

Mahendra Singh

❑ **B. Tech Gold Medalist**

- ❑ **Mentored Lakhs of students**
- ❑ **Mentored AIR 49 in JEE**
- ❑ **Multiple AIR Under 500**
- ❑ **Got Teaching Excellence Award by Unacademy**





📅 April 20, 2022

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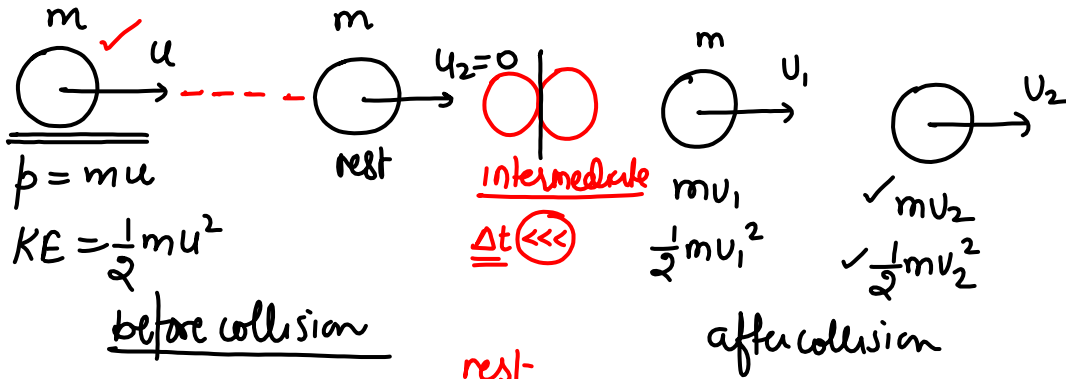


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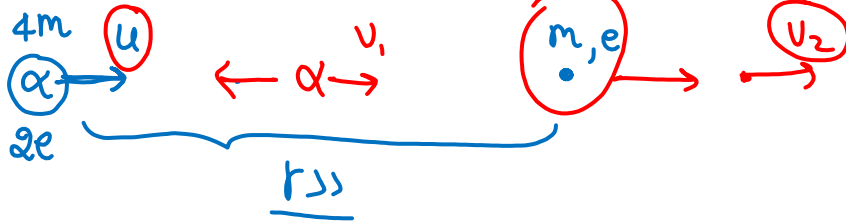
Collision

↳ Event $\Rightarrow$ transfer of momentum
Energy
 instantaneous

(eg)



#



To transfer (P) and (E)
 is it necessary to have
contact?

Yes

No

Collision

→ forces are internal only, $\Delta \vec{p} = 0$. $\vec{P} = \text{conserved}$

* Elastic *

• $\vec{P}_i = \vec{P}_f$ — (1)

• $K_i = K_f$

• $e = 1$ — (2)

