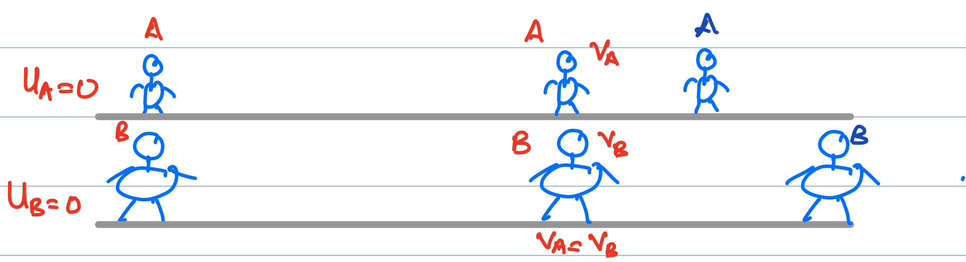
Dynamics: Study of motion with reference to force and mass is dynamics i.e Newton's laws of motion are the bases for Dynamics.

Inertia:

Concept: Property of matter which represent the reluctance against any change of motion or at rest.

Dependance: Inertia $\propto$ mass

Example: Race b/w a slim and fat person:-



Observation: (i) From rest to motion: $t_A < t_B$

(ii) From motion to rest: $t_A < t_B$

Reason: $(mass)_A < (mass)_B$

Result: $(Inertia)_A < (Inertia)_B$

Linear momentum:-

Def. Product of mass and velocity is momentum.

Symbol: P

Formula: $P = mv$

m - Mass (Measure of Inertia in an object.)

v - Velocity

Units $kg\, m\, s^{-1}$ $\left\{ \left[kg \frac{m}{s}\right]\left[\frac{s}{s}\right] = \left(kg \frac{m}{s^2}\right)(s) = Ns \right.$

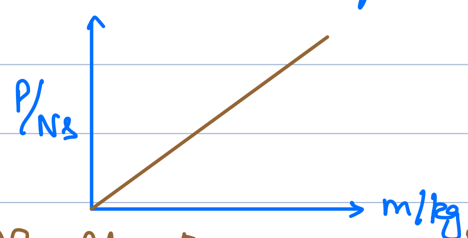
P.S: Vector

Direction: Towards the direction of velocity.

Dependance: $P = mv$

(i) Mass:

$P \propto m$ for constant velocity

