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Momentum and Collisions

Study Guide — Momentum & Collisions

Pre-med/IB-style questions on momentum (as a vector), impulse, force–time graphs, conservation conditions, center of mass motion, recoil/explosions, and 1D/2D collisions (elastic/inelastic). Designed to be conceptual and trap common misconceptions.

75 items — Study Guide with Answers

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1 **Which statement best defines linear momentum?**

A $p = (1/2)mv^2$, a scalar that depends on speed only

B **$p = m \cdot v$ (a vector), in the direction of velocity** ✓

C $p = F/\Delta t$, the force per unit time

D $p = mg$, a downward force due to gravity

E $p = m/a$, a measure of inertia

▶ **Explanation:** Linear momentum is defined as $p = m \cdot v$ (a vector). It points in the same direction as velocity. $(1/2)mv^2$ is kinetic energy, not momentum.

2 **Which of the following is a correct SI unit for momentum?**

A $kg \cdot m^2/s^2$

B N/m

C J/s

D **$kg \cdot m/s$** ✓

E $N \cdot m$

▶ **Explanation:** Momentum has units mass × velocity = $kg \cdot m/s$. ($kg \cdot m^2/s^2$) and $N \cdot m$ are joules (energy), and J/s is watt (power).

3 **Impulse J is best described as:**

A The rate of change of momentum

B The product of mass and acceleration

C **The change in momentum of an object** ✓

D The work done by a force

E The distance traveled during a force

▶ **Explanation:** Impulse equals the change in momentum: $J = \Delta p$ (vector quantity). The rate of change of momentum is force: $F = dp/dt$ (vector form).

4 **A force acts for a time interval. On a force–time graph, the impulse delivered equals:**

A The slope of the graph

B **The area under the curve** ✓

C The maximum force value

D The final force value minus the initial

E The time at which force is largest

▶ **Explanation:** Impulse is $J = \int F\,dt$. Graphically, that is the area under the force–time curve, not the slope or the peak alone.

5 **Which statement about momentum is correct?**

A **Momentum can be conserved even when kinetic energy is not conserved.** ✓

B Momentum is conserved only in perfectly elastic collisions.

C Momentum is always zero if an object is moving in a circle.

D Momentum is a scalar, so direction is irrelevant.

E Momentum conservation requires that no forces act at all.

▶ **Explanation:** Total momentum of an isolated system is conserved in any collision (elastic or inelastic) if net external impulse is zero. Kinetic energy can be transformed to internal energy in inelastic collisions.

6 **For a system of objects, linear momentum is conserved when:**

- A All forces are equal and opposite
- B Kinetic energy is conserved
- C Objects stick together
- D All internal forces are zero
- E **The net external impulse on the system is zero** ✓

▶ **Explanation:** Momentum conservation requires zero net external impulse (or negligible external impulse during the interaction). Internal forces can be large but cancel in the system sum.

7 **Two carts collide on a frictionless track. During the collision, cart A exerts a force on cart B. Compared to this force, the force cart B exerts on cart A is:**

- A Larger, because B resists more
- B Smaller, because A started the collision
- C **Equal in magnitude and opposite in direction** ✓
- D In the same direction, because both move forward
- E Zero if the collision is perfectly inelastic

▶ **Explanation:** Newton's 3rd law: interaction forces come in equal-and-opposite pairs, regardless of masses or whether they stick.

8 **A 2 kg cart and a 1 kg cart move with the same speed. Which has the larger momentum magnitude?**

- A **The 2 kg cart** ✓
- B The 1 kg cart
- C They have the same momentum
- D Neither has momentum unless accelerating
- E Cannot be determined

▶ **Explanation:** Momentum magnitude is $p = mv$. At the same speed, the larger mass has the larger momentum.

9 **Two objects have the same momentum magnitude. Object A has smaller mass than object B. Which statement about their speeds is correct?**

- A They must have the same speed
- B A must be slower
- C Speed is unrelated to momentum
- D **A must be faster** ✓
- E A must be at rest

▶ **Explanation:** For fixed momentum $p = mv$, a smaller mass requires a larger speed $v = p/m$.

10 **Two objects have the same momentum magnitude p but different masses. Which object has the larger kinetic energy?**

- A The larger mass

- **B** **The smaller mass** ✓
- **C** They have the same kinetic energy
- **D** The one moving slower
- **E** Cannot be determined

▶ **Explanation:** Using $K = p^2/(2m)$, for the same p a smaller mass gives a larger kinetic energy. Momentum and kinetic energy scale differently.