↓
coefficient
of restitution

$$e = \frac{\text{velo of sep.}}{\text{velo of app}}$$

no loss of energy

Inelastic

loss of energy

$$\vec{P}_i = \vec{P}_f$$

$$K_i \neq K_f$$

$$0 < e < 1$$

e given, $\underline{u}_1$ and $\underline{u}_2$

$\underline{u}_1$ and $\underline{u}_2$, $e = ?$

perfectly inelastic

maximum loss

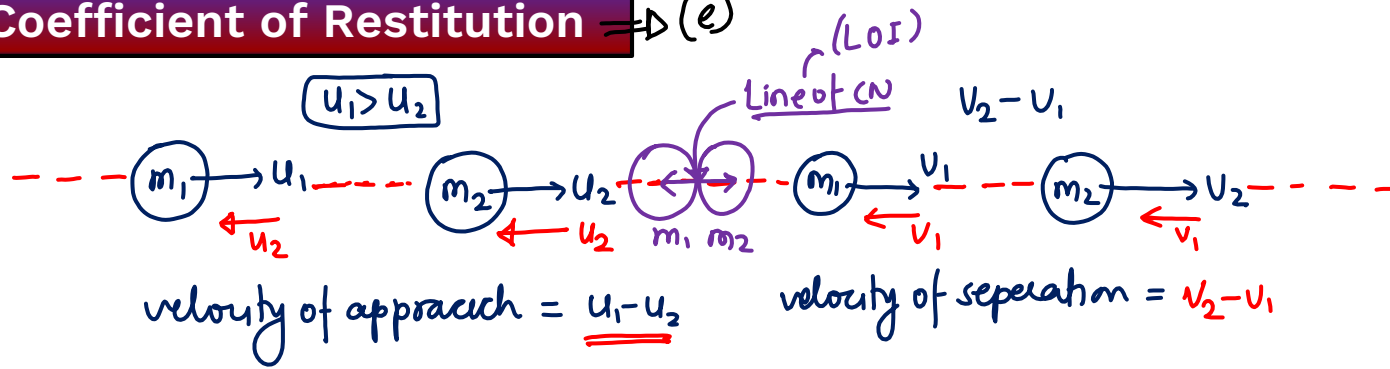
particle/bodies move together
after collision

velocity of separation = 0

$e = 0$

$\vec{P}_i = \vec{P}_f$

Coefficient of Restitution $\Rightarrow (e)$



$$e = \left(\frac{\text{velo of sep}}{\text{velo of app}} \right) \text{ along LOI}$$

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

While using this formulae
Use all velocity with proper sign
convention

$$\begin{aligned} \longrightarrow & (+) \\ \longleftarrow & (-) \end{aligned}$$

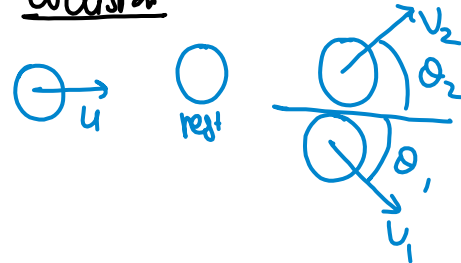
Collision :-

head on collision

bodies before and
after collision move
along the same line.

Oblique collision

bodies move in different
direction before and after
collision





Example

A nucleus moving with velocity $\vec{v}$ emits an α -particle. If the velocities of α -particle and the

remaining nucleus be $\vec{v}_1$ and $\vec{v}_2$ and their masses be m_1 and m_2 , then -

- (A) All velocity vectors $\vec{v}$, $\vec{v}_1$ and $\vec{v}_2$ must be parallel
- X (B) $\vec{v}$ must be parallel to $(\vec{v}_1 + \vec{v}_2)$
- ✓ (C) $\vec{v}$ must be parallel to $(m_1 \vec{v}_1 + m_2 \vec{v}_2)$
- (D) None of above

$M = (m_1 + m_2)$
 m_2
 m_1

$\vec{P}_i = (m_1 + m_2) \vec{u}$
 $\vec{P}_f = m_1 \vec{u}_1 + m_2 \vec{u}_2$

$\vec{P}_i = \vec{P}_f$

$\vec{u} = \frac{m_1 \vec{u}_1 + m_2 \vec{u}_2}{(m_1 + m_2)}$



Example

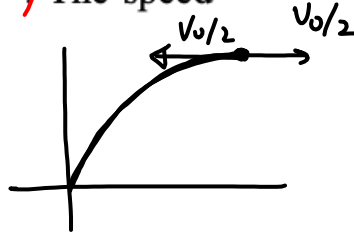
A projectile is ~~fixed~~ ^{launched} with velocity v_0 at an angle 60° with horizontal. At top of its trajectory it explodes into three fragment of equal mass.

