JEE MAIN | IIT JEE

# Collision

## Conservation of Momentum

REVISION in 60 Min

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# Topics to covered

1. Understanding of Momentum Conservation
2. COM at rest question
3. Boy-Trolley Situation
4. Gun-Bullet Problem (*muzzle velocity*)
5. Explosion Concept
6. Explosion of Projectile
7. Bullet hitting Block / Bob
8. Block moving over another block
9. Two Block Spring System
10. Understanding of Head-on vs Oblique Collision
11. Concept of Impulse
12. Coefficient of Restitution
13. Collision with Floor
14. Head-on Collision
15. Oblique Collision
16. Mass-variation Concept

JOIN

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| Chapter | Formulae_Concept VIDEO LINK |
|---|---|
| Unit & Dimensions | https://youtu.be/wdd-wlZF4Hk |
| Errors and Vectors | |
| Vernier Calliper | https://youtu.be/pVoN045dV8I |
| Screw Gauge | https://youtu.be/gYd2PtmZ0mw |
| Kinematics_Motion in 1d | https://youtu.be/U4NNxFaFliE |
| Kinematics_Motion in 2d | https://youtu.be/4_Zo5WhMf7w |
| Laws of Motion | https://youtu.be/7JlR8gNRQIs |
| Friction | https://youtu.be/Rn1bLst7eGk |
| Work Energy Power | https://youtu.be/kjrXoE-kDI8 |
| Circular Motion | https://youtu.be/KnFymKHlkT0 |
| Centre of Mass | https://youtu.be/ads35RKD618 |
| Collision | |
| Rotational Motion_Moment of Inertia | https://youtu.be/9ckZdOhy3z0 |
| Gravitation | https://youtu.be/rAj2huLVaEk |
| Properties of Solids | https://youtu.be/gSXxjk89I_c |
| Fluids Statics (Part 1) | https://youtu.be/RFKx9B9yo3M |
| Fluid Dynamics (Part 2) | https://youtu.be/Y717vQpUEJQ |
| Fluid Properties (Part 3) | https://youtu.be/V8xUWWK2oT0 |
| Simple Harmonic Motion | https://youtu.be/RIb7ofNG09I |
| Thermal Properties | |
| KTG | https://youtu.be/XO1tvFhIa0I |
| Thermodynamics | https://youtu.be/iz_kf1jRDRw |
| Wave Motion -Organ Pipes and Resonance Tube | https://youtu.be/fB7pfJ77za8 |
| Wave Motion - Doppler's Effect | https://youtu.be/9-BxOaamnwg |
| Electrostatics | https://youtu.be/3stXbGRMcrk |
| Capacitors | https://youtu.be/EXEiickNUkY |
| Current Electricity | https://youtu.be/gm8FUfjrX18 |
| Moving Charges and Magnetic Effect of Current | https://youtu.be/ULD2Ok1CGJk |
| Earth's Magnetism | https://youtu.be/a4CT5uVwAK4 |
| Magnetic Properties | https://youtu.be/63cwdYXNlYE |
| EMI | https://youtu.be/puVavm_GFRM |
| Alternating Current | https://youtu.be/74dTY-pzM_o |
| Ray Optics | https://youtu.be/BhnyTWzIlBA |
| Wave Optics Part 1_Interference | https://youtu.be/LG5nlE8XTeI |
| Wave Optics Part 2_Diffraction_Polarization | https://youtu.be/ymMyyJGGqnY |
| Optical Instruments | https://youtu.be/OQssbDH0A4I |
| Electromagnetic Waves | https://youtu.be/bcVXgEkyQZY |
| Semiconductors_Basics + Zener Diode | https://youtu.be/_A2JomQ7-50 |
| Semiconductors_Transistors | https://youtu.be/psDwl84Nzb0 |
| Semiconductors_Logic Gates | https://youtu.be/pZdQAzLbFTo |
| Communication Systems | https://youtu.be/8NgMqK9X79Y |
| Modern Physics_Part 1_Atomic Physics | https://youtu.be/9VKUnE3mpHk |
| Modern Physics_Part 2_Photoelectric Effect | https://youtu.be/24oTQp84jrk |
| Modern Physics_Part 3_Dual Nature of Light | https://youtu.be/0zoR_saMAQY |
| Modern Physics_Part 4_Radioactivity | https://youtu.be/AdX3YBhQyog |
| Modern Physics_Part 5_Nuclear Physics | https://youtu.be/VDWqVahGixc |
| Modern Physics_Part 6_X Rays | https://youtu.be/dSHXdzX7NX0 |

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# 1. Understanding of Momentum Conservation

$\vec{F}_{net} = M\vec{a}_{cm}$ & $\vec{P}_{net} = M\vec{V}_{cm}$

$\vec{F}_{net} = \dfrac{d\vec{P}_{net}}{dt}$ $\{M$ : system mass$\}$

If $\vec{F}_{net} = 0$

$\Downarrow$

$\vec{P}_{net} = \text{const.}$

$\Downarrow$

$\vec{V}_{cm} = \text{const.}$

If $V_{cm} = 0$, it remain zero

$\Rightarrow$ cm at rest although particles in system may move

If $V_{cm} \neq 0$

$\Rightarrow$ cm continues to move with const velocity.

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## 2. COM at rest ($\vec{F}_{net} = 0$, $V_{cm} = 0$)

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots}{m_1 + m_2 + \cdots}$$

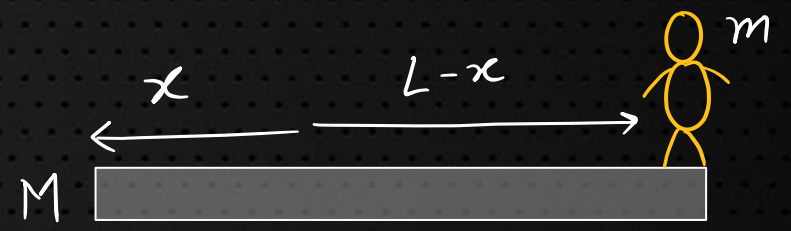
$$\Rightarrow 0 = m_1\Delta\vec{r}_1 + m_2\Delta\vec{r}_2 + \cdots$$

$$\{\Delta\vec{r}_{cm} = 0\}$$

# here $\Delta\vec{r}_1$, $\Delta\vec{r}_2$ ... are w.r.t. ground

Ex 1. If boy walks to other end of Plank, find distance moved by Plank.