11 **A ball of mass m moving right hits a wall and stops (does not bounce). The direction of the impulse on the ball from the wall is:**

- **A** To the right, because the ball was moving right
- **B** Upward, because the wall supports the ball
- **C** **To the left, opposite the initial momentum** ✓
- **D** Zero, because the ball stops
- **E** Downward, because gravity acts

▶ **Explanation:** Impulse equals change in momentum. The ball's momentum changes from $+mv$ to 0, so Δp is to the left (negative direction).

12 **A ball hits a wall and rebounds straight back with the same speed it had before impact. Compared with the case where it hits and stops, the magnitude of the impulse on the ball is:**

- **A** Smaller, because it bounces
- **B** The same
- **C** Zero, because speed is unchanged
- **D** **Larger (in fact, double if speeds are equal)** ✓

E Impossible to compare

▶ **Explanation:** Stopping changes momentum from $+mv$ to 0 ($|\Delta p| = mv$). Rebounding to $-mv$ changes momentum by $-2mv$, so the impulse magnitude is $2mv$, larger.

13 **Why does an airbag reduce injury in a crash (conceptually)?**

A It reduces the change in momentum to nearly zero

B It increases the speed change

C It makes the collision perfectly elastic

D It increases the impulse delivered

E **It increases the stopping time, reducing the average force for the same impulse ✓**

▶ **Explanation:** For a given change in momentum, impulse is fixed (Δp). Average force is $F_{avg} = \Delta p / \Delta t$, so increasing Δt lowers average force.

14 **A car's crumple zone is designed to deform during a collision. The best physics reason is to:**

A **Increase the collision time to reduce the average force ✓**

B Reduce the car's mass so momentum is conserved

C Make kinetic energy conserved

D Increase the car's final speed after impact

E Eliminate the impulse on the passengers

▶ **Explanation:** Crumple zones increase the time over which momentum changes, reducing the average (and peak) forces on occupants for the same Δp.

15 **Which type of collision is defined by conservation of BOTH momentum and kinetic energy (for the system)?**

- A Perfectly inelastic collision
- B **Perfectly elastic collision** ✓
- C Any collision where objects stick
- D Any collision in which momentum is not conserved
- E A collision with friction present

▶ **Explanation:** A perfectly elastic collision conserves both momentum and kinetic energy. In inelastic collisions, some kinetic energy becomes internal energy, though momentum can still be conserved.

16 **In a perfectly inelastic collision between two objects, which statement must be true?**

- A Kinetic energy is conserved
- B Both objects bounce apart
- C Momentum of each object is conserved
- D **The objects move together with a common final velocity** ✓
- E No energy is transformed into heat or deformation

▶ **Explanation:** Perfectly inelastic means the objects stick together and share a final velocity. Momentum of the system can be conserved, but kinetic energy is not conserved.

17 **A system starts at rest and explodes into two pieces in empty space (negligible external forces). What can you say about the two momenta immediately after the explosion?**

- A They must be equal (same vector)
- B The larger piece must have the larger momentum
- **C They must be equal in magnitude and opposite in direction ✓**
- D Both momenta must be zero
- E They must both point upward

▶ **Explanation:** Initial total momentum is zero. With no external impulse, total momentum remains zero, so the two momenta must add to zero: $p1 + p2 = 0$, meaning they are equal in magnitude and opposite in direction.

18 A moving object explodes into fragments in midair. Neglecting air resistance during the short explosion time. The center of mass of the fragments will:

- **A Continue along the same trajectory it would have followed without the explosion ✓**
- B Stop instantly because momentum is redistributed
- C Move upward because internal forces push outward
- D Move in the direction of the largest fragment
- E Change direction randomly

▶ **Explanation:** Internal forces cannot change the motion of the center of mass. With negligible external impulse during the explosion, the COM continues with the same velocity it had at that instant (same overall trajectory).

19 Two ice skaters push off each other from rest. Skater A has smaller mass than skater B. Immediately after pushing, which is correct?

- A A has smaller speed because it is lighter
- **B A has larger speed because momentum magnitudes must match ✓**

- C Both have the same speed because forces are equal
- D Both have zero momentum because they started at rest
- E B has larger acceleration because it is heavier

▶ **Explanation:** Total momentum stays zero, so the skaters' momenta are equal and opposite. With $p = mv$, the smaller mass must have larger speed to have the same momentum magnitude.

