READ MODE · ANSWER FIRST

Centre of mass and collision problems for Class 11 JEE

Learn centre of mass, momentum, restitution, elastic and inelastic collisions, plus a reliable Class 11 JEE solving method.

CHEAT SHEET · 6 ESSENTIAL IDEAS

The whole story in 6 lines

Choose the system and axes, conserve momentum, add the collision condition, solve, then check signs and energy.

1. The centre of mass is a mass-weighted position, so it lies closer to the heavier particle.
2. Internal collision forces change individual motions but only external force changes centre-of-mass motion.
3. A signed diagram turns momentum conservation into the first reliable collision equation.
4. Restitution fixes relative separation speed, while the centre-of-mass frame exposes the simplest elastic motion.
5. Momentum stays conserved across isolated collisions, but kinetic energy depends on the restitution regime.
6. In two dimensions, conserve momentum separately along chosen axes and then rebuild the result vector.

Setup

A 2 kg mass moving right meets a 1 kg mass moving left. The impact lasts an instant, yet two unknown outgoing velocities must obey strict rules.

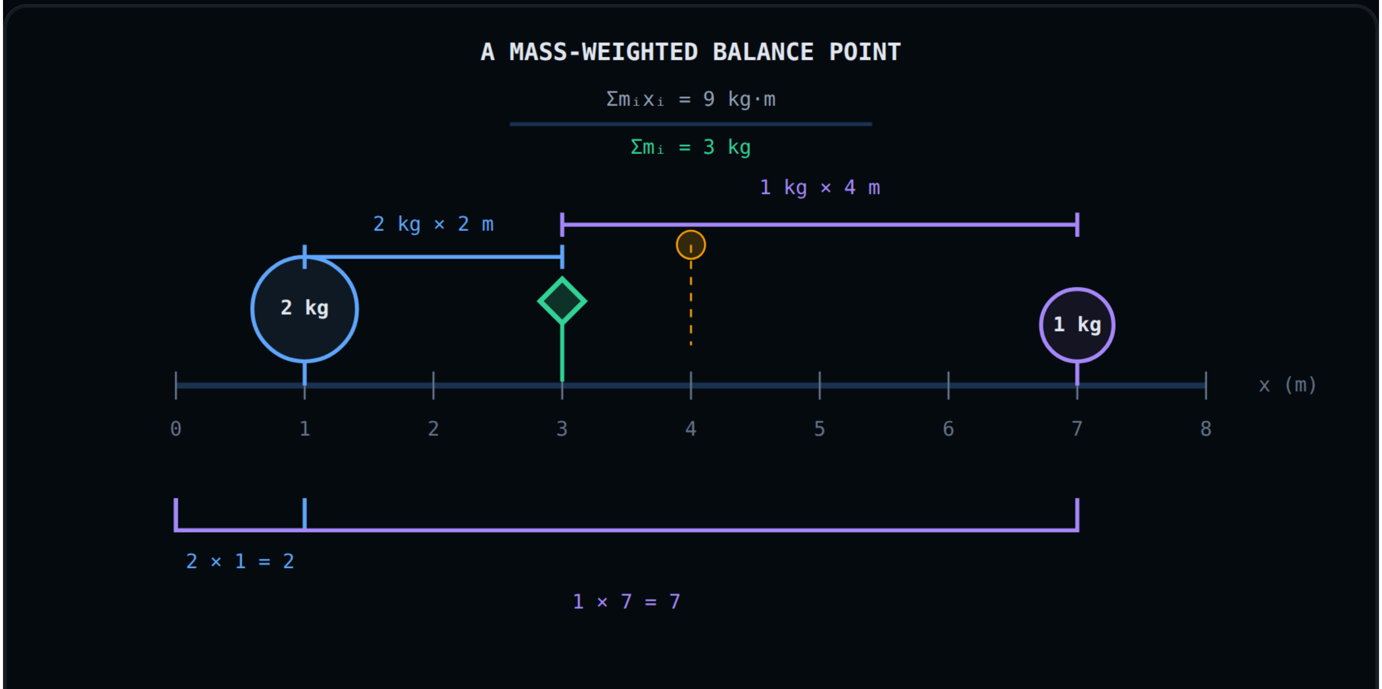
The centre of mass is the mass-weighted average position. Momentum combines mass with velocity, so direction matters as much as speed.