Sol$^n$:




$$m_1\Delta x_1 + m_2\Delta x_2 = 0$$

$$\Rightarrow m(L-x) + M(-x) = 0$$

$$\therefore x = \frac{mL}{m+M}$$ Ans

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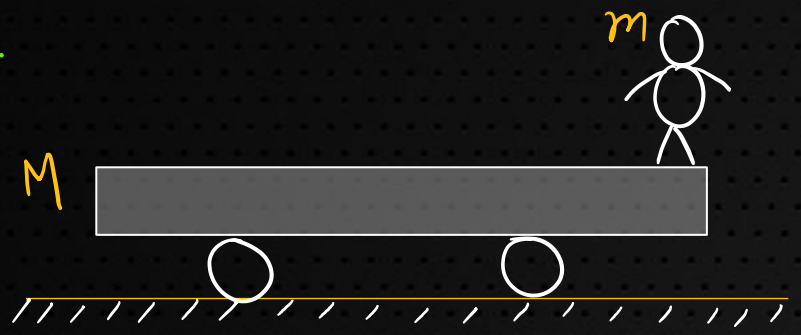
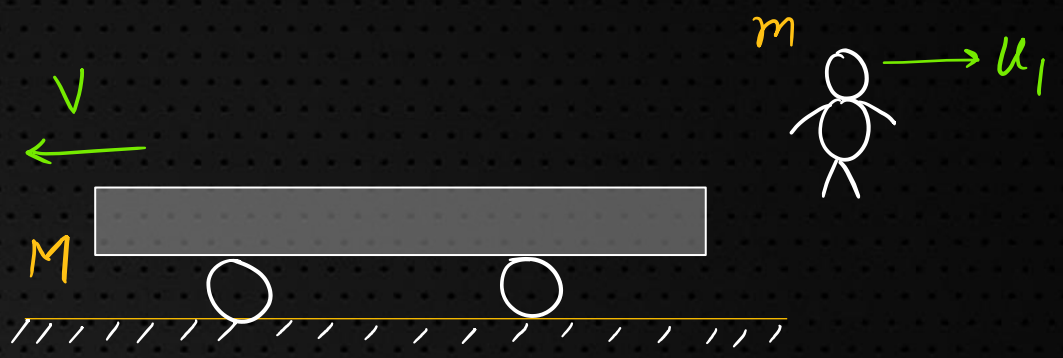
# 3. Boy-Trolley Situation ($\vec{F}_{net} = 0$, $\vec{P}_{net} = \text{Const.}$)

Ex 2.




Initially all at rest. Boy jumps with $u$ (relative to trolley). Find trolley velocity.

Soln: NOTE – $u$ is rel to trolley after jump.




$$V_{b/T} = V_b - V_T \Rightarrow u = u_1 + V \Rightarrow u_1 = u - V$$

$$\because \vec{P}_i = 0 \Rightarrow \vec{P}_f = 0$$

$$\Rightarrow m u_1 = MV$$

$$\Rightarrow m(u - V) = MV \Rightarrow V = \frac{mu}{m+M}$$ Ans

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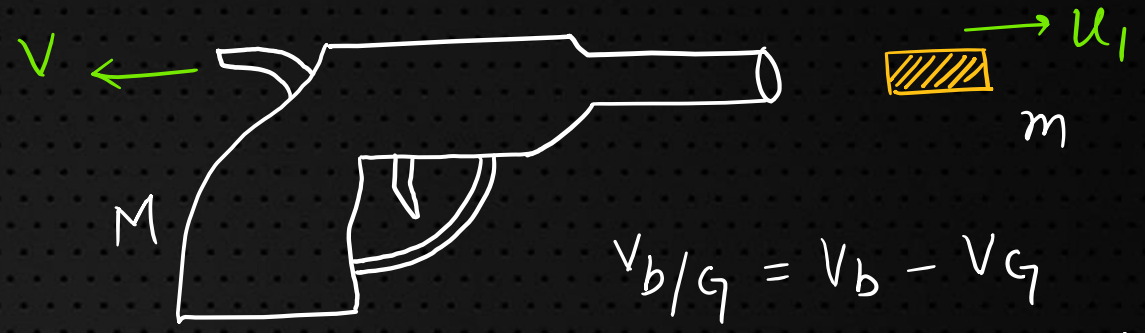
# 4. Gun- bullet (muzzle velocity)

Ex 3.

Muzzle velocity is $u$, find recoil speed of gun.

Sol$^n$: Note – Muzzle vel. is vel of bullet w.r.t muzzle (end of Gun)




$$v_{b/G} = v_b - v_G$$

$$\Rightarrow u = u_1 + V \Rightarrow u_1 = u - V$$

$$\because \vec{P_i} = 0 \Rightarrow \vec{P_f} = 0$$

$$\Rightarrow MV = m(u - V)$$

$$\therefore V = \frac{mu}{m+M}$$ Ans

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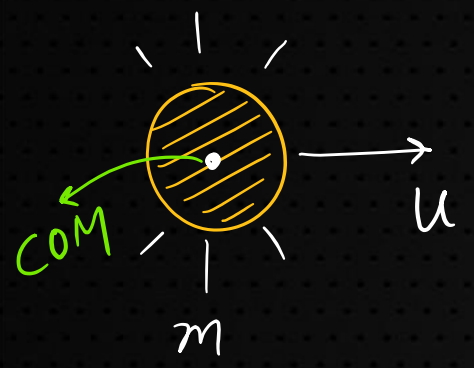
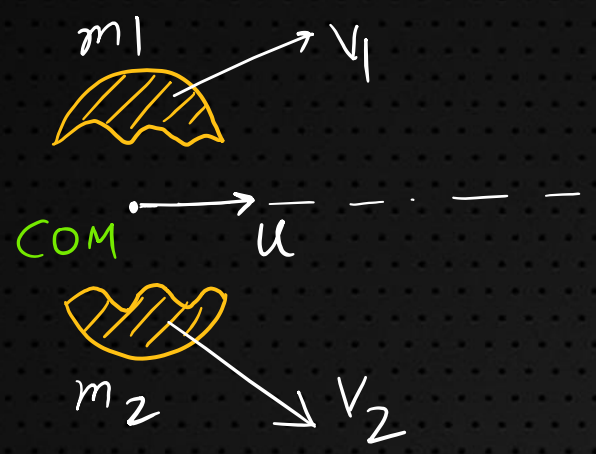
# 5. Explosion Concept



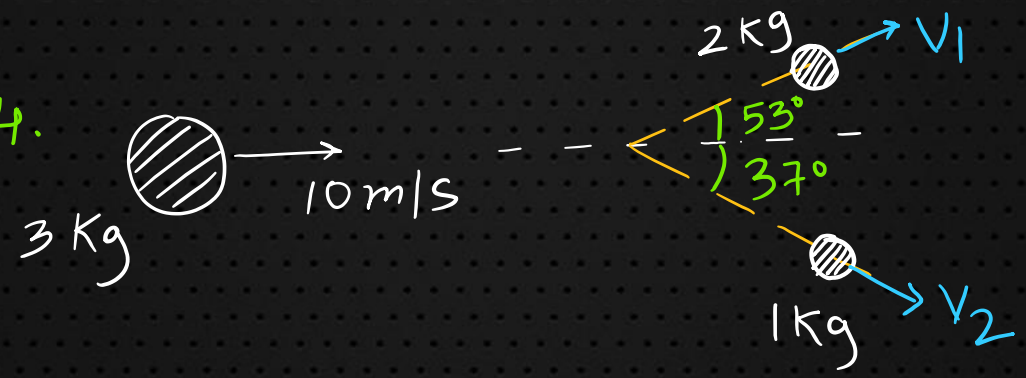

(i) Explosion due to internal forces,

$\because \sum \vec{F}_{ext} = 0 \Rightarrow \vec{P}_{sys} = \text{Const}$

$\Rightarrow \vec{V}_{cm} = \text{const}$

(ii) $m\vec{u} = m_1\vec{V}_1 + m_2\vec{V}_2$

Ex 4.