20 A gun fires a bullet horizontally. Ignoring external forces during firing, which statement is correct?

- A Only the bullet has momentum after firing
- B Only the gun has momentum after firing
- C Gun and bullet momenta are in the same direction
- D Momentum is not conserved because there is an explosion
- E **Gun and bullet momenta are equal in magnitude and opposite in direction ✓**

▶ **Explanation:** The gun–bullet system starts with total momentum zero. After firing, momentum is conserved, so $p_{gun} + p_{bullet} = 0$: equal magnitudes, opposite directions (recoil).

21 A small car collides with a massive truck. During the collision, the force on the car from the truck compared to the force on the truck from the car is:

- A **Equal in magnitude and opposite in direction ✓**
- B Much larger on the car because it is smaller
- C Much larger on the truck because it is heavier
- D Zero on the truck because it barely moves
- E Equal only if the collision is elastic

▶ **Explanation:** Newton's 3rd law: interaction forces are equal and opposite. The car can suffer greater acceleration because a = F/m, not because the force is larger.

22 A ball is brought to rest from speed v. If the stopping time is doubled while the change in momentum is the same, the average stopping force magnitude is:

- A Doubled
- B Unchanged
- C **Halved** ✓
- D Quadrupled
- E Zero

▶ **Explanation:** Average force is $F_{avg} = \Delta p/\Delta t$. If Δp is fixed and Δt doubles, F_{avg} halves.

23 Which scenario produces the largest magnitude change in momentum for the SAME ball (same mass) and the SAME incoming speed v?

- A It stops after hitting a wall
- B It continues forward but slows down slightly
- C It continues forward with the same speed
- D **It rebounds straight back with speed v** ✓
- E It moves sideways at speed v

▶ **Explanation:** Largest $|\Delta p|$ occurs when momentum reverses direction. From +mv to −mv gives $\Delta p = -2mv$ (magnitude 2mv), larger than stopping (mv).

24 **A force–time graph is a triangle that rises from 0 to F_{max} and returns to 0 over time T. The impulse equals:**

- A **$(1/2)F_{max}$ T** ✓
- B F_{max} T
- C F_{max}/T
- D $2F_{max}$ T
- E 0

▶ **Explanation:** Impulse is area under the force–time curve. For a triangle with base T and height F_{max}, area $= (1/2) \cdot T \cdot F_{max}$.

25 **Two different collisions produce the same impulse on an object. Collision 1 lasts longer than collision 2. Which statement about the average force is correct?**

- A Average forces are equal because impulse is equal
- B **Collision 1 has smaller average force because the same impulse is spread over a longer time** ✓
- C Collision 1 has larger average force because it lasts longer
- D Average force depends only on mass, not time
- E Average force must be zero in both cases

▶ **Explanation:** $F_{avg} = J/\Delta t$. For the same impulse, larger Δt means smaller average force.

26 **A cart moving right experiences a constant net force to the right. Which statement about its momentum is correct?**

- A Momentum stays constant because force is constant

B Momentum decreases because it is moving right

C Momentum changes direction but not magnitude

D Momentum must be conserved

E **Momentum increases in the rightward direction over time** ✓

▶ **Explanation:** Net force is the rate of change of momentum: $F = dp/dt$ (vector form). A rightward net force increases the rightward momentum.

27 **Two carts of equal mass m move on a frictionless track. Cart A moves right with speed v, cart B is at rest. They collide and stick together. Their speed immediately after collision is:**

A v

B 2v

C **v/2** ✓

D 0

E Cannot be determined

▶ **Explanation:** Momentum conservation: initial $p = mv$. Final mass $= 2m$, so $v_f = (mv)/(2m) = v/2$.

28 **Cart A (mass m) moves right with speed v and collides with cart B (mass 3m) at rest. They stick together. The final speed is:**

A v/2

B **v/4** ✓

C 3v/4

D v

E 0

▶ **Explanation:** Initial momentum is mv. Total mass after sticking is 4m, so $v_f = mv/(4m) = v/4$.

29 **Two identical carts move toward each other on a frictionless track with equal speeds v. They collide and stick. The final velocity is:**

A +v

B −v

C +v/2

D **0** ✓

E Cannot be determined

▶ **Explanation:** Equal and opposite momenta cancel, so total momentum is zero. After sticking, the combined cart must have zero velocity.

30 **Two objects collide and stick together. Which statement is always true for the system (during the collision), assuming negligible external impulse?**

A **Total momentum is conserved** ✓

B Total kinetic energy is conserved

C Mechanical energy is conserved

D Each object's momentum is conserved

E The final speed must be the average of the initial speeds

▶ **Explanation:** With negligible external impulse, total momentum of the system is conserved. Kinetic energy generally decreases in a sticking collision.

