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⇒ Dynamics

Newton's 1st law: (law of Inertia)

If resultant force is zero i.e if forces are balanced then

Rest ⟶ Rest

Constant velocity ⟶ Constant velocity.

Define Force:

⇒ Force is equal to rate of change of momentum

Topic: Momentum

Date:

Momentum - It is the product of mass and velocity of a object

$$p = m \times v$$

"It is amount of motion in a body"

→ Momentum is a vector quantity.

→ SI unit $kgms^{-1}$ or Ns

+ve →

A: $v = 20m/s$ →

mass = 300kg.

$p = mv$

$p = 300 \times 20$

$= 6000\ kgms^{-1}$

B: $v = 300m/s$ →

mass = 20kg

$p = mv$

$p = 20 \times 300$

$= 6000 kgms^{-1}$

Here you can clearly observe both heavier and lighter object has same amount of momentum as they have different velocities.

Change in momentum:

Change = finid - initid.

∴ Δ = delta/Change

$\Delta p = p_f - p_i$

Δp

$\Delta p = mv - mu$

Example 1 (Speeds up)

mass = 7kg

$V = 2m/s$ $V = 10m/s$

$\Delta p = mv - mu$

$= 7(10) - 7(2)$

$= 70 - 14$

$= 56\ kgms^{-1}$

Example 2

mass = 20.0kg →

$20m/s = u =$ Rest $v = 0$

i) Calculate change in momentum:

$\Delta p = p_f - p_i$

$= mv - mu$

$20(0) - 20(20)$

$-400\ kgms^{-1}$ * Object is slowing down.

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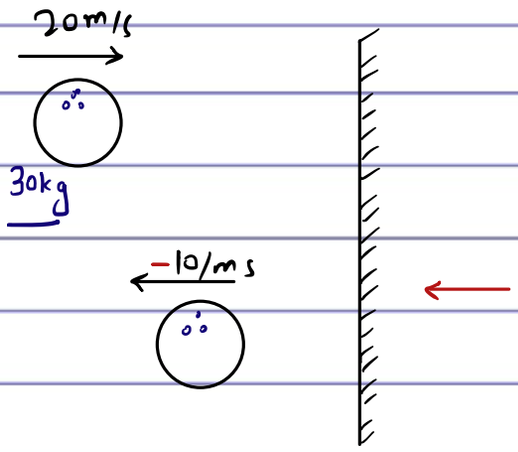


⇒ Force: Rate of change of momentum is called force.

$$F = \frac{\Delta p}{\Delta t}$$

$$F = \frac{mv - mu}{t}$$

$$F = \frac{m(v-u)}{t} = \text{acceleration}$$

$$F = ma$$

The ball is travelling to the right the speed of the ball is 20 m/s afte rebounding the speed is 10m/s cdculate change in momentum.

$$\Delta p = p_f - p_i$$

$$= mv - mu$$

$$= 30(-10) - 30(20)$$

$$-300 - 600$$

$$-900 \text{ kgms}^{-1}$$

$$F = \frac{mv - mu}{t}$$

$$Ft = mv - mu$$

Topic: _____ Date: _____

Impulse: The product of force and time of application of force.

$$F = \frac{\Delta P}{\Delta t}$$

$$F \times \Delta t = \Delta P$$

" A large force applied for a short duration can bring in a small change in momentum as a small force would if applied for a larger duration.

---

* Force is Rate of change of momentum.

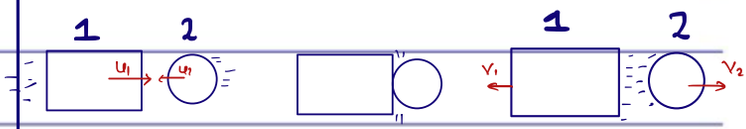
$$F = \frac{mv - mu}{t}$$

$$F = m\left(\frac{v-u}{t}\right) \rightarrow a$$

$$F = ma$$

Law of Conservation of momentum:

• For a closed system/Isolated system the total momentum before collision is equal to the total momentum after collision.