First fragment retraces the path, second moves

vertically upward with speed $\left(\frac{3v_0}{2}\right)$. The speed of third fragment –

- (A) $\frac{3v_0}{2}$
(C) v_0

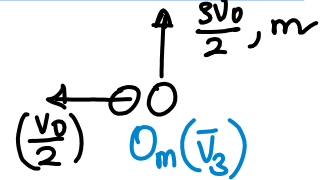
- (B) $\frac{5v_0}{2}$
(D) $2v_0$



$$|\vec{v}_3| = \sqrt{(2v_0)^2 + \left(\frac{3v_0}{2}\right)^2}$$

$$v_0 \cos 60^\circ = \frac{v_0}{2}$$

$\rightarrow$
3m



$$\vec{P}_1 = 3m \frac{v_0}{2} (\hat{i})$$

$$\vec{P}_2 = m \frac{v_0}{2} (-\hat{i}) + m \frac{3v_0}{2} \hat{j} + m \vec{v}_3$$

$$\frac{3mv_0}{2} \hat{i} = -\frac{mv_0}{2} \hat{i} + \frac{3mv_0}{2} \hat{j} + m \vec{v}_3$$

$$2mv_0 \hat{i} - \frac{3mv_0}{2} \hat{j} = m \vec{v}_3$$

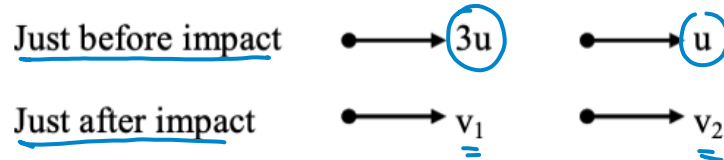
$$\vec{v}_3 = 2v_0 \hat{i} - \frac{3v_0}{2} \hat{j}$$



Example

Two smooth objects with a coefficient of restitution (e) collides directly and bounce as shown

Newton's law of restitution gives :



(A) $e \times 4u = v_2 + v_1$

(B) $e \times 2u = v_1 - v_2$

✓ (C) $e \times 2u = v_2 - v_1$

(D) it cannot be applied as the masses are not known

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

$$e = \frac{v_2 - v_1}{3u - u}$$

$$2u \times e = v_2 - v_1$$

#

Before collision After collision

3u u v₁ v₂

→ ← → →

$$e = \frac{v_2 - v_1}{3u - (-u)} = \frac{v_2 - v_1}{4u}$$
$$4u \times e = v_2 - v_1$$



Example

If two object collide with each other then -

(P) for elastic collision (X) conservation of
mechanical energy

(Q) for inelastic collision $\longrightarrow$ (Y) conservation of linear
momentum

~~(A)~~ $P \rightarrow X, Q \rightarrow Y$

✓ (B) $P \rightarrow X, Y$ and $Q \rightarrow Y$

~~(C)~~ $P \rightarrow Y, Q \rightarrow X$

(D) $P \rightarrow X, Y$ and $Q \rightarrow \text{None}$



Example

When two bodies collide elastically, then-

- (A) kinetic energy of the system alone is conserved
- (B) only momentum is conserved
- ☒ (C) both energy and momentum are conserved
- (D) neither energy nor momentum is conserved





Example



Which of the following is not a perfectly inelastic collision-

- (A) capture of an electron by proton
- ✓ ~~(B)~~ man jumping onto a moving cart
- (C) collision between glass balls
- (D) a bullet fired into a block of wood such that it is embedded in the wood



Example

$e=1$

A particle strikes elastically with another particle with velocity V . After collision, it moves with half the velocity in the same direction. Find the velocity of the second particle if it is initially at rest :

(A) $\frac{3V}{2}$

(B) $\frac{V}{2}$

(C) V

(D) none of these



$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

$$1 = \frac{v_2 - V/2}{V - 0}$$

$$V = v_2 - \frac{V}{2}$$

$$v_2 = \frac{3V}{2}$$

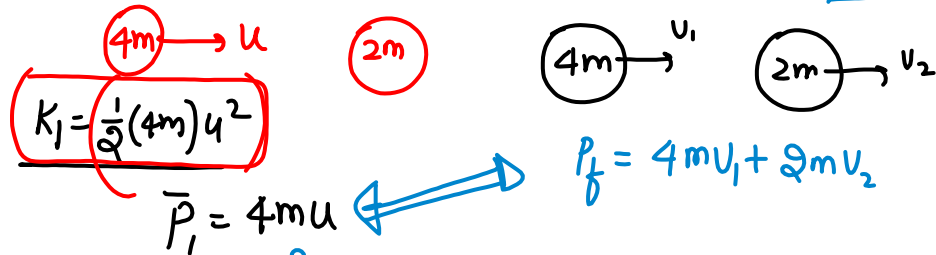


Example

Body A of mass $4m$ moving with speed u collides with another body B of mass $2m$ at rest. The collision is head on and elastic in nature. After the collision the fraction of energy lost by the colliding body A is