31 **In a 1D perfectly elastic collision, cart A (mass m) moving right hits cart B (mass m) at rest. Which outcome is correct?**

- A Both carts move right at speed v/2
- B **Cart A stops and cart B moves right at speed v** ✓
- C Cart A rebounds left at speed v and cart B stays at rest
- D Both carts stop
- E They stick together

▶ **Explanation:** For equal masses in a 1D elastic collision with one initially at rest, the carts exchange velocities: A gives its speed to B.

32 **In a 1D perfectly elastic collision, a small cart (mass m) moving right hits a much larger cart (mass 5m) at rest. What is the most likely qualitative outcome for the small cart?**

- A It continues right with almost the same speed
- B It stops and stays at rest
- C It speeds up to the right
- D **It rebounds (moves left) after the collision** ✓
- E It must stick to the large cart

▶ **Explanation:** For an elastic collision with target initially at rest, $v1' = (m1-m2)/(m1+m2)\ v1$. If $m1 < m2$, the result is negative (rebound).

33 **In a 1D perfectly elastic collision, a heavy cart (mass 5m) moving right hits a light cart (mass m) at rest. Which is most plausible for the heavy cart afterward?**

- A **It continues moving right (slower than before)** ✓
- B It must rebound left
- C It must come to rest
- D It must move right faster than before
- E It must stick to the light cart

▶ **Explanation:** When the moving mass is much larger than the stationary target in an elastic collision, it tends to keep moving in the same direction with slightly reduced speed, while the light target can be launched forward.

34 **A moving car collides with a wall rigidly attached to Earth. The momentum of the car alone is not conserved because:**

- A Momentum is never conserved in collisions
- B Kinetic energy is not conserved
- C The wall is stationary so it cannot exert force
- D Internal forces are not equal and opposite
- E **There is a large external impulse on the car from the wall (Earth)** ✓

▶ **Explanation:** The car is not an isolated system: the wall/Earth exerts a large external force/impulse on it, changing its momentum. If you include Earth, total momentum is conserved (approximately).

35 **A hockey puck slides on ice and experiences negligible friction. Which statement about the puck's momentum is correct?**

- A Momentum decreases because it is moving

- B **Momentum remains constant because net external force is ∼0** ✓
- C Momentum increases because the puck has kinetic energy
- D Momentum must be zero if the puck moves in a straight line
- E Momentum is conserved only if the puck is at rest

▶ **Explanation:** With negligible net external force, momentum remains constant in both magnitude and direction (Newton's 1st law in momentum form).

36 **A particle moves at constant speed in a circle. Which statement about its momentum is correct?**

- A Momentum is constant because speed is constant
- B Momentum is zero because it returns to the start
- C **Momentum changes because its direction changes** ✓
- D Momentum can change only if kinetic energy changes
- E Momentum is conserved for the particle

▶ **Explanation:** Momentum is a vector. Even if speed is constant, velocity direction changes in circular motion, so momentum changes and a net force is required.

37 **Two objects collide and then move off in different directions on a frictionless surface. Which conservation law can always be applied to the system during the collision (neglect external impulse)?**

- A **Conservation of momentum (in each direction)** ✓
- B Conservation of kinetic energy
- C Conservation of speed
- D Conservation of acceleration

E Conservation of force

▶ **Explanation:** If the system is isolated (negligible external impulse), total momentum is conserved as a vector, so both x- and y-components are conserved separately.

38 A moving cart collides with another and they stick together. Which statement about kinetic energy is correct?

A It must increase because momentum is conserved

B It must be conserved because the carts are on a frictionless track

C It must become zero

D **It decreases (some becomes internal energy like heat/sound/deformation)** ✓

E It becomes equal to the momentum

▶ **Explanation:** In a sticking collision, kinetic energy is not conserved: some mechanical energy becomes internal energy. Momentum can still be conserved if external impulse is negligible.

39 Two carts stick together after colliding on a frictionless track. In which special case is kinetic energy NOT lost in this sticking process?

A When one cart is much heavier than the other

B **When both carts already move with the same velocity before contact** ✓

C When the collision time is very short

D When both carts are made of rubber

E When the carts have equal mass

▶ **Explanation:** If the carts already share the same velocity, there is no relative motion to remove—sticking does not change their kinetic energy (it's like they were already moving together).