Before collision After collision

⇒ Total momentum before = Total momentum after

Collision Collision.

$$p_{1_B} + p_{2_B} = p_{1_a} + p_{2_a}$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

u_1, u_2 = Initial velocity v_1, v_2 = final velocity.

* Make sure to use correct signs for velocity

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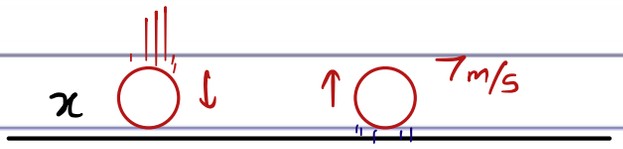
Q) $u = 4.3 m/s$

$t = 1.51$ (to reach the ground)



A ball started at an initial velocity of 4.3m/s and took 1.5s to reach the ground

i) Calculate final velocity as it hits the ground?

$v = u + at$

$v = 4.3 + (9.81)(1.51)$

$v =$ 19.1 m/s

ii) Given that it rebounds with the speed of 7 m/s calculate the change in momentum during the impact. mass = (50 g)

$\Delta p = mv - mu$

$(0.05)(+7) - (0.05)(-19.1)$

iii) time of impact is 12.5 ms calculate force exerted on the ground during impact.

$F = \frac{\Delta p}{t}$

$= \frac{1.3}{12.5 \times 10^{-3}}$

$=$ 104.8 N

$$KE = \frac{p^2}{2m}$$

How to prove this?

$\frac{1}{2}mv^2 = KE$

$p = mv$

$\frac{1}{2}mv \times v$

$\frac{p}{m} = v$

$\frac{1}{2}pv = KE$

$\frac{1}{2}p\left(\frac{p}{m}\right) = KE$

$$\boxed{KE = \frac{p^2}{2m}}$$

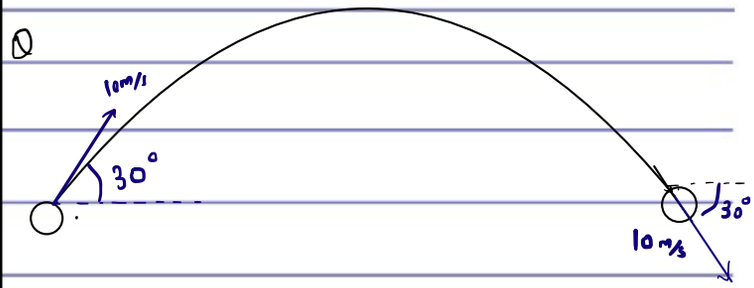
$F = ma$

$p = mv$

$\Delta p = Ft$

$\Delta p = p_f - p_i$

Impulse $= \Delta p = Ft$



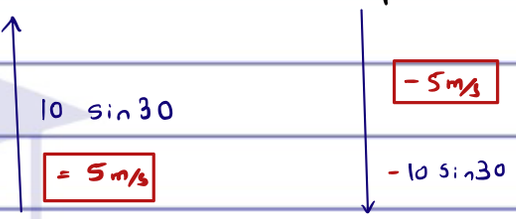
Calculate Δp for the projectile motion

① Δp (in the horizontal plane)

Since horizontal velocity remains constant throughout.

Δp (in horizontal plane $= 0$)

② Change in momentum in vertical plane.



mass $= 20$ kg

$\Delta p = p_f - p_i$

$= 20(-5) - (20)(+5)$

$= -200$ Ns / kgms^{-1}

* CAIE they take final direction as positive.

Topic: _____ Date: _____

How to obtain a relationship b/w momentum of an object (P) and its (KE)

Prove $KE = \frac{P^2}{2m}$

⇒ Principle of Conservation of momentum / Law of conservation of momentum

The nature of collision b/w two bodies can be classified either as

i) Elastic Collision

ii) In Elastic Collision.

Elastic Collision

→ The momentum of system remains conserved.

