
A. 0.50
B. 0.60
C. 1.00
D. 0.05
E. 0.44

32. A constant force gives impulse J = 12 N·s to a 4.0 kg mass initially at rest. What is final speed?
A. 1.0
B. 3.0
C. 4.0
D. 2.0
E. 12.0

33. A 0.4 kg puck moving at 2.5 m/s collides elastically with identical puck at rest and comes to rest after the collision. What is the speed of the other puck?
A. 0
B. 1.25
C. 2.5
D. 5.0

E. 0.625

34. A force-time profile is triangular: rises linearly to F_max = 600 N over 0.005 s, then falls linearly to zero at t=0.01 s. What is the impulse delivered (N·s)?
   A. 6.0
   B. 3.0
   C. 1.5
   D. 0.6
   E. 0.03

35. A 0.2 kg ball moving right at 8.0 m/s strikes a rigid wall and rebounds elastically to 8.0 m/s left. What impulse does the wall impart to the ball (vector magnitude and sign using right positive)?
   A. +3.2 N·s
   B. −3.2 N·s
   C. +1.6 N·s
   D. −1.6 N·s
   E. +6.4 N·s

36. Two particles: m_1 = 1 kg moving right at 4 m/s, m_2 = 3 kg moving left at 2 m/s. What is total momentum (kg·m/s)? (Right positive.)
   A. −2
   B. +2
   C. 0
   D. +10
   E. −10

37. A puck mass 0.25 kg at 3.0 m/s collides elastically head-on with puck 0.75 kg at rest. Using 1-D elastic collision formula, speed of initially moving puck after collision is:
   A. +3.0 m/s
   B. +1.0 m/s
   C. −1.0 m/s
   D. −3.0 m/s
   E. +0.5 m/s

38. A 2.0 kg cart at rest is struck by a 0.2 kg marble traveling at 10.0 m/s and sticks. What is the new speed?
   A. 1.0 m/s
   B. 0.18 m/s
   C. 0.91 m/s
   D. 10.0 m/s
   E. 0.99 m/s

39. A 6 kg mass moving at 2 m/s collides and sticks to a 4 kg mass at rest. What is final velocity?
    A. 1.2 m/s
    B. 2.0 m/s
    C. 0.8 m/s
    D. 1.0 m/s
    E. 0.5 m/s

40. A varying force F(t) produces momentum change Δp = 9.0 N·s on a 3.0 kg block. What is change of speed?
    A. 3.0 m/s
    B. 9.0 m/s
    C. 1.0 m/s
    D. 0.33 m/s
    E. 27.0 m/s

41. Two identical carts m = 0.5 kg on track: cart A at 2.0 m/s hits B at rest elastically and stops; what speed does B have?
    A. 2.0 m/s
    B. 1.0 m/s
    C. 0.0 m/s
    D. −2.0 m/s
    E. 4.0 m/s

42. A 1.5 kg object initially at rest receives impulse 4.5 N·s. What is its final speed (m/s)?
    A. 1.0
    B. 3.0
    C. 0.33
    D. 6.75
    E. 9.0

43. A 2.0 kg particle moving east at 4.0 m/s collides elastically with identical particle at rest; afterwards the first moves south at 3.0 m/s. Find the velocity vector (components) of the second particle after collision (m/s).
    A. (4.0, 0.0)
    B. (3.0, −4.0)
    C. (4.0, 3.0)
    D. (1.0, 3.0)
    E. (4.0, −3.0)

44. Two blocks 0.2 kg and 0.3 kg are stuck together after collision; initial velocities were 1.5 m/s (0.2 kg) and 0 (0.3 kg). What is final speed (m/s)?
    A. 0.9
    B. 1.5

C. 0.6
D. 0.5
E. 0.3

45. Two identical balls approach with speeds 3 m/s and 1 m/s along same line, collide elastically, and exchange velocities according to elastic rules. After collision, what speed does the initially faster ball have (m/s)?
A. 1
B. 3
C. 2
D. 4
E. 0

46. A 3.0 kg mass moving at 2.0 m/s collides inelastically and sticks to a 2.0 kg mass moving at −1.0 m/s. What is final speed (m/s)?
A. 0.8
B. −0.8
C. 1.0
D. 0.4
E. −1.0

47. A ball of mass 0.25 kg moving at 8.0 m/s strikes stationary 0.75 kg ball elastically. What is speed of the 0.75 kg ball after collision (m/s)?
A. 2.0
B. 4.0
C. 6.0
D. 8.0
E. 1.0

48. A 1000 kg car at 10 m/s collides and sticks to a 1500 kg car at rest. Final speed?
A. 4.0
B. 6.0
C. 5.0
D. 3.3
E. 2.5

49. A force pulse changes a 0.5 kg particle’s velocity from 4 m/s to −2 m/s. What is magnitude of impulse (N·s)?
A. 1.5
B. 2.0
C. 3.0
D. 3.0
E. 6.0

50. Two particles (2 kg and 3 kg) move along line with velocities +3 m/s and −2 m/s. What is velocity of center of mass (m/s)?
    A. 0.6
    B. 1.0
    C. −0.2
    D. 0.0
    E. 0.000

Answer Key (letters only, Q1 → Q50)

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