40 **A student says: "If momentum is conserved, kinetic energy must be conserved too." Which response is correct?**

- A Correct, because both are based on Newton's 3rd law
- B Correct, because momentum and kinetic energy are the same thing
- C Correct only in 1D collisions
- D Correct only if masses are equal
- E **Incorrect: momentum can be conserved in inelastic collisions where kinetic energy decreases** ✓

▶ **Explanation:** Momentum conservation requires negligible external impulse. Kinetic energy is conserved only in elastic collisions. In inelastic collisions, some kinetic energy becomes internal energy while momentum can remain conserved.

41 **Two objects collide briefly on a rough floor. If the collision time is very short, why might we still approximate momentum conservation for the two-object system?**

- A Because friction forces stop existing during collisions
- B Because kinetic energy is always conserved in short collisions
- C **Because the external impulse from friction during the short time can be negligible compared to the internal collision impulse** ✓
- D Because the objects are identical
- E Because momentum is always conserved even with large external forces

▶ **Explanation:** Momentum is conserved if net external impulse is negligible. Over a very short collision time, friction's impulse may be small compared to the large internal forces between the objects, so total momentum is approximately conserved.

42 **A ball hits the floor and bounces straight up. During the collision, the impulse on the ball from the floor points:**

- A **Upward** ✓
- B Downward
- C Sideways
- D Zero because it returns upward
- E Toward the center of Earth only

▶ **Explanation:** Impulse equals change in momentum. The ball's momentum changes from downward to upward, so Δp is upward; the floor must deliver an upward impulse.

43 **A ball hits the floor and does NOT bounce (it comes to rest). Compared to bouncing with the same incoming speed, the impulse magnitude on the ball is:**

- A Larger for stopping because it ends at rest
- B **Smaller for stopping than for bouncing back** ✓
- C The same because it hits the floor either way
- D Zero in both cases
- E Impossible to compare

▶ **Explanation:** Stopping changes momentum from $-mv$ to 0 ($|\Delta p|=mv$). Bouncing back changes from $-mv$ to $+mv$ ($|\Delta p|=2mv$), which is larger.

44 **In a collision between two objects, which statement about impulse is correct?**

- A The heavier object receives a larger impulse
- B The faster object receives a larger impulse

C Impulse is the same as force, so it depends only on peak force

D Only the object that changes direction receives impulse

E **Each object receives an impulse equal in magnitude and opposite in direction (action–reaction)** ✓

▶ **Explanation:** Because the forces are equal and opposite at each instant (Newton's 3rd law), the impulses (time integrals of force) are also equal and opposite for the two objects.

45 A cart of mass m moving right at speed v collides head-on and sticks to an identical cart moving left at speed v/2. The direction of the final velocity is:

A **To the right** ✓

B To the left

C Zero (they stop)

D Perpendicular to the original line

E Cannot be determined

▶ **Explanation:** Take right as positive: initial momentum $= m(v) + m(-v/2) = +mv/2$, which is to the right. Momentum conservation means final momentum (and thus final velocity) is to the right.

46 A puck at rest explodes into three equal pieces on frictionless ice. Two pieces fly off with equal speeds in opposite directions. The third piece must:

A Move in the same direction as one of the pieces

B Move faster than the other two

C **Remain at rest (zero momentum)** ✓

D Move perpendicular to the other two

E Have the largest kinetic energy

▶ **Explanation:** The two equal and opposite momenta already sum to zero, matching the initial zero momentum. So the third piece must have zero momentum (remain at rest).

47 **An object initially at rest breaks into two pieces that move at right angles to each other. Which statement is correct?**

- A This is impossible because momenta must be equal
- B This is possible only if the two pieces have equal masses
- C This is possible only if they have equal speeds
- D **This is impossible for exactly two pieces; their momenta must be opposite directions to sum to zero** ✓
- E This is always possible because kinetic energy is created

▶ **Explanation:** With only two pieces and initial total momentum zero, the momentum vectors must add to zero: $p1 + p2 = 0$, so they must be opposite directions, not perpendicular.

48 **A cart collision occurs on a frictionless surface. Initially, total y-momentum of the system is zero. After the collision, which must be true about y-momentum?**

- A Each object must have zero y-momentum
- B **The sum of y-momenta of all objects must still be zero** ✓
- C Total y-momentum becomes positive because objects scatter
- D Total y-momentum becomes negative because of gravity
- E y-momentum is not conserved, only x-momentum is

▶ **Explanation:** Momentum conservation is vector conservation. If external impulse is negligible, each component is conserved, so total y-momentum remains zero even if individual y-momenta are nonzero.