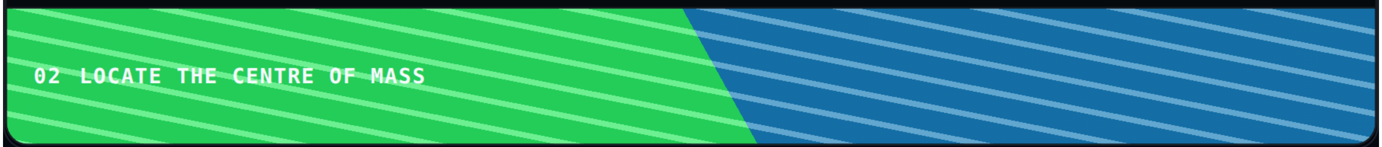
Impulse measures how force changes momentum over a time interval. Restitution compares relative separation speed with relative approach speed after contact.

We will locate the centre, follow its motion, build a signed ledger, solve in its frame, compare collision types, and finish with a two-dimensional method.

The mystery now has a map. Every numerical result will come from one computed example, so signs and conservation checks remain consistent. Let us begin with the balance point.

Locate the centre of mass





Our first task is purely geometric. Place the 2 kg particle at 1 metre and the 1 kg particle at 7 metres on one signed ruler.

A simple midpoint would ignore mass. Instead, multiply each position by its mass, which gives weighted moments of 2 kg metres and 7 kg metres.

Add those two contributions before dividing by total mass. The numerator is 9 kg metres while the total mass is 3 kg.

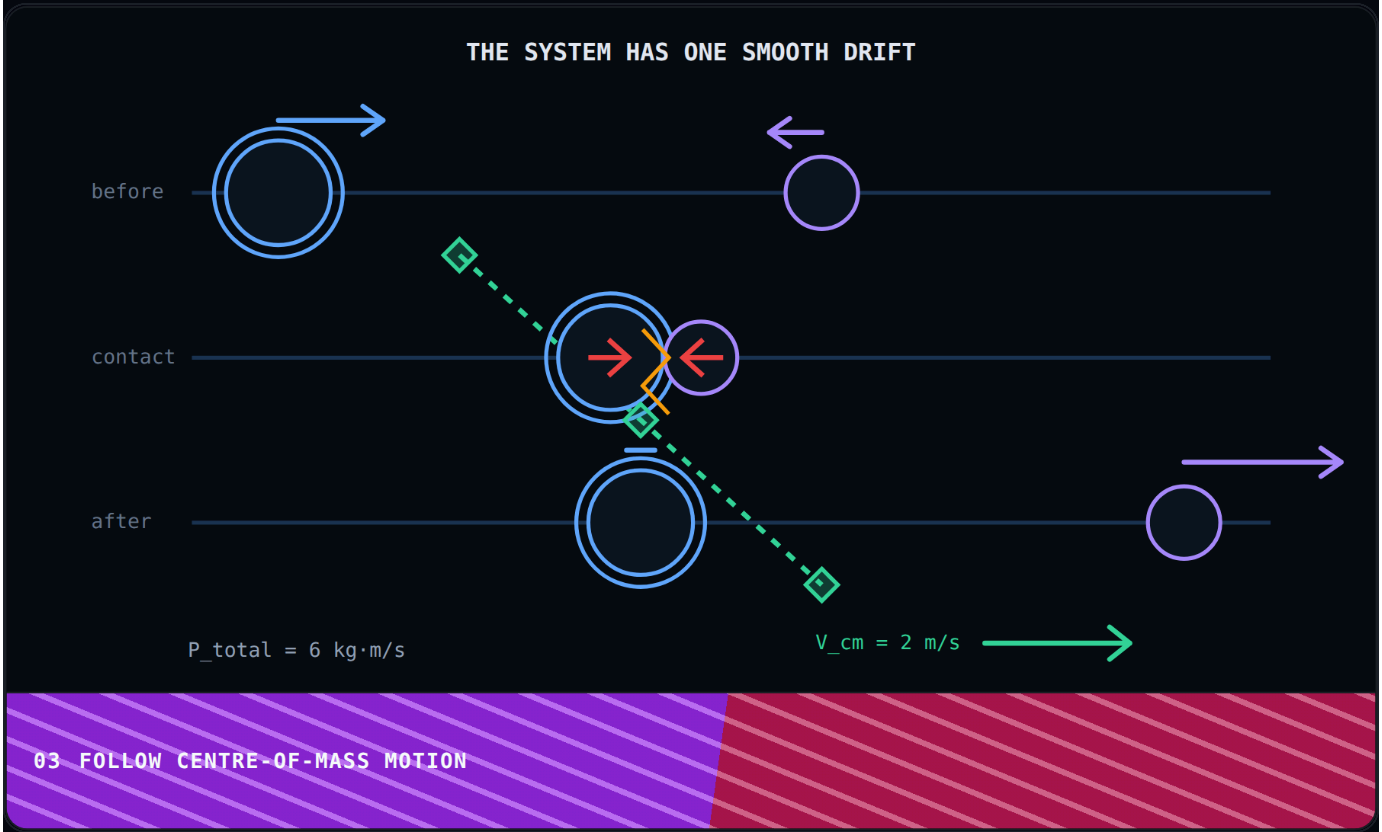
The weighted average gives 3 metres. That result already predicts the marker must sit closer to the heavier particle at 1 metre.