→ The KE of the system remains conserved.

→ The total Energy of a system also remains conserved.

→ The speed of approach before collision = Speed of seperation

(1)

Speed of Approach = 7+3 = 10

Speed of Approach. = x + y

(2)

Speed of Approach = 20-12=8

SOA = x - y

If Particles are travelling in apposite direction we need to add the values.

If Particle are travelling in same direction we subtract the values.

Speed of separation = 9 +11 = 20ms^{-1}

SOS = x + y

Speed of Separation = 12 - 5 - 7ms

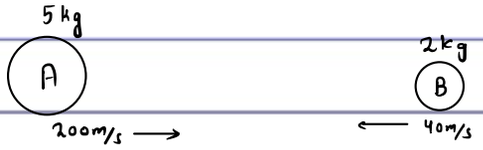
SOS = y - x

If particles are moving in opposite direction we add them.

If particles are moving in same direction we subtract them.

Topic: _____ Date: _____

Q) Example of how to apply property of Elastic collision to solve questions.



before collision

After Collision.

* Given that collision is Elastic.

1) Form an equation based on

SOA = SOS

$200 + 40 = x + y$

$240 = x + y$ → (1)

2) Form an equation based on Pricple of conservation of momentum.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$5(200) + 2(-40) = 5(x) + 2(y)$

$1000 - 80 = 5x - 2y$

$920 = -5x + 2y$ → (2)

$x = -63$ m/s

Negative answer implies A is travelling opposite to the direction originally marked on diagram.

$y = 303$ m/s

Positive answer implies that B goes in some direction as marked on diagram.

Q)

Before After.

Elastic Collision

Find 2 equations to find x and y

1) SOA = SOS

$10 = x + y$

2) Principle of conservation of momentum.

$(2)(7) + (2)(-3) = (2)(-x) + 2(y)$

$14 - 6 = -2x + 2y$

$8 = -2x + 2y$

$x = 3$ m/s $y = 7$ m/s

Conclusion: For identical masses performing Elastic Collsion speeds will get interchanged.

i.e Initial speed of A becomes final speed of B and Initial speed of B become final speed of A.

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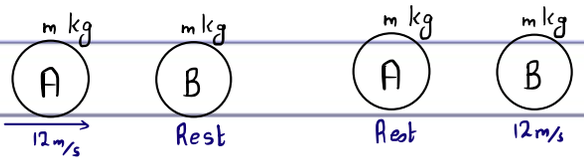
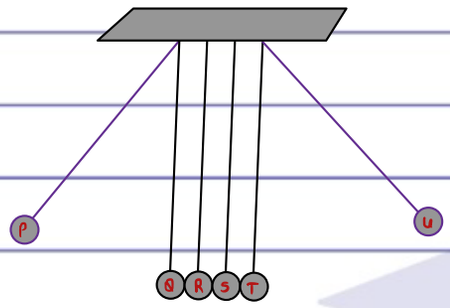
Question?

For identical masses performing elastic collision,



Similar Situation can occur in Snooker ball



Note: Momentum of first ball transfers into the last ball hence all balls in the middle remain at rest only the first and last ball moves back and forth. {This is called Newton Cradle}

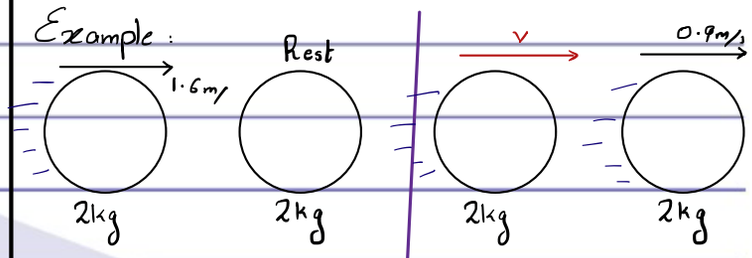
In Elastic Collision:

* Momentum of System remains conserved.
* Total Energy of System remains conserved.
* Since KE is not conserved

Hence KE (after collision) < KE (Before collision)

SOA ≠ SOS

Example:



Before After.

i) Calculate "v"?