49 **Two identical pucks on frictionless ice move so that one has momentum mv in +x and the other has momentum mv in +y. They collide and stick together. The direction of their combined velocity is closest to:**

- A Along +x only
- B Along +y only
- C **At 45° between +x and +y** ✓
- D Along −x
- E Along −y

▶ **Explanation:** Total momentum is the vector sum: equal x and y components. That resultant points diagonally at 45° in the first quadrant. Sticking changes mass but not direction of total momentum.

50 **For the same two-puck situation (equal momenta in +x and +y) and they stick, what happens to the speed compared to v (the speed of each puck before, assuming each puck has mass m)?**

- A It becomes v
- B It becomes 2v
- C It becomes $\sqrt{2}$ v
- D **It becomes less than v** ✓
- E It becomes zero

▶ **Explanation:** Total momentum magnitude is $\sqrt{(mv)^2+(mv)^2} = \sqrt{2}$ mv. Combined mass is 2m, so speed is $(\sqrt{2}\ mv)/(2m) = (\sqrt{2}/2)v$, which is less than v.

51 **A bullet embeds in a wooden block that is free to slide on frictionless ice. Which statement is correct for the bullet+block system during the embedding?**

- A **Momentum is conserved, but kinetic energy decreases ✓**
- B Both momentum and kinetic energy are conserved
- C Momentum is not conserved because they stick
- D Kinetic energy increases because of an explosion
- E Momentum becomes zero because the bullet stops

▶ **Explanation:** Embedding is a perfectly inelastic collision: the system momentum is conserved (no external impulse), but kinetic energy decreases as some becomes internal energy (heat/deformation).

52 A bullet embeds in a block. If the block is much more massive than the bullet, the block's speed after impact will be:

- A Larger than the bullet's initial speed
- B **Much smaller than the bullet's initial speed ✓**
- C Equal to the bullet's initial speed
- D Exactly half the bullet's initial speed
- E Zero no matter what

▶ **Explanation:** Momentum conservation gives v_{final} $(m_{bullet}\ v_{bullet})/(m_{block} + m_{bullet})$. If m_{block} m_{bullet}, the final speed is small compared with the bullet's initial speed.

53 A person stands on a frictionless skateboard and throws a heavy ball forward. Immediately after the throw, the person+skateboard moves:

- A Forward, because the ball pushes them forward
- B Forward if the ball is heavy enough
- C **Backward, to conserve momentum ✓**

D Not at all, because internal forces cancel

E Upward, due to the reaction force

▶ **Explanation:** Initially total momentum is zero. Throwing the ball forward gives it forward momentum, so the person+skateboard must gain equal backward momentum to keep total momentum zero.

54 Two skaters (m and 2m) start at rest and push off. If they push so that the smaller skater leaves with speed v, the larger skater's speed is:

A **v/2** ✓

B v

C 2v

D v/4

E Cannot be determined

▶ **Explanation:** Their momentum magnitudes must match: $m \cdot v = 2m \cdot V$, so $V = v/2$ (opposite direction).

55 A student claims: "During a collision, the object that ends up with more kinetic energy must have received more impulse." Which is the best correction?

A Correct, impulse measures kinetic energy transfer directly

B Correct, because impulse equals work

C Incorrect: impulse is always zero in collisions

✓ D **Incorrect: impulse depends on change in momentum, not directly on kinetic energy**

E Incorrect only for elastic collisions

▶ **Explanation:** Impulse is Δp, a vector. Kinetic energy depends on v^2 and can change in complex ways. You can have equal and opposite impulses on two objects even if kinetic energies change differently.

56 **Which statement about conservation laws is most accurate for an isolated system during a collision?**

- A **Total momentum is always conserved; kinetic energy is conserved only if the collision is elastic ✓**
- B Total kinetic energy is always conserved; momentum only sometimes
- C Both momentum and kinetic energy are always conserved
- D Neither momentum nor kinetic energy is conserved
- E Momentum is conserved only if objects stick together

▶ **Explanation:** Momentum conservation follows from negligible external impulse. Kinetic energy conservation requires no conversion to internal energy, which is the defining feature of an elastic collision.

57 **A ball of mass m moving at speed v is brought to rest. Another identical ball moving at speed 2v is brought to rest. The ratio of impulses required (second:first) is:**

- A 1/2
- B 1
- C **2 ✓**
- D 4
- E 8

▶ **Explanation:** Impulse magnitude equals change in momentum: $|\Delta p| = mv$. For speed $2v$, $|\Delta p| = m(2v) = 2mv$, which is double.