- (a) $5/9$ (b) $1/9$ (c) $8/9$ (d) $4/9$

(NEET 2019)



$$4m u = 2m (2v_1 + v_2)$$

$$2v_1 + v_2 = 2u \quad \text{--- (1)}$$

$$-v_1 + v_2 = u \quad \text{--- (2)}$$

$$\begin{aligned} 2v_1 + v_2 &= 2u \\ -2v_1 + 2v_2 &= 2u \end{aligned}$$

$$3v_2 = 4u$$

$$v_2 = \frac{4u}{3}$$

$$v_1 = v_2 - u = \frac{4u}{3} - u = \frac{u}{3}$$

$$\textcircled{A} K_{E_f} = \left(\frac{1}{2} (4m) \left(\frac{u}{3} \right)^2 \right) \cdot \frac{1}{9}$$

$$\frac{K_i - K_f}{K_i} = \frac{1 - \frac{1}{9}}{1} = \frac{8}{9}$$



Example

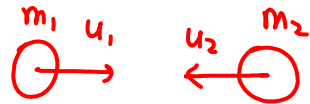
Two solid balls of rubber A and B whose masses are 200gm and 400gm respectively, are moving in mutually opposite directions. If the velocity A is 0.3 m/s and both the balls come to rest after collision, then the velocity of ball B is-

(A) 0.15 ms^{-1}

(B) -0.15 ms^{-1}

(C) 1.5 ms^{-1}

(D) none of these



$$P_i = 0 = m_1 u_1 - m_2 u_2$$

rest
 $P_f = 0$

$$u_2 = \frac{m_1 u_1}{m_2} = \frac{200(0.3)}{400} = 0.15$$



Example

As shown in figure A, B and C are identical balls B and C are at rest and, the ball A moving with velocity v collides elastically with ball B, then after collision –



- (A) ~~X~~ All the three balls move with velocity $v/2$
- (B) ~~X~~ A comes to rest and (B + C) moves with velocity $v/\sqrt{2}$
- (C) ~~X~~ A moves with velocity v and (B + C) moves with velocity v
- (D) ☒ A and B come to rest and C moves with velocity v





Example

Six identical balls are lined up along a straight frictionless groove. Two similar balls moving with speed v along the groove collide with this row on extreme left side end. Then –

- ☒ (A) One ball from the right end will move on with speed $2v$, all the other remains at rest
- ☒ (B) Two balls from the extreme right will move on with speed v each and the remaining balls will be at rest
- (C) All the balls will start moving to right with speed $v/8$ each
- (D) All the six balls originally at rest will move on with speed $v/6$ each and the two incident ball will come to rest



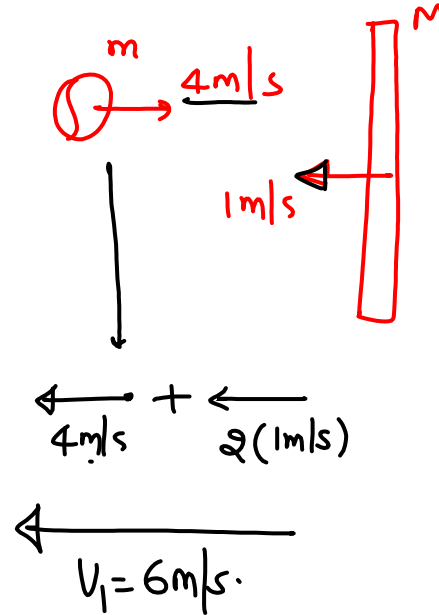


Example

$$M \gg m$$

A ball of mass m approaches a wall of mass M ($\gg m$) with speed 4 m/s along the normal to the wall. The speed of wall is 1 m/s towards the ball. The speed of the ball after an elastic collision with the wall is -