The balance marker lands at 3 metres. Its arms are 2 metres and 4 metres, so both sides produce the same 4 kg metre turning effect.

Centre of mass is a position, not necessarily a material point. The weighted ruler is the safe starting method for any collection of point masses. Next we will let both masses move.

STAGE 3 OF 8

Follow centre-of-mass motion



The weighted position becomes more powerful once particles move. For our collision, total momentum is plus 6 kg metres per second and total mass is 3 kg.

Their centre therefore moves right at 2 metres per second. Individual velocities may change during contact, but the total momentum fixes this shared drift.

At contact, each mass exerts a large force on the other for the same short time. Does that force pair make the centre marker jump?

PAUSE AND PREDICT

Does the internal force pair make the centre marker jump?

- **No, it keeps the same velocity**
- **Yes, it stops during contact**
- **Yes, it suddenly speeds up**

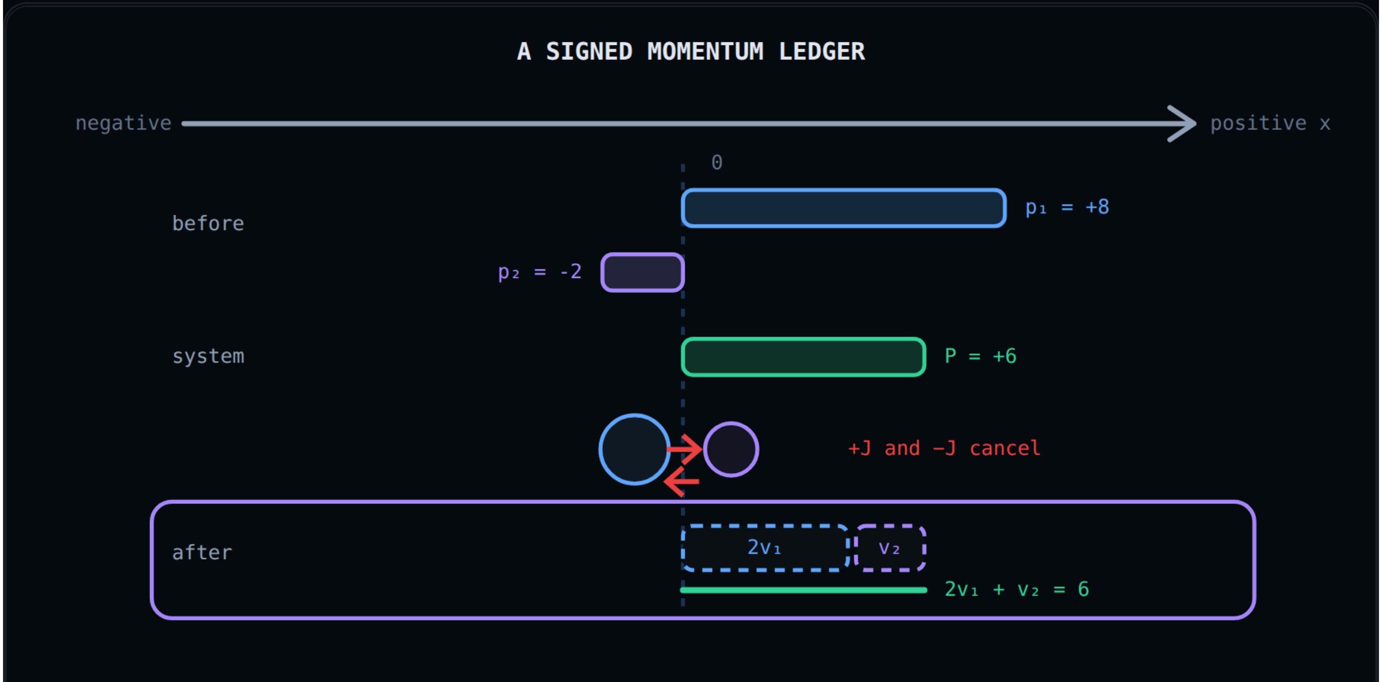
Skip this check

The completed snapshots keep the green markers equally spaced through approach, compression, and separation. The bodies change their relative motion while the system drift remains plus 2 metres per second.