Principle of Conservation of momentum.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$(2)(1.6) + 2(0) = (2)(v) + (2)(0.9)$

$\boxed{v = 0.7\ m/s}$

ii) Show that this is In Elastic collision?

In terms of KE

* KE before collision.

$\frac{1}{2}(2)(1.6)^2 + 0 = 2.56\ J$ ← Since KE is lost its Inelastic

KE of system after collision.

$\frac{1}{2}(2)(0.7)^2 + \frac{1}{2}(2)(0.9)^2 = 1.3\ J$

In terms of speed of approach

SOA before = $\boxed{1.6\ m/s}$

SOS after = $0.9 - 0.7 = \boxed{0.2\ m/s}$

Since SOA ≠ SOS its inelastic.

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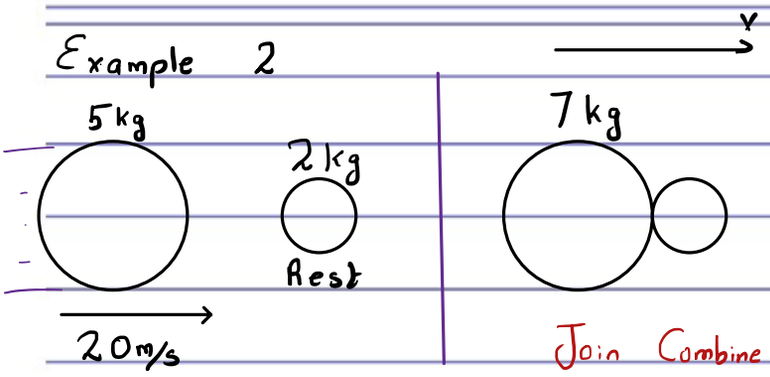
Example 2



Given that the particles joins up after collision and they move with a common velocity (v) and determine weather collision is Elastic or In Elastic

* Principle of Conservation of momentum.

$(5)(20) + (2)(0) = (5+2)v$

$v = 14.3$ m/s

* Nature of collision:

SOA before collision = 20 m/s

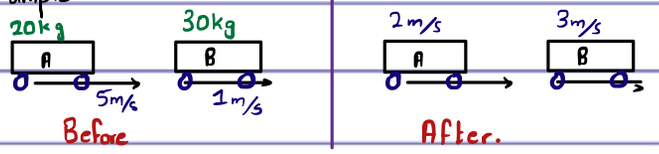
SOS after collision = 0 m/s

* Since they have joined up ∴ Seperation not possible hence Zero)

SOA ≠ SOS hence Inelastic

→ Note : Whenever two object join up and more together with a common velocity we can conclude (without working) that the nature of collision will be Inelastic.

Example : 3



i) Calculate change in momentum of "A"?

$\Delta P_A = P_f - P_i \Rightarrow 20(2) - (20)(5)$

$-60\ Ns$

ii) Calculate change in momentum of "B"

$P_f - P_i \Rightarrow (30)(3) - (30)(1)$

iii) From the above example how can we conclude that the momentum of the system remains conserved?

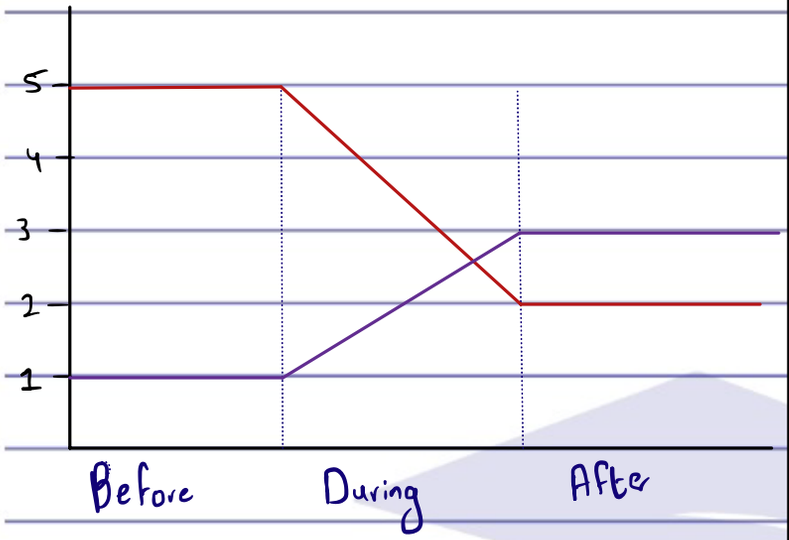
Ans) Loss in momentum of A is equal to the gain in momentum of B?