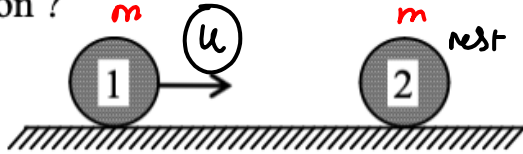
- (A) 5 m/s away from the wall
- (B) 9 m/s away from the wall
- (C) 3 m/s away from the wall
- ✓ (D) 6 m/s away from the wall





Example

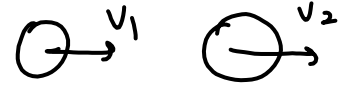
Ball 1 collides with an another identical ball 2 at rest as shown in figure. For what value of coefficient of restitution e, the velocity of second ball becomes two times that of 1 after collision?



- (A) 1/3
(C) 1/4

- (B) 1/2
(D) 1/6

$$v_2 = 2v_1$$



$$p_i = p_f$$

$$mu = m(v_1 + v_2)$$

$$\begin{aligned} u_1 + v_2 &= u \\ -u_1 + v_2 &= eu \end{aligned}$$

$$2v_2 = u(1+e)$$

$$4eu = u(1+e)$$

$$4e - e = 1$$

$$e = \frac{1}{3}$$

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

$\downarrow$
 u

$$v_2 - v_1 = eu$$

$$v_2 - \frac{v_2}{2} = eu$$

$$v_2 \frac{1}{2} = eu$$

$$v_2 = 2eu$$



Example

A moving block having mass m , collides with another stationary block having mass $4m$. The lighter block comes to rest after collision. When the initial velocity of the lighter block is v then the value of coefficient of restitution (e) will be $v = u$

- (a) 0.5 ☒ (b) 0.25 (c) 0.8 (d) 0.4

(NEET 2018)



$$V_1 = 0 = V_2 - eu$$

$$\boxed{V_2 = eu} = \frac{4 + eu}{5}$$

$$5eu = 4(1 + e)$$

$$4e = 1$$



Example

$$e = 0$$

After perfectly inelastic collision between two $m_1 = m_2$ identical particles moving with same speed in different directions, the speed of the particles become half the initial speed. The angle between the velocities of the two before collision is -

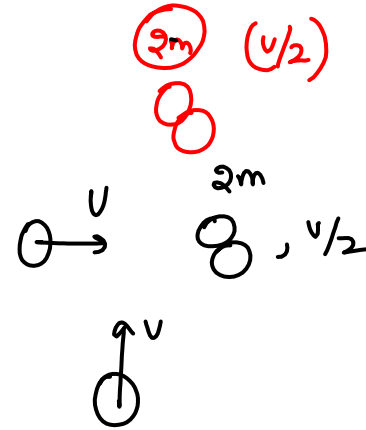
(A) 60°

(B) 45°

(C) 120°

(D) 30°

(C)





Example HW

In one dimensional collision of two particles velocities are interchanged when

- (i) collision is elastic and mass are equal
- (ii) collision is inelastic but masses are unequal

Select the correct alternative

- (A) only (i) is correct
- (B) only (ii) is correct
- (C) both (i) and (ii) are correct
- (D) both (i) and (ii) are wrong

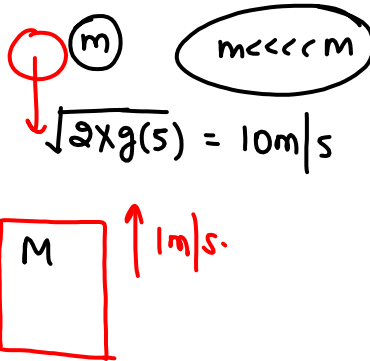




Example

A ball falls from a height of 5m and strikes a lift which is moving in the upward direction with a velocity of 1m/s, then the velocity with which the ball rebounds after collision will be -