58 **Two identical balls roll toward each other with speeds v and v (opposite directions) and bounce off in a perfectly elastic, symmetric collision. Which is correct about the total momentum?**

- A Total momentum becomes positive because they rebound
- B **Total momentum remains zero before and after** ✓
- C Total momentum becomes larger in magnitude
- D Total momentum is undefined because directions change
- E Total momentum equals the sum of speeds

▶ **Explanation:** Equal and opposite momenta cancel, giving total momentum zero. In an isolated collision, total momentum remains the same (zero).

59 **A moving cart collides and sticks to a stationary cart on a frictionless track. Compared with the initial kinetic energy of the moving cart, the final kinetic energy of the combined carts is:**

- A Greater because mass increased
- B The same because momentum is conserved
- C Zero because they stick
- D **Smaller (some kinetic energy is converted to internal energy)** ✓
- E Impossible to compare

▶ **Explanation:** A sticking collision is inelastic: for a given momentum, combining masses reduces speed, and some kinetic energy is converted into internal energy (deformation/heat/sound).

60 **In a 1D collision, two objects interact but experience no external forces. Which statement about the center of mass (COM) is correct?**

- A **The COM moves with constant velocity through the collision** ✓
- B The COM must stop during the collision because forces are large
- C The COM changes direction depending on how elastic the collision is
- D The COM always follows the heavier object
- E The COM moves only if kinetic energy is conserved

▶ **Explanation:** With no net external force, total momentum is constant, so the center of mass velocity (p_{total}/M_{total}) is constant through the interaction.

61 **A student throws a ball straight up while standing on frictionless ice. Neglecting air resistance and the brief push time, what can you say about the horizontal momentum of the student+ball system?**

- A It increases because the student did work
- B It decreases because gravity acts
- C It becomes zero at the top of the ball's path
- D **It remains constant (there is essentially no external horizontal impulse)** ✓
- E It is not defined for vertical throws

▶ **Explanation:** Gravity acts vertically, so it gives no horizontal impulse. With negligible horizontal external forces, horizontal momentum of the system stays constant.

62 **A ball is thrown upward and later caught by the same person while standing on frictionless ice. After the full process (throw + catch), the person's final velocity is:**

A Forward, because they threw the ball forward

B **The same as initially (zero), because the system returns to its initial momentum state** ✓

C Backward, because catching always pushes you back

D Upward, because the ball came down

E Impossible to predict

▶ **Explanation:** Ignoring external horizontal impulse, total momentum is conserved. The person gives the ball momentum when throwing but receives equal and opposite momentum when catching, returning to the original momentum state.

63 Which statement about momentum conservation is correct in different inertial reference frames?

A Momentum is conserved only in the frame where the center of mass is at rest

B Momentum conservation depends on the observer's speed, so it can be true in one frame and false in another

C **If momentum is conserved in one inertial frame for an isolated system, it is conserved in all inertial frames** ✓

D Momentum is never conserved in moving frames

E Only kinetic energy is frame-independent

▶ **Explanation:** Momentum values change between frames, but the conservation law (same total momentum before and after for an isolated system) holds in all inertial frames.

64 A cart collides elastically with an identical cart at rest. Which statement about energy transfer is correct?

A **The moving cart can transfer all of its kinetic energy to the stationary cart** ✓

B The moving cart must keep at least half its kinetic energy

C No kinetic energy is transferred in elastic collisions

D Energy transfer depends only on collision time, not mass

E Elastic collisions always result in both carts moving

▶ **Explanation:** For equal masses in a 1D elastic collision where one is initially at rest, they exchange velocities. The initially moving cart stops, so it transfers essentially all kinetic energy to the other cart.

65 In a 1D elastic collision where a moving object hits a stationary target, when is the fraction of kinetic energy transferred to the target maximized (for a given incoming speed)?

A When the target is much heavier than the projectile

B When the projectile is much heavier than the target

C **When the projectile and target have equal masses** ✓

D When the collision is perfectly inelastic

E When friction is large

▶ **Explanation:** Maximum kinetic energy transfer in a 1D elastic collision with a stationary target occurs when masses are equal (classic result used in billiards).

66 A 2 kg cart moving at speed v collides and sticks to a 2 kg cart at rest. A different 4 kg cart moving at speed v collides and sticks to a 4 kg cart at rest. Comparing the final speeds in the two scenarios:

A The first final speed is larger because mass is smaller

B **They are the same fraction of v (both are v/2)** ✓

C The second final speed is larger because momentum is larger

D The first final speed is v/4

E Impossible to compare

▶ **Explanation:** For equal-mass sticking with one initially at rest, $v_f = v/2$ regardless of the mass value (since momentum and total mass scale together).