$\Delta P_A = -\Delta P_B$

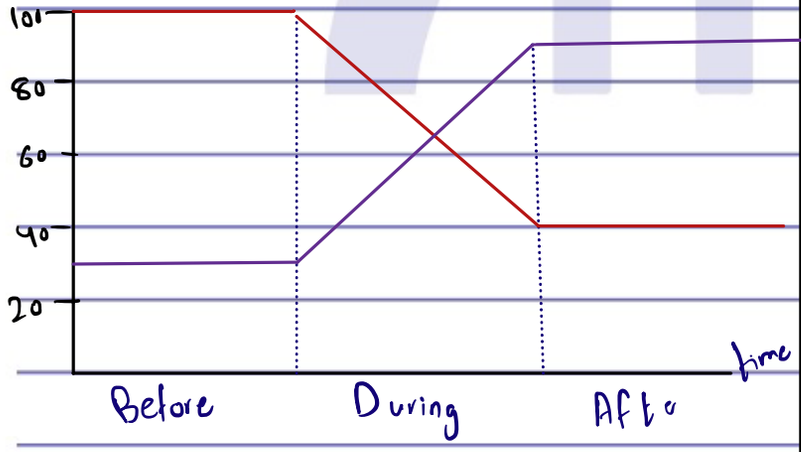
Note : Change in momentum of A is equal to the opposite change in momentum of B.

Topic: _____ Date: _____

Sketch a velocity time graph before during and after collision for A and B.



v) Sketch momentum time graph during and After collision



vi) Show that during collision, force which A applies on B is equal and opposite to force which B applies on A

Ans:

$$\Delta P_A = -\Delta P_B$$

Since $\Delta P = F \times t \quad \therefore \Delta P_A = F_A \times t_A$

$$F_A \times t_A = F_B \times t_B$$

Since $t_A = t_B$ (Because both particles collide for the same time hence time can be cancelled out)

$$F_A \times \cancel{t_A} = F_B \times \cancel{t_B}$$

$$F_A = -F_B \text{ (Proved !!!)}$$

→ Newton's third law.

* To Every action there is an equal and opposite reaction 1 mark.

AS level: The forces are equal in magnitude, The two forces are opposite in direction, The two forces act on different bodies

$$F_A = -F_B$$

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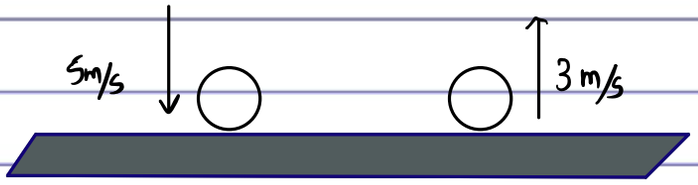
Q) A ball falls vertically and strikes a metal plate. It rebounds from the plate as shown



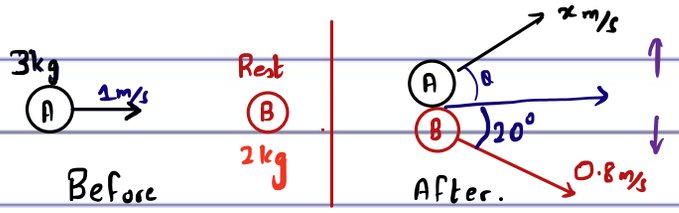
⇒ Explain how principle of conservation of momentum applies in this case? (3)

* The ball losses momentum upon the impact.