- (A) 11 m/s downwards
- ✓ (B) 12 m/s upwards
- (C) 13 m/s upwards
- (D) 12 m/s downwards



$$\begin{aligned} &\uparrow 10\text{m/s} \\ &+ \\ &\uparrow 2(1) \end{aligned}$$



Example



A Particle of mass m moving with velocity u_1 collides elastically with another particle of same mass moving with velocity u_2 in the same direction. After collision their speeds are v_1 and v_2 respectively then-

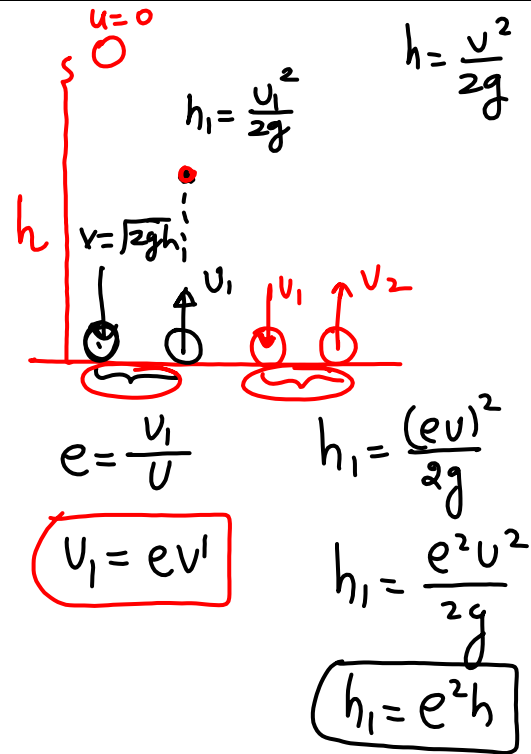
(1) $u_1 + v_1 = v_2 + u_2$

(2) $u_1 - v_1 = v_2 + u_2$

- (A) Both the equations 1 and 2 are correct
- (B) Both the equations 1 and 2 are incorrect
- (C) Equation 1 is correct but not 2
- (D) Equation 2 is correct but not 1



Collision of Object Falling from Height



$$e = \frac{v_2}{v_1}$$

$$v_2 = ev_1 = e(ev)$$

$$v_2 = e^2v$$

$$v_3 = e^3v$$

$$v_4 = e^4v$$

$$v_n = e^n v \quad ***$$

$$h_2 = \frac{v_2^2}{2g} = \frac{(e^2v)^2}{2g} = e^4 \frac{v^2}{2g}$$

$$h_2 = e^{2 \times 2} h$$

$$h_3 = e^{2 \times 3} h$$

$$h_4 = e^{2 \times 4} h$$

$$\vdots$$

$$h_n = e^{2n} h$$



Example

A ball is dropped from a height h on the ground.

If the coefficient of restitution is e , the height to which the ball goes up after it rebounds for the

n^{th} time is-

(A) he^{2n}

(B) he^n

(C) $\frac{e^{2n}}{h}$

(D) $\frac{h}{e^{2n}}$



Example

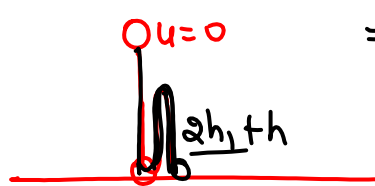
A ball is dropped from a height h on a floor of coefficient of restitution e . The total distance covered by the ball just before second hit is :

(A) $h(1 - 2e^2)$

~~(B)~~ $h(1 + 2e^2)$

(C) $h(1 + e^2)$

(D) he^2



$$\Rightarrow d = 2 \times e^2 h + h$$
$$=$$



Example



A ball of mass 10 g is dropped on the ground from a height of 10m. It rebounds to a height of 2.5 m. If the ball is in contact with the ground for 0.01 s, then which statement is correct ?

(A) Impulse force between the ground and ball is 15 N

(B) Impulse force between the ground and ball is $5\sqrt{2}\text{N}$

(C) Coefficient of restitution between the ground and ball is $1/4$

(D) Coefficient of restitution between the ground and ball is $1/2$





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