The rule is external force equals total mass times centre-of-mass acceleration. During a short isolated collision, external impulse is negligible compared with the contact impulses.

Internal forces rearrange motion inside the system, but only external impulse changes the centre path. Next we will turn that statement into a signed momentum equation.

Build the momentum ledger



04 BUILD THE MOMENTUM LEDGER

We now know the system total controls centre motion. To build the collision equation, choose right as positive before substituting any speed.

The 2 kg particle contributes plus 8 kg metres per second. The 1 kg particle moves left, so its contribution is minus 2.

Adding signed bars gives plus 6 kg metres per second. A speed-only calculation would wrongly produce plus 10 and send the centre too fast.

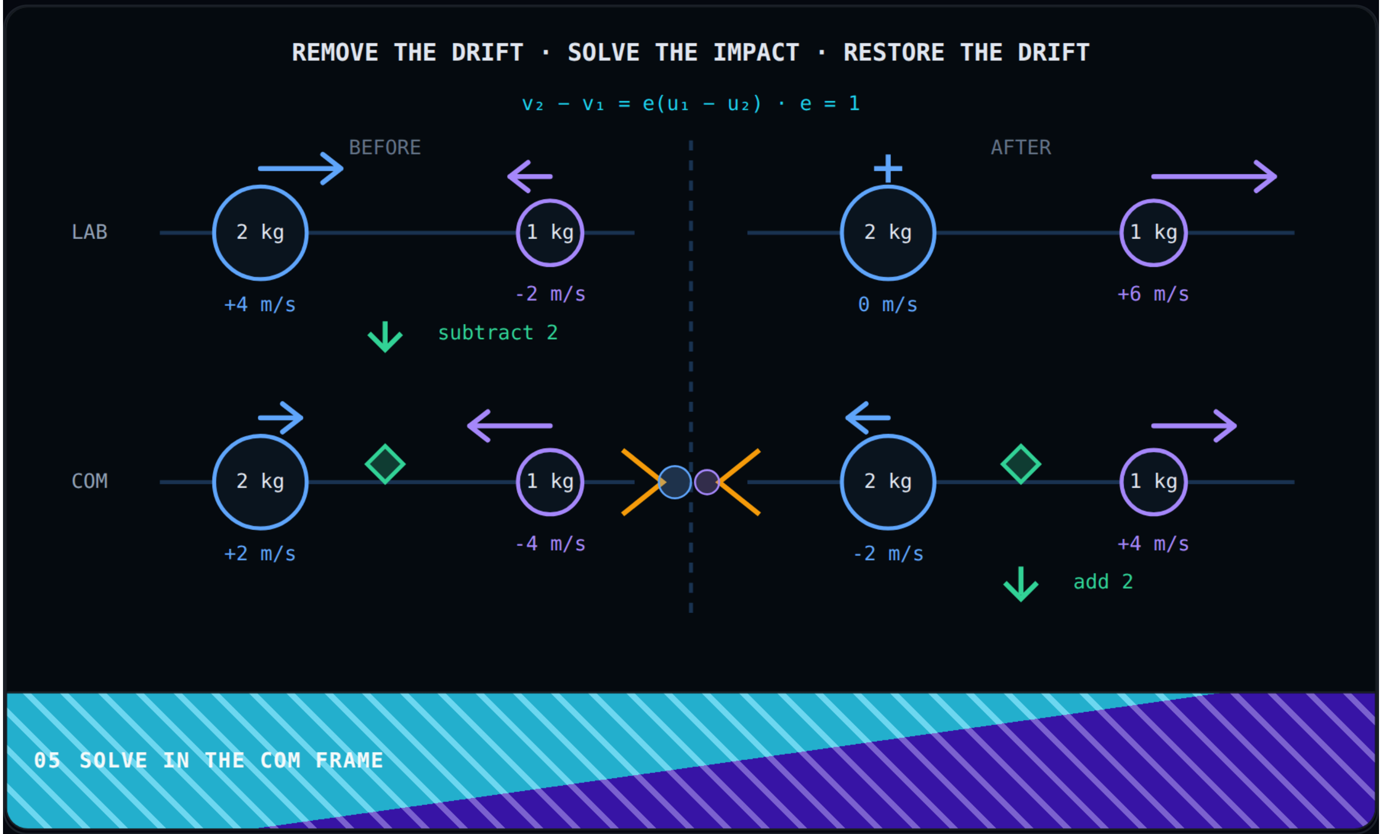
During contact, the impulse on mass 1 equals the opposite impulse on mass 2. Those internal changes cancel when both particles belong to the chosen system. This is Newton’s third law inside one system.