* This loss in momentum is transfered /gained by the metal plate.

* Therefore although the momentum of the ball changes but the momentum of the system that is Ball + metal plate remains conserved.

How to apply law of conservation of momentum in two dimentions.



Apply law of conservation of momentum to find "x" and "θ".

① Law in horizontal plane.

+ →

$3(1) + 2(0) = (3)x\cos\theta + (2)(0.8\cos 20)$

$3 = x\cos\theta + 1.5$

$x\cos\theta = 0.5$ ——— ①

Vertical Plane:

+ ↑

$0 + 0 = 3x\sin\theta + 2(-0.8\sin 20)$

$3x\sin\theta = 2(0.8\sin 20)$

$3x\sin\theta = 0.55$

$x\sin\theta = 0.18$ ——— ②

To find θ ⇒ eq ② ÷ eq 1

$\frac{x\sin\theta}{x\cos\theta} = \frac{0.18}{0.5}$ $\theta = 20°$

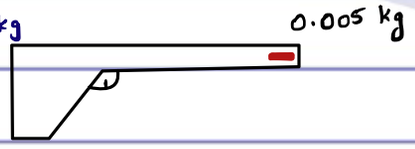
find x ?

$\tan\theta = \frac{0.18}{0.5}$

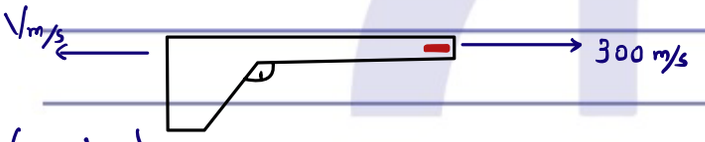
Topic: _____ Date: _____

find x by substituting Q in any equation.

How to apply Principle of conservation of momentum in situation where initial momentum of the system is zero.



Q) Revolver with a bullet in it initially both at Rest.



(recoil velocity)

→ Since the initid momentum is zero for LOCOM to be valid, the final momentum of system must also remains zero.

→ This is only possible if the 2 bodies have equal momentum in opposite direction so that they cancel out the effect of Each other.

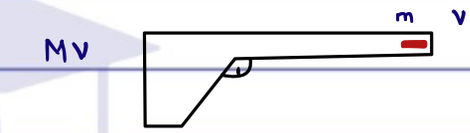
Calculate the Recoil velocity of the Gun?

Principle of conservation of momentum. Method 1

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$0 + 0 = 0.005(300) + 2(-x)$

$x =$ **0.75 m/s**



$MV = mv$

$2(x) = (0.005)(300)$

$x =$ **0.75**

The above working can also be done using ratio method.

According to $P = mv$, m and velocity are inversly proportional to each other hence

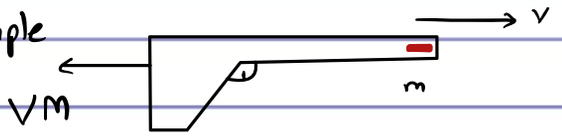
$M = 2kg$ $m = 0.005kg$

Since mass of gun is 400 times heavier then bullet hence velocity will be 400 times less. $\frac{300}{400} = 0.75 m/s$

Next slide

Topic: _____ Date: _____

Example



Show that $\frac{M}{m} = \frac{v}{V}$

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$0 + 0 = M(-V) + mv$

$+MV = mv$

$$\frac{M}{m} = \frac{v}{V}$$

ii) Show

$$\frac{KE \text{ of gun}}{KE \text{ of bullet}} = \frac{V}{v}$$

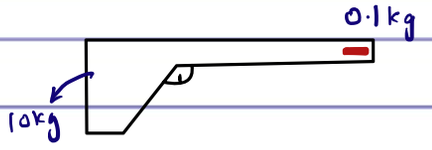
$$\frac{KE_g}{KE_b} = \frac{\frac{1}{2}M(V)^2}{\frac{1}{2}mv^2}$$

$$= \frac{\frac{1}{2}MVV}{\frac{1}{2}mvv} \quad \therefore MV = mv$$

$$\frac{KE_g}{KE_b} = \frac{V}{v}$$

→ KE of 2 bodies depends upon ratio of these velocities.