67 Two cars collide and stick. In the short collision time, external impulses are negligible. Immediately after collision, the combined wreck moves in the direction of:

A The heavier car's original direction only

B The faster car's original direction only

C The direction of the larger force during collision

D **The vector sum of the two cars' initial momenta (the total momentum direction)** ✓

E The direction of the average velocity of the two cars

▶ **Explanation:** With momentum conservation, the final momentum of the combined mass equals the initial total momentum vector. Therefore the wreck moves in the direction of the total momentum.

68 Two equal masses collide and stick. One was moving north, the other east, with equal speeds. The combined object moves:

A North

B **Northeast (45° between north and east)** ✓

C East

D Southwest

E It stops

▶ **Explanation:** Equal masses with equal speeds have equal momentum magnitudes in perpendicular directions. The vector sum points at 45° between them (northeast).

69 **A student says: "Because the forces in a collision are equal and opposite, the net force on each object must be zero." What is the correct response?**

- A Correct; Newton's 3rd law makes acceleration impossible
- B Correct only when the masses are equal
- C Correct only for perfectly elastic collisions
- D Incorrect because forces are not actually equal
- E **Incorrect: equal-and-opposite forces act on different objects, so they do not cancel on a single object** ✓

▶ **Explanation:** Newton's 3rd law pairs act on different bodies. On one object, there can be a large net force causing acceleration (and momentum change) during the collision.

70 **A force acts on an object for time Δt, producing impulse J. If the same impulse is delivered with a force that peaks higher but acts for a shorter time, what can be the same?**

- A **The change in momentum can be the same (since it depends on impulse), even if the force-time shape differs** ✓
- B The change in momentum must be larger if the peak force is larger
- C The change in momentum must be smaller if the time is shorter
- D The impulse must be larger if the peak force is larger
- E Impulse depends only on peak force, not on time

▶ **Explanation:** Impulse is the area under the force–time curve. Different shapes can have the same area, producing the same Δp even with different peak forces and durations.

71 **In which situation is it most appropriate to include Earth as part of your "system" to apply momentum conservation?**

- A Two carts collide on a frictionless track
- B Two skaters push off each other on ice
- C **A ball bounces off a wall bolted to the ground** ✓
- D A puck explodes into fragments in space
- E Two billiard balls collide on a smooth table

▶ **Explanation:** When a wall is attached to Earth, the wall can deliver a large external impulse to the ball. Momentum of the ball alone is not conserved, but the momentum of the ball+Earth system is (approximately).

72 **An object's momentum changes from $+p$ to $-p$ in one dimension. The magnitude of the change in momentum is:**

- A 0
- B p
- C $-p$
- D **2p** ✓
- E p/2

▶ **Explanation:** $\Delta p = p_{final} - p_{initial} = (-p) - (+p) = -2p$, so the magnitude is 2p.

73 **A collision is labeled "elastic." Which statement must be true (for the system)?**

- A Objects must stick together
- B **Total kinetic energy is the same before and after the collision ✓**
- C Total momentum is zero
- D No forces act during the collision
- E The heavier object must end up faster

▶ **Explanation:** Elastic collisions conserve kinetic energy (and momentum, if isolated). Sticking is inelastic, and momentum need not be zero—only conserved.

74 Two objects collide and then separate. The coefficient of restitution e describes how "bouncy" the collision is and is defined (in 1D) as:

- A **Relative speed of separation divided by relative speed of approach ✓**
- B Relative speed of approach divided by relative speed of separation
- C Impulse divided by kinetic energy
- D Force divided by time
- E Total momentum after divided by total momentum before

▶ **Explanation:** In 1D, e = (speed of separation)/(speed of approach). For a perfectly elastic collision e=1; for perfectly inelastic e=0 (objects do not separate).

75 A soccer ball is kicked so that its speed increases in the forward direction. During the kick, the net impulse on the ball is best described as:

- A Backward because the foot pushes backward on the air
- B Zero because contact time is short
- C Upward because the ball lifts
- D Perpendicular to motion because forces are perpendicular

E **Forward, in the direction of the ball's change in momentum** ✓

▶ **Explanation:** Impulse points in the direction of Δp. If the ball's speed increases forward, its momentum increases forward, so the net impulse on the ball is forward.