Find $V_1$ & $V_2$.

Sol$^n$: $\vec{P}_x = \text{const} \Rightarrow 30 = 2V_1\cos 53^\circ + V_2\cos 37^\circ$ —(i)

$\vec{P}_y = \text{const} \Rightarrow 0 = 2V_1\sin 53^\circ - V_2\sin 37^\circ$ —(ii)

$\therefore V_1 = 9\ m/s,\ V_2 = 24\ m/s$

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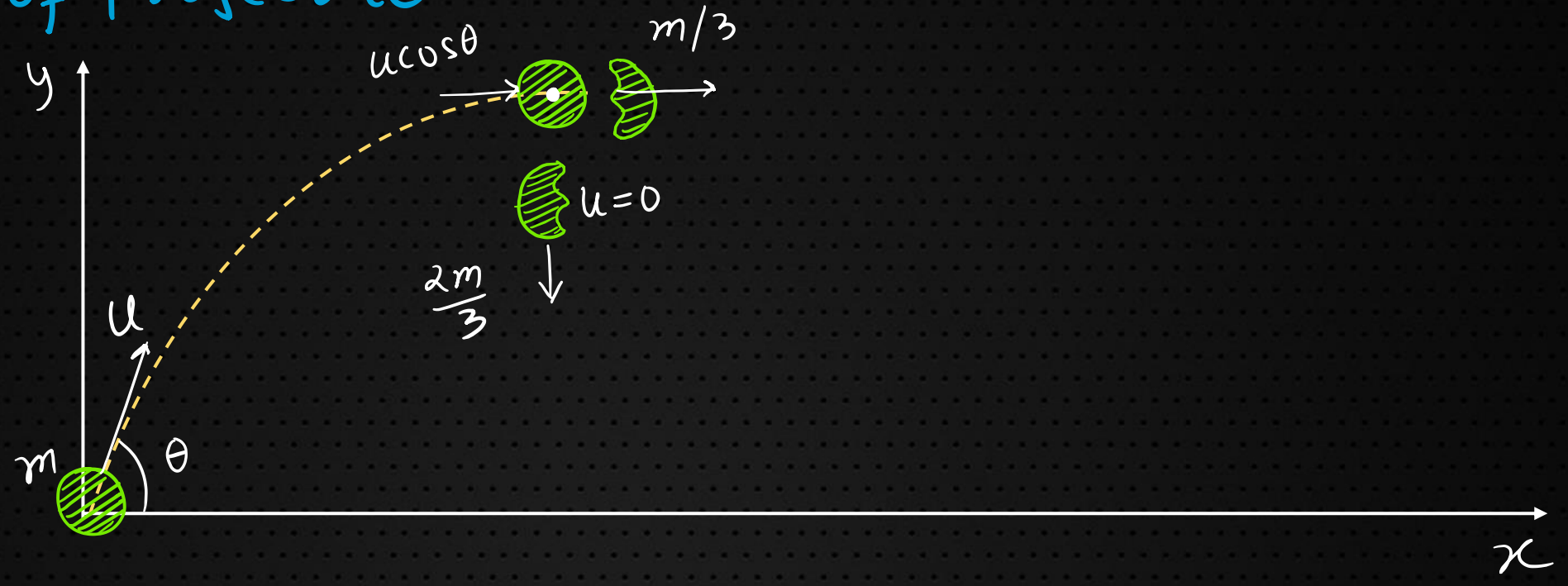
# 6. Explosion of Projectile

Ex 5. Find distance of $\frac{m}{3}$ from origin.

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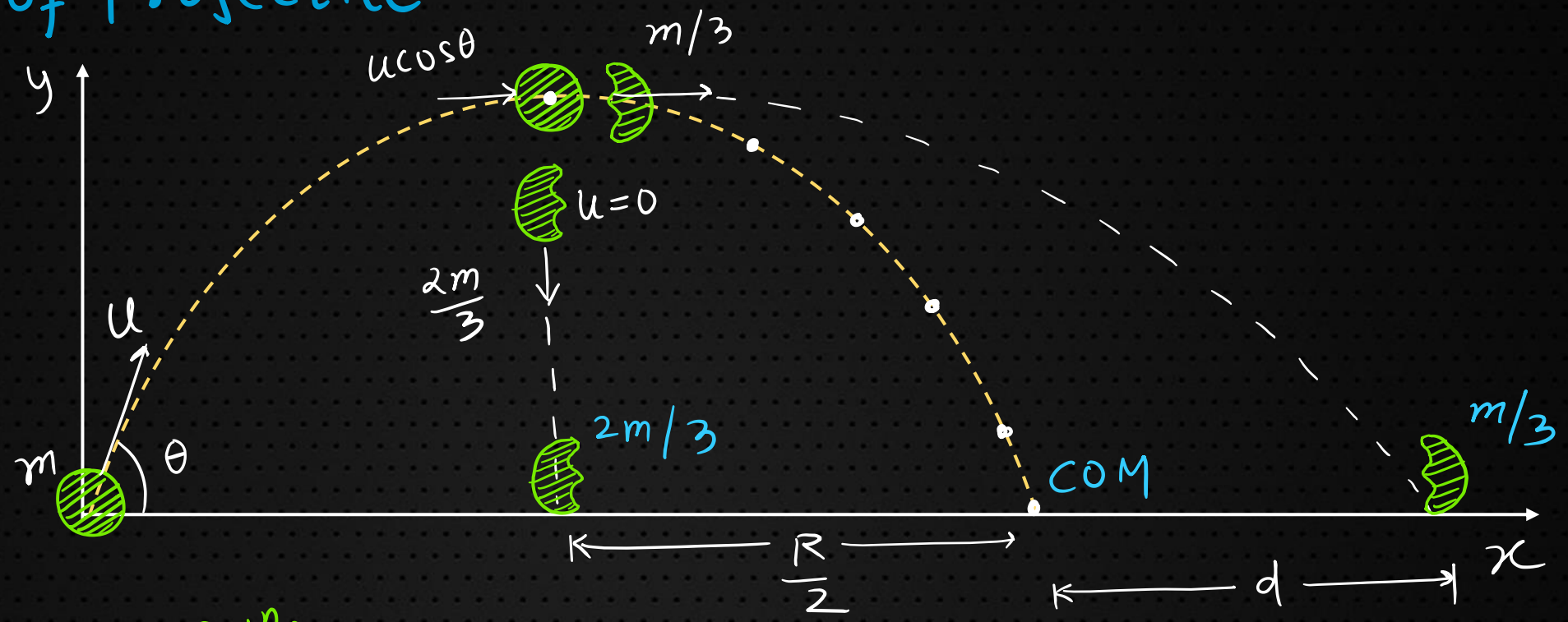
# 6. Explosion of Projectile

Ex 5. Find distance of $\frac{m}{3}$ from origin.