Example.



Q Calculate Ratio of $KE_g \div KE_b$

Step1 = $\frac{\text{Mass gun}}{\text{mass bullet}}$ $\frac{10}{0.1} = \frac{100}{1}$

Since $m \propto \frac{1}{V}$ $\quad p = mv$ $\quad m \propto \frac{1}{v}$

$$\frac{V_{gun}}{v_{bullet}} = \frac{1}{100}$$

Step 3 Since ratio of KE depends on ratio of velocity.

$$\frac{KE_{gun}}{KE_{bullet}} \rightarrow \frac{1}{100}$$

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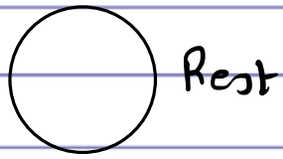
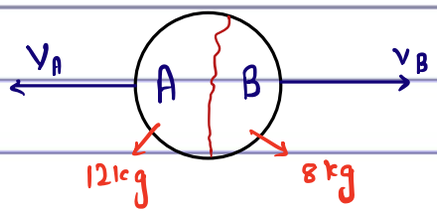
Explosion:





i) Ratio of $\frac{mA}{mB} = \frac{12}{8}$

ii) Ratio $\frac{V_A}{V_B} = \frac{8}{12}$

iii) Ratio $\frac{KE_A}{KE_B} = \frac{8}{12}$

Total KE is given as "E"

Find Fraction of KE possessed by A

Find fraction of KE possessed by B

$\frac{8}{12+8}$

of A $\frac{8}{20}$ Hassan 20 Kahan sa aaya?

of B $= \frac{12}{20}$

$\frac{12}{12+8}$

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Topic: _____ Date: _____

a) mass of oxygen atom is
= 16 Relative atomic mass.

Actual mass of oxygen atom
16u

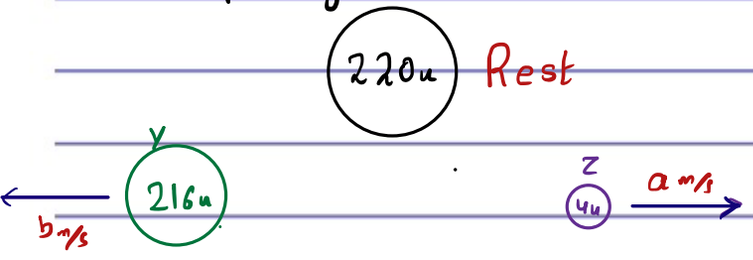
* where u is unified atomic mass

$1u = 1.66 \times 10^{-27}$ kg In data sheet.

Mass of oxygen in kg
2.7×10^{-26} kg

Q) mass of Helium atom
4u $\Rightarrow 4(1.66 \times 10^{-27})$
$\Rightarrow 6.6 \times 10^{-27}$

A nucleus X (220 u) is initially at rest. It splits into 2 fragments Y and Z of masses 216u and 4u respectively as shown



a) Given that KE of Z is 1.0×10^{-13} J calculate speed of Z?

$\frac{1}{2} mv^2$

$\frac{1}{2}(4u)(a)^2 = 1.0 \times 10^{-13}$

b) Hence calculate speed of Y?

+ →

$0 = 4u(1.0 \times 10^{-13}) + (216u)(-b)$

=

$b(216u) = 4u(1.0 \times 10^{-13})$

$216b = 4 \times 1.0 \times 10^{-13}$

$b = \frac{4 \times 1.0 \times 10^{-13}}{216}$

1.9×10^{-15}

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