The after side must total the same plus 6. The first equation is therefore 2 times v1 plus 1 times v2 equals 6, with signed final velocities.

Momentum conservation gives one equation for two unknown final velocities. A second physical condition is still required. Next restitution will supply it.

Solve in the COM frame

★ If you remember one thing · In the centre-of-mass frame, an elastic head-on collision reverses each velocity; adding the shared drift returns the lab result.



The momentum ledger left two unknowns. Restitution adds relative separation speed equals e times relative approach speed, using one consistent positive direction. Together they determine both unknown velocities uniquely.

For an elastic collision, e equals 1. Subtract the shared plus 2 metre per second centre velocity from both incoming laboratory velocities.

The centre-frame velocities become plus 2 and minus 4. Their weighted momenta cancel exactly, so the green centre marker is stationary in this frame.

Elasticity preserves kinetic energy and zero total momentum in the centre frame. What can both centre-frame velocities do after a real collision?

PAUSE AND PREDICT

What can both centre-frame velocities do after the elastic collision?

- Reverse direction with unchanged magnitudes
- Both remain stopped

Continue unchanged through each other

Skip this check

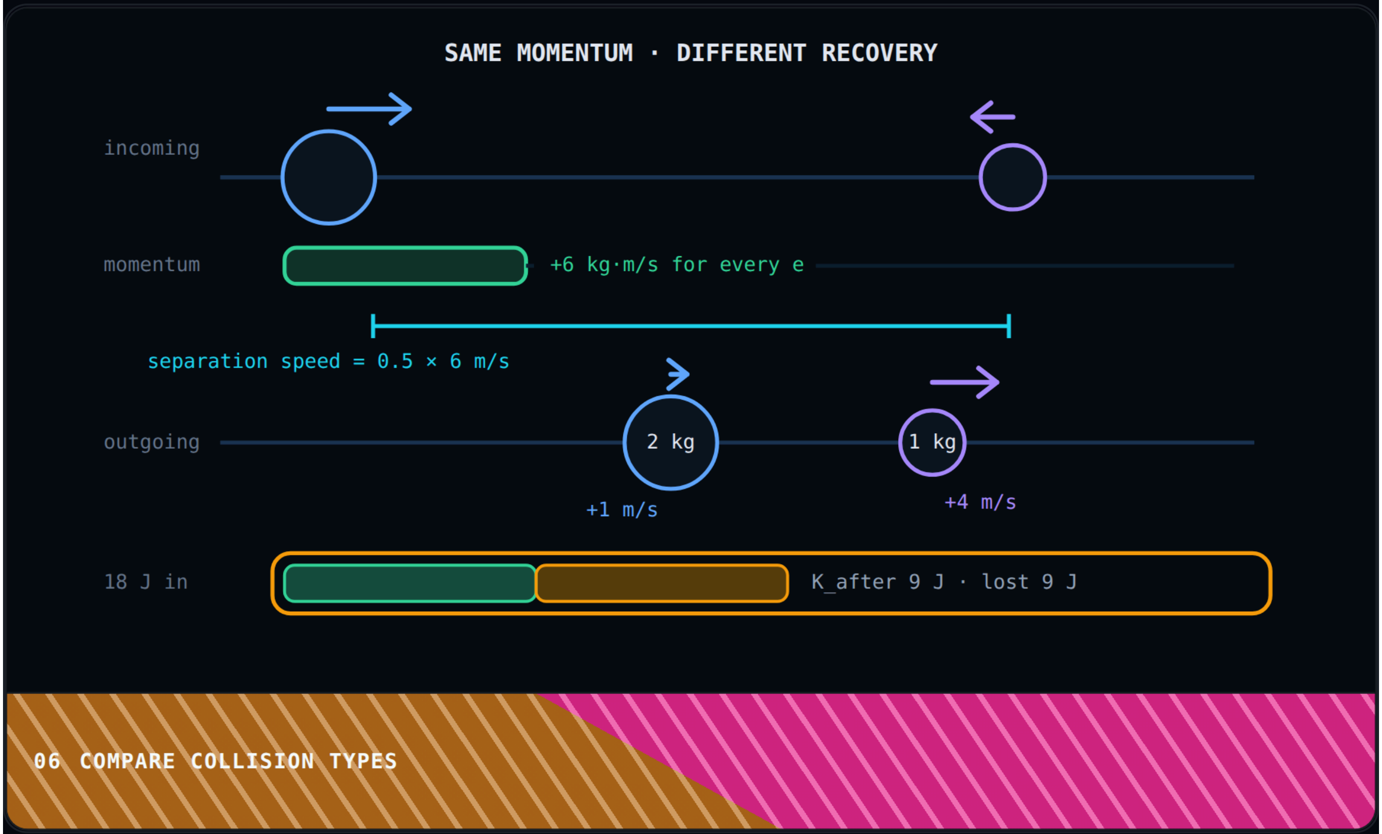
Both centre-frame arrows reverse together. Adding plus 2 back gives v1 equals zero and v2 equals plus 6 metres per second in the laboratory frame.

Momentum supplied the shared drift while restitution fixed the relative motion. This same pair solves every direct two-body collision. Next we will vary restitution.

STAGE 6 OF 8

Compare collision types

Try it in Watch mode. Make the 2 kg particle stop while total momentum remains plus 6.



The elastic solution recovered all relative speed, but real impacts may recover less. We keep the same masses and incoming velocities so only restitution changes.

Momentum remains plus 6 for every setting because restitution describes internal recovery. It cannot alter the isolated system total or the plus 2 centre velocity.

As e falls from one toward zero, the relative separation speed shrinks. Which e value makes both particles share one final velocity?

PAUSE AND PREDICT

Which e value makes both particles share one final velocity?