Sol$^n$:

$$\frac{2m}{3} \times \frac{R}{2} = \frac{m}{3} \times d$$

$$\Rightarrow d = R$$

$\therefore$ Answer $= d + R = 2R$

$$= 2 \times \frac{u^2 \sin 2\theta}{g}$$

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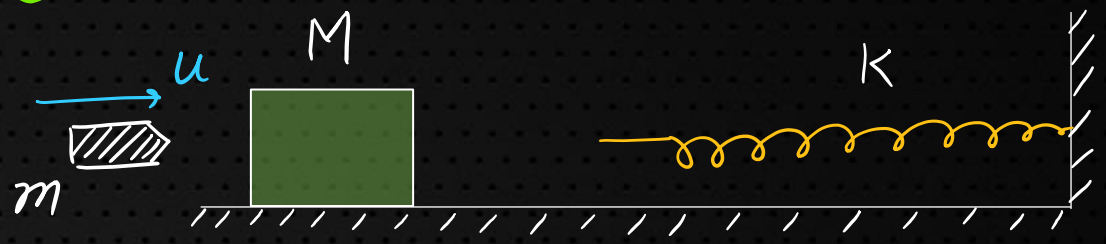
# 7. Bullet hitting Block/Bob

↳ many Questions are formed

$\vec{P} = \text{Const}$

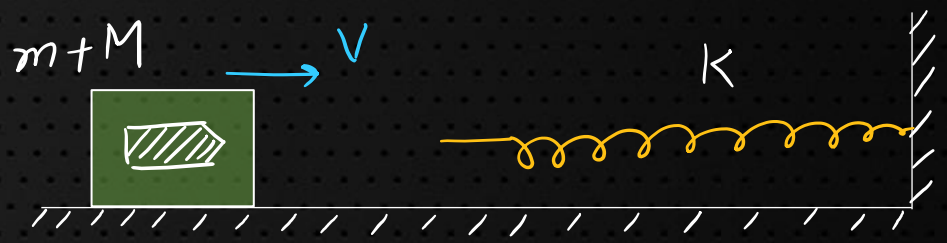
$KE + P.E = \text{Const.}$

Ex 6 :




bullet gets embedded in block.
Find max Compression in spring.

Sol$^n$:




$$mu = (m+M)V \Rightarrow V = \frac{mu}{m+M}$$

Loss in KE = Gain in PE $\Rightarrow \frac{1}{2}(m+M)\left(\frac{mu}{m+M}\right)^2 = \frac{1}{2}Kx^2$

$$\therefore x = \frac{mu}{\sqrt{K(m+M)}}$$

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# 7. Bullet hitting Block/Bob

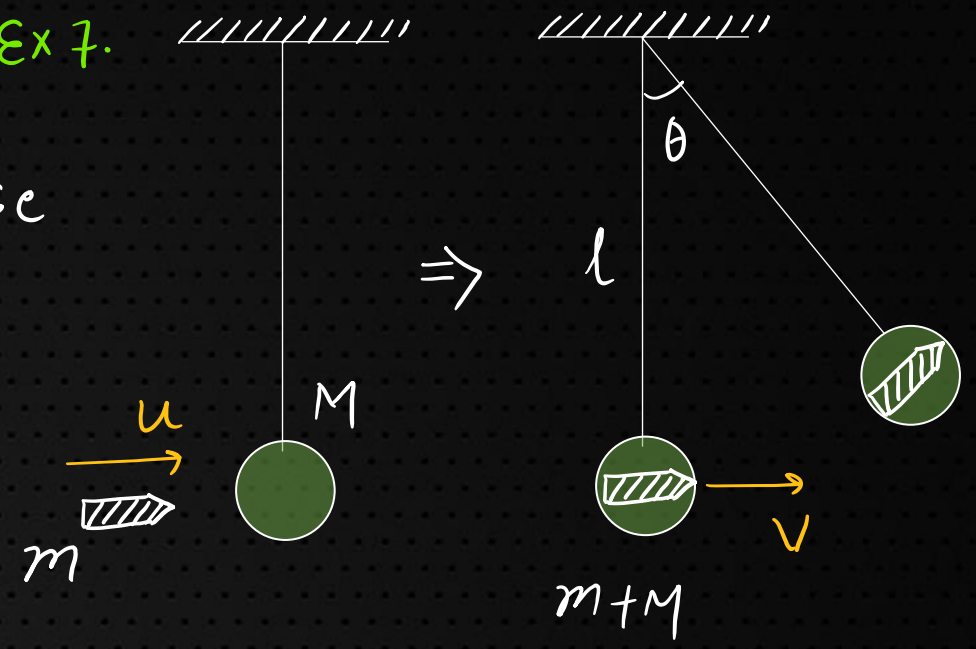
↳ many Questions are formed

$\vec{P} = \text{Const}$

$KE + P.E = \text{Const.}$

Ex 7.

Analyse




(i) $mu = (m+M)V$

$\Rightarrow V = \dfrac{mu}{m+M}$

(ii) If $V \geq \sqrt{5gL}$ ⟶ full circle

If $V \leq \sqrt{2gL}$ ⟶ find θ (angular amplitude)

$\frac{1}{2}(m+M)V^2 = (m+M)g \times L(1-\cos\theta)$

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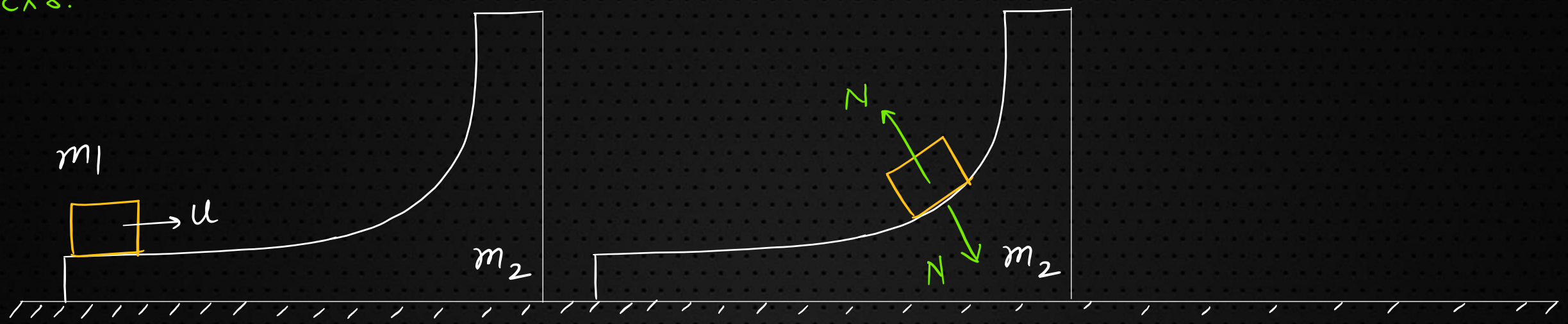
# 8. Block moving over another block

Ex 8.




no friction any where

Let us analyse.

↳ $F_{net}$ along horizontal $= 0 \Rightarrow \vec{P}_x = \text{const.}$

$F_{net}$ along vertical $\neq 0 \Rightarrow \vec{P}_y \neq \text{const.}$

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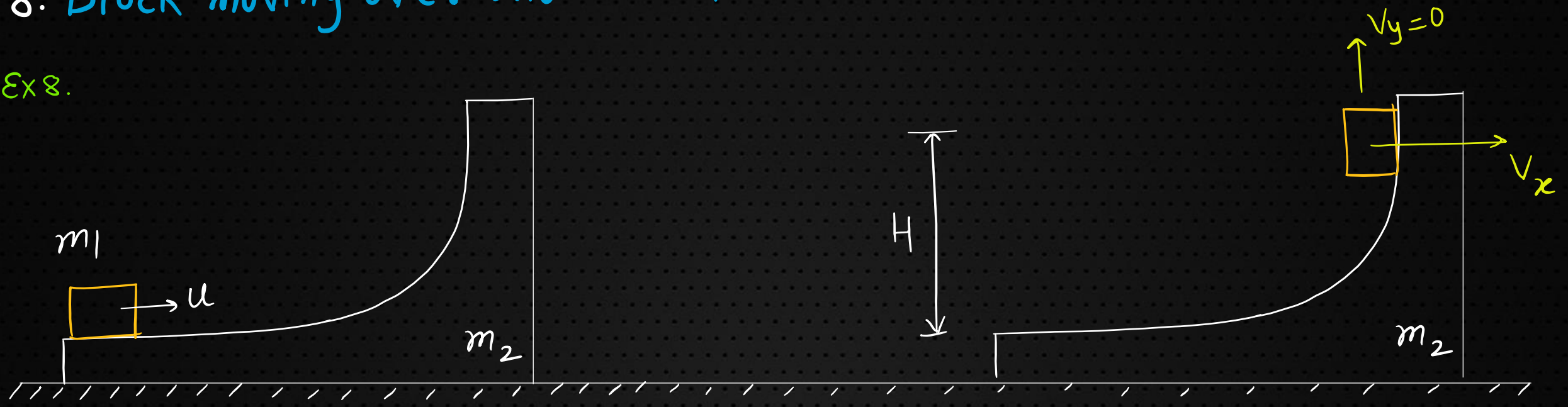
# 8. Block moving over another block

Ex 8.




no friction any where

Let us analyse.

(i) $\vec{P}_x = \text{const} \Rightarrow m_1 u = (m_1 + m_2) V_x$

$$\Rightarrow V_x = \frac{m_1 u}{m_1 + m_2}$$

(ii) Gain in PE = Loss in KE

$$\Rightarrow m_1 g h = \frac{1}{2} m_1 u^2 - \frac{1}{2}(m_1 + m_2) V_x^2$$

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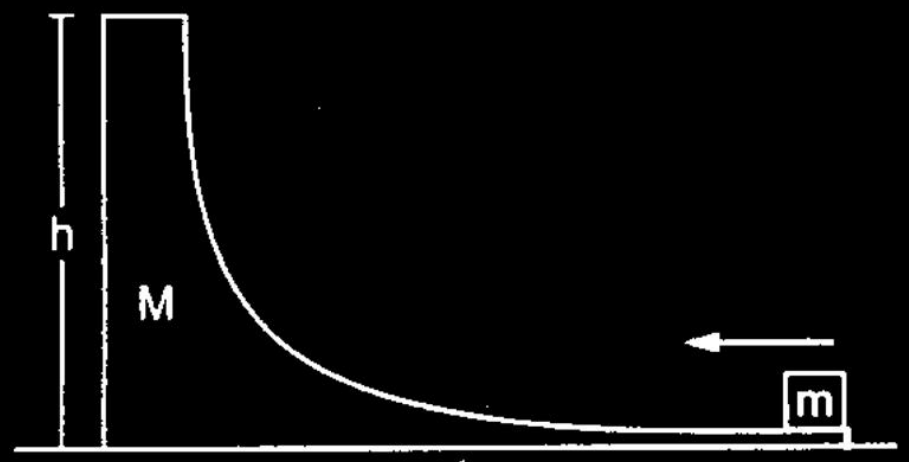
**61.** Figure (9-E22) shows a small body of mass $m$ placed over a larger mass $M$ whose surface is horizontal near the smaller mass and gradually curves to become vertical. The smaller mass is pushed on the longer one at a speed $v$ and the system is left to itself. Assume that all the surfaces are frictionless. (a) Find the speed of the larger block when the smaller block is sliding on the vertical part. (b) Find the speed of the smaller mass when it breaks off the larger mass at height $h$. (c) Find the maximum height (from the ground) that the smaller mass ascends. (d) Show that the smaller mass will again land on the bigger one. Find the distance traversed by the bigger block during the time when the smaller block was in its flight under gravity.

HCV




https://youtu.be/d3c8mXZUU5s

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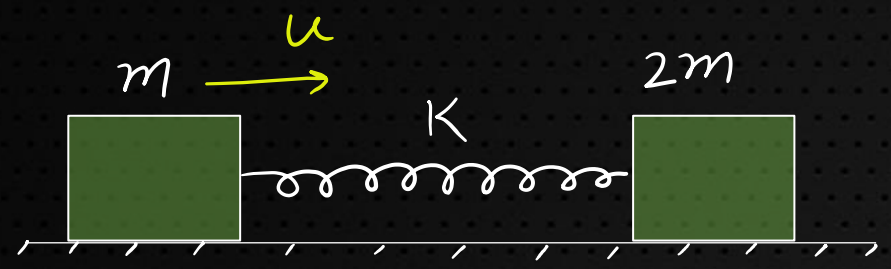
# 9. Two Block - Spring System

Ex 9.




Spring in natural length

Find max compression in spring.

## 1st Method

Sol$^n$: At max comp. both block has same speed.

(i) $\vec{P} = \text{const} \Rightarrow mu = mV + 2mV$

$\Rightarrow V = u/3$

(ii) $T.E = \text{const} \Rightarrow \frac{1}{2}mu^2 = \frac{1}{2}mV^2 + \frac{1}{2}2mV^2 + \frac{1}{2}Kx^2$

$\Rightarrow x = u\sqrt{\frac{2m}{3K}}$

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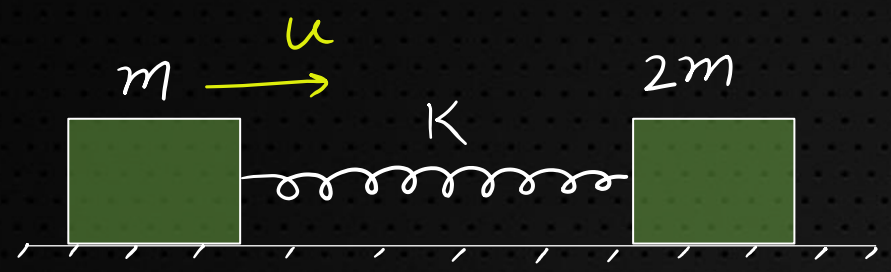
# 9. Two Block - Spring System

Ex 9.

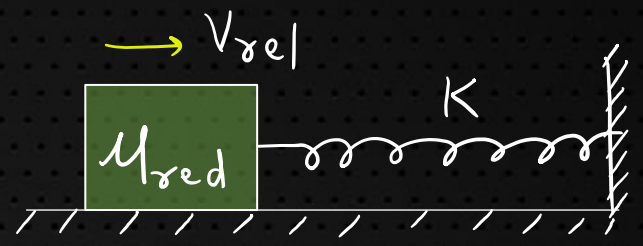



Spring in natural length

Find max compression in spring.

## 2nd Method

Sol$^n$:




$$\mu_{red} = \frac{m_1 m_2}{m_1 + m_2}$$

Loss in KE = Gain in PE

$$\Rightarrow \frac{1}{2}\mu_{red} V_{rel}^2 = \frac{1}{2}Kx^2$$

$$\Rightarrow \frac{1}{2}\left(\frac{m \times 2m}{3m}\right) \times u^2 = \frac{1}{2}Kx^2$$

$$\therefore x = u\sqrt{\frac{2m}{3K}}$$

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# 10. Understanding of Head-on vs Oblique Collision

LOM → Line of Motion

LOI → Line of Impact

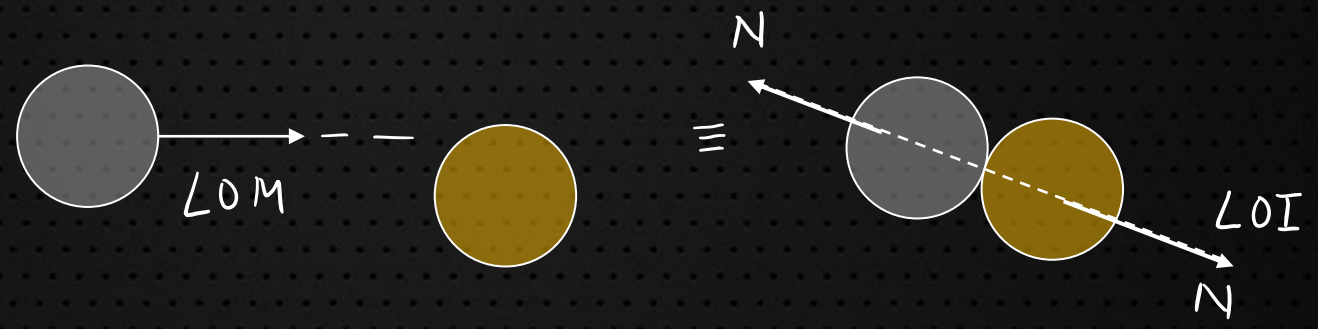
Head-on → LOM & LOI are same

Oblique → LOM & LOI are different

(a)

Head-on

(b)




Oblique

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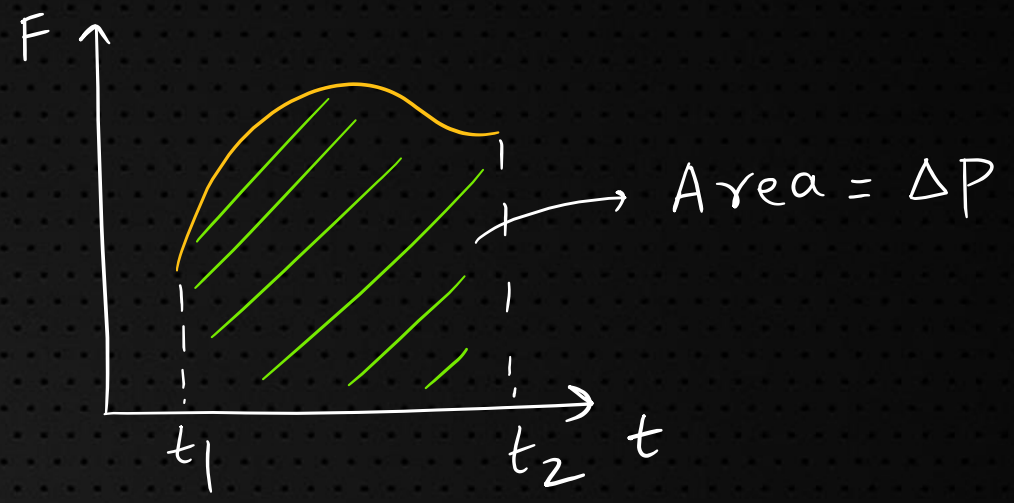
# 11. Concept of Impulse (J) → Change in P due to F ($t_1 \to t_2$)

$$F = \frac{dp}{dt} \Rightarrow dp = F\,dt$$

$F = \text{const.}$ $\qquad$ $F = f(t)$

$$\Delta P = F\,\Delta t \qquad \Delta P = \int_{t_1}^{t_2} F\,dt$$

$\Delta P \to J$




(i) Impulsive force → Large force acting for short time (they bring ΔP)

NOTE: During collision / impact mg is taken as non-impulsive (no ΔP due to mg)

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# 12. Coefficient of Restitution (e)

$$e = \frac{\text{Vel of separation of pt. of Contact}}{\text{Vel of approach of pt. of Contact}}$$

{Vel along Line of impact}

collision on basis of K.E loss

- Elastic: $e = 1$
- Partial Elastic: $0 < e < 1$
- Inelastic: $e = 0$

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# 12. Coefficient of Restitution (e)

$$e = \frac{\text{Vel of separation of pt. of Contact}}{\text{Vel of approach of pt. of Contact}}$$

{Vel along Line of impact}

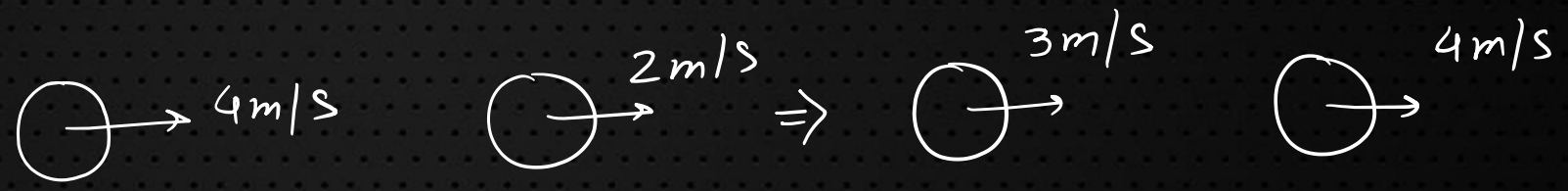
Elastic
$e = 1$

Partial Elastic
$0 < e < 1$

Inelastic
$e = 0$

} collision on basis of K.E loss

(a)




$$e = \frac{4-3}{4-2} = \frac{1}{2}$$

(b)

$$e = \frac{5-3}{4+1} = \frac{2}{5}$$

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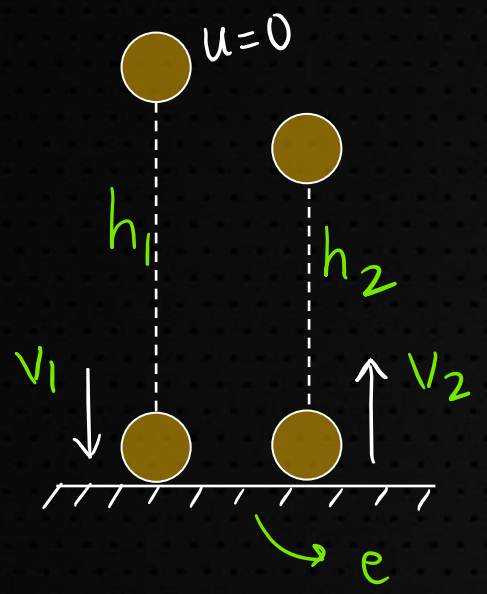
# 13. Collision with Floor




(i) $e = \frac{v_2}{v_1} \Rightarrow v_2 = e v_1 \quad \{ v_1 = \sqrt{2gh_1} \}$

(ii) $h_2 = \frac{v_2^2}{2g} = \frac{e^2 v_1^2}{2g} = e^2 h_1$

A rubber ball is released from a height of 5 m above the floor. It bounces back repeatedly, always rising to $\frac{81}{100}$ of the height through which it falls. Find the average speed of the ball. (Take g = 10 $ms^{-2}$)

(1) 3.0 $ms^{-1}$ (2) 3.50 $ms^{-1}$

(3) 2.0 $ms^{-1}$ (4) 2.50 $ms^{-1}$

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click

https://youtu.be/ocJJa_lXm64

Q4

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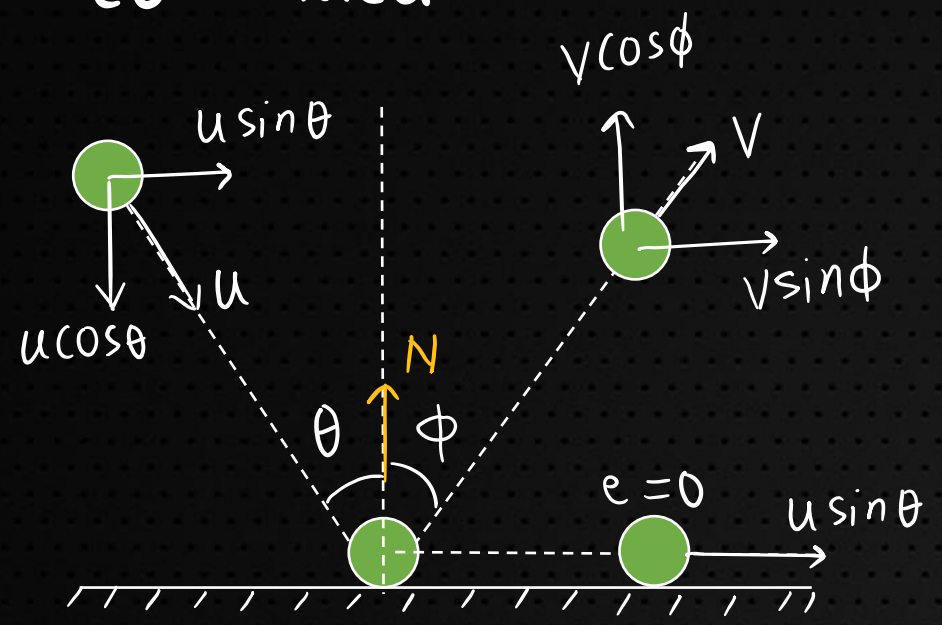


$v\sin\phi = u\sin\theta$ — (1)

(as no Normal is $\perp$ to it)

(i) If $e=1 \Rightarrow v=u$ & $\phi=\theta$

(ii) If $0<e<1 \Rightarrow v\cos\phi = eu\cos\theta$ — (2)

$(1)/(2) \Rightarrow \boxed{\tan\phi = \dfrac{\tan\theta}{e}}$

$(1)^2+(2)^2 \Rightarrow \boxed{v = u\sqrt{\sin^2\theta + e^2\cos^2\theta}}$

(iii) If $e=0 \Rightarrow v\cos\phi = 0$

Ball moves horizontally

(iv) Impulse, $\Delta p = m(v\cos\phi + u\cos\theta)$

$\{J = 2mu\cos\theta,\ e=1\}$

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# 14. Head-on Collision

(i) $P_i = P_f \Rightarrow m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

(ii) $e = \dfrac{v_2 - v_1}{u_1 - u_2}$

using these two eqn find $v_1$ & $v_2$

$e = 1$

KE = Const

$K_i = K_f$

$0 < e < 1$

KE Loss

$K_i - K_f$

$e = 0$

KE Loss Max

$K_i - K_f$

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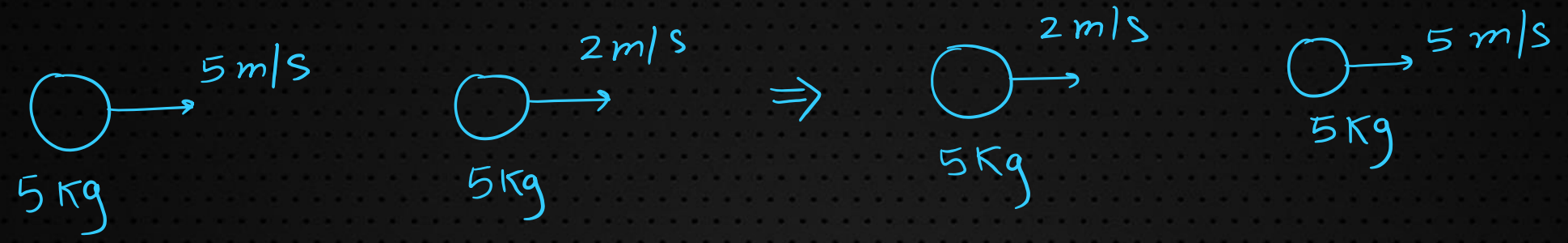
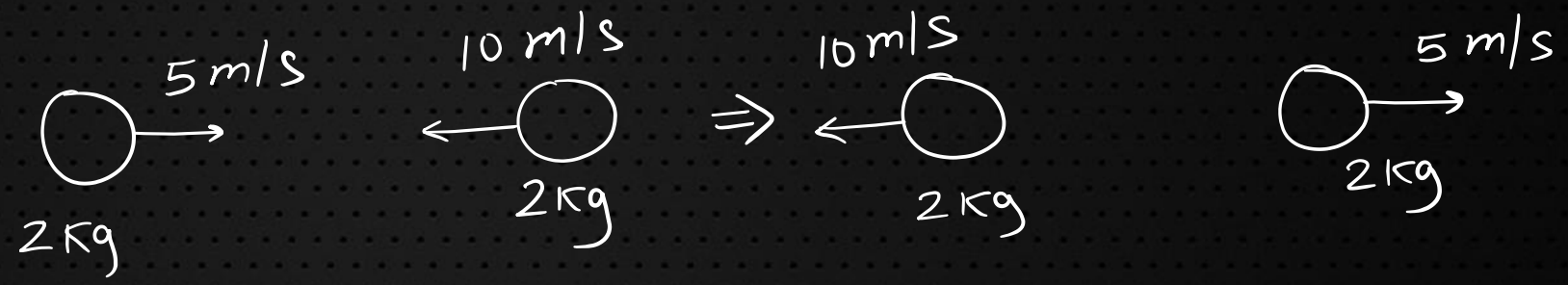
... continued

Note: If $m_1 = m_2$ & $e = 1$, then after collision bodies exchange velocities

(a)




(b)




(c)

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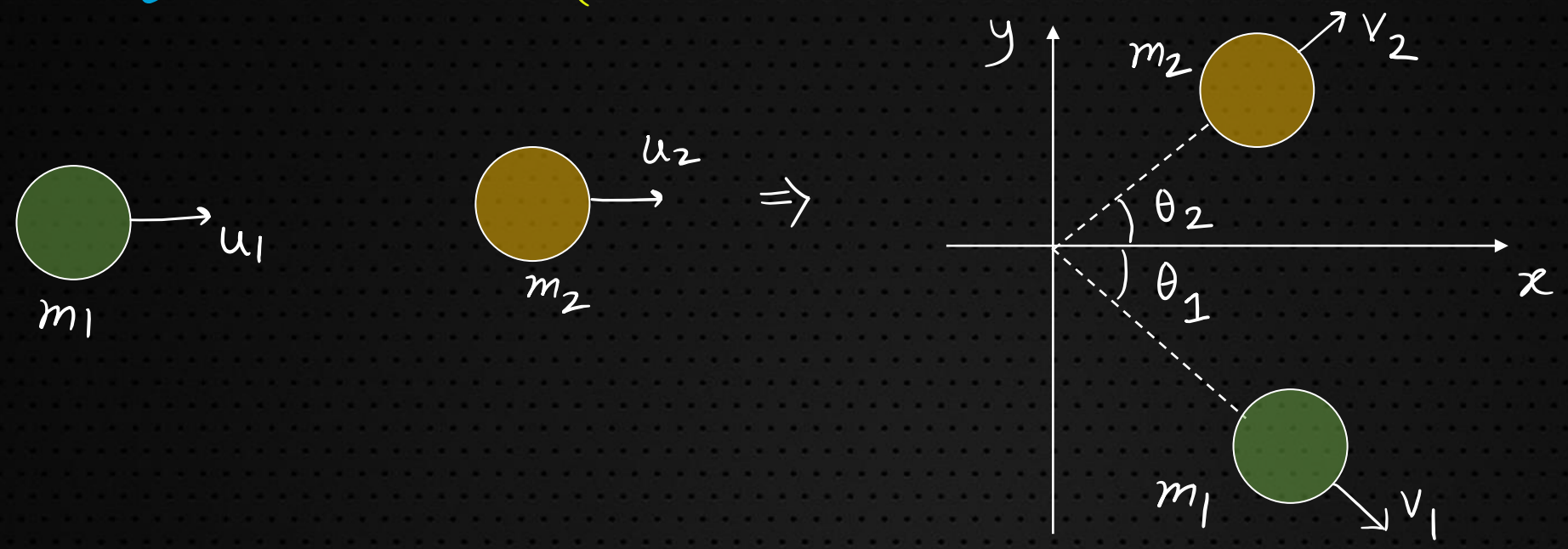
# 15. Oblique Collision (elastic, $e=1$) → 2D Collision




(i) $\vec{P}_x = \text{const} \Rightarrow m_1 u_1 + m_2 u_2 = m_1 v_1 \cos\theta_1 + m_2 v_2 \cos\theta_2$

(ii) $\vec{P}_y = \text{const} \Rightarrow 0 = m_2 v_2 \sin\theta_2 - m_1 v_1 \sin\theta_1$

(iii) $\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$

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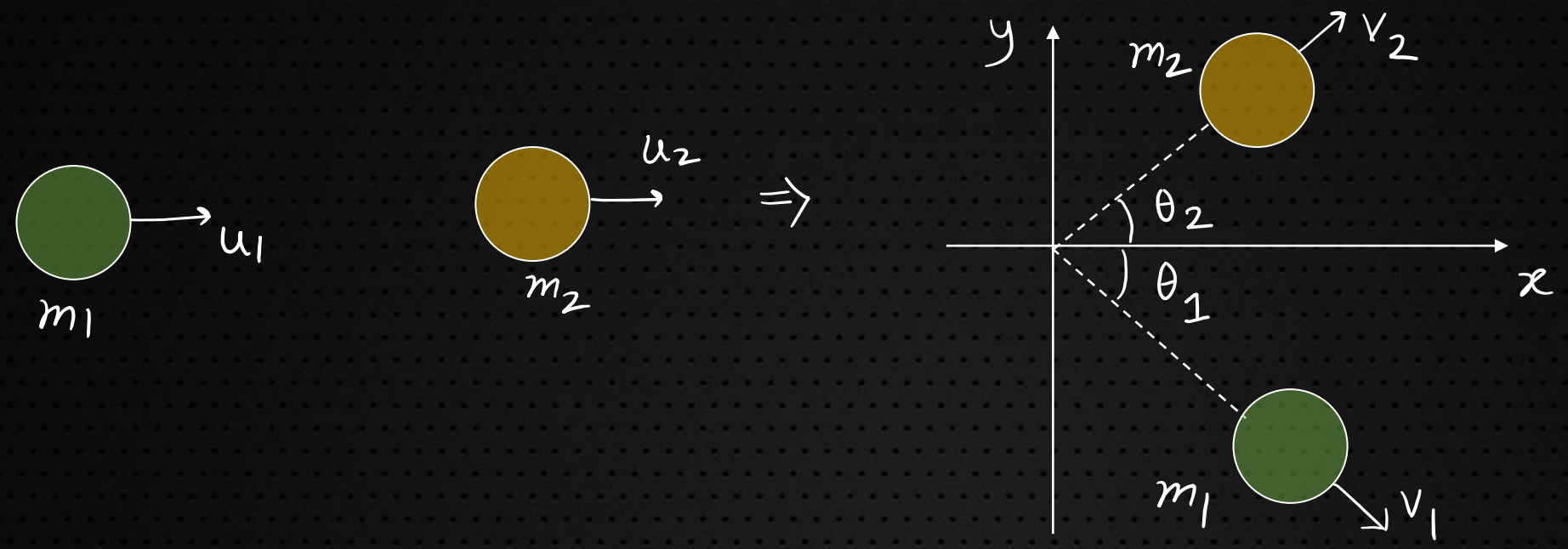
# ... Continued




Note: If $m_1 = m_2$, $u_2 = 0$, elastic collision

$$\Rightarrow \boxed{\theta_1 + \theta_2 = 90^\circ}$$

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# 16. Mass - Variation

$F_{th} = V_{rel} \frac{dm}{dt}$

mass ejection rate $= \frac{dm}{dt}$ kg/s

click

https://youtu.be/kZyhkHWifbA

# PYQs LINKS (JEE MAIN)

| 2021 Feb | 2021 March | 2021 July | 2021 August | 2020 |
|---|---|---|---|---|
| https://youtu.be/JBndilWvPwA | https://youtu.be/ocJJa_lXm64 | https://youtu.be/5P1QCbU-t84 | https://youtu.be/LIKVg9txoas | https://youtu.be/ZeEzCS5uCmk |

CLICK

# 37 Questions

Revision Series Playlist Link https://bit.ly/3eBbib9

JEE Main PYQs Link https://bit.ly/2S54jzh Chapter wise 2021, 2020, 2018

GoldMine Link https://bit.ly/2VhOGFF

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