- e = 0
- e = 0.5
- e = 1

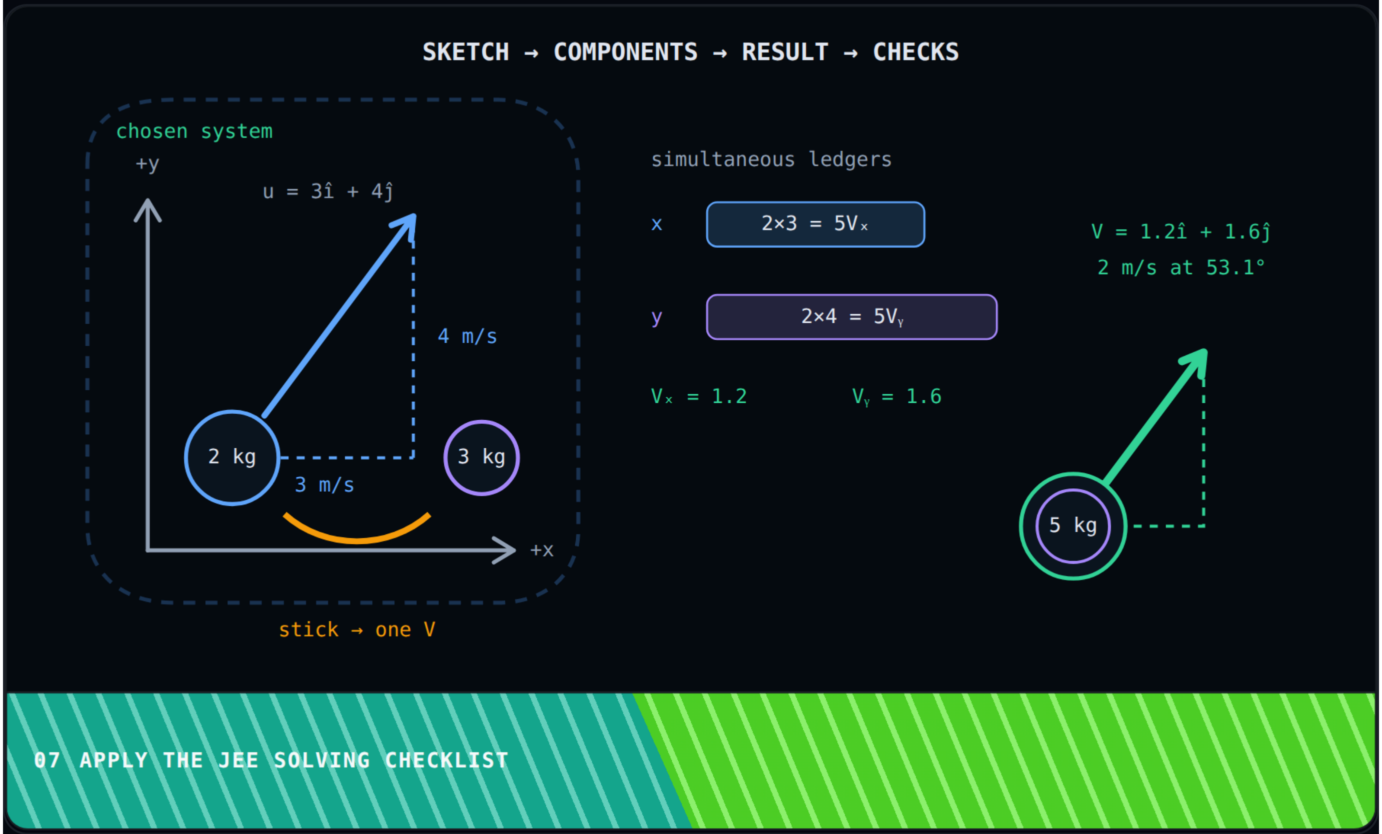
Skip this check

The final arrows and kinetic-energy bar now follow the selected e. The system always keeps 6 kg metres per second of momentum, while converted energy ranges from zero to 12 joules.

Switch the Restitution control through each value. Compare sticking, partial separation, and full transfer against the changing kinetic-energy bar.

Momentum conservation identifies the system invariant. Restitution identifies collision type, outgoing relative speed, and kinetic-energy loss. Next we will organize these ideas for unfamiliar JEE problems.

Apply the JEE solving checklist



We now have the laws, so the final stage turns them into a repeatable exam method. Start by choosing the complete interacting system and drawing velocity arrows.

A 2 kg point mass moves at 3 i plus 4 j metres per second. It sticks to a stationary 3 kg target after impact.

Choose x and y axes before writing components. Sticking means both masses share one final velocity, which removes separate final-velocity unknowns.

Conserve x momentum and y momentum at the same time. The initial components are 6 and 8 kg metres per second while the combined mass is 5 kg.

Dividing each component by 5 gives 1.2 i plus 1.6 j metres per second. The resultant speed is 2 and its direction is 53.1 degrees above positive x.

Finish every collision with checks for units, momentum components, plausible signs, and kinetic energy. Extra unknowns require another condition such as restitution. Now let us connect the whole method.

Recap

We started with a weighted ruler. Multiplying each position by its mass placed the centre closer to the heavier particle.

Then repeated snapshots separated internal violence from system motion. Equal and opposite contact impulses left the centre velocity unchanged.

Next a signed momentum ledger made direction explicit. The isolated system kept plus 6 kg metres per second before and after contact.

The centre frame removed common drift. Restitution then fixed relative motion, and elastic velocities reversed cleanly before returning to the laboratory frame.

Changing restitution exposed the invariant and the tradeoff. Momentum stayed fixed while kinetic energy recovery ranged from none to complete.

Finally, the two-dimensional example split one vector law into simultaneous x and y ledgers, then recombined the solved components.

The complete method is one connected loop. Choose system and axes, conserve momentum, add the collision condition, solve, then check signs, components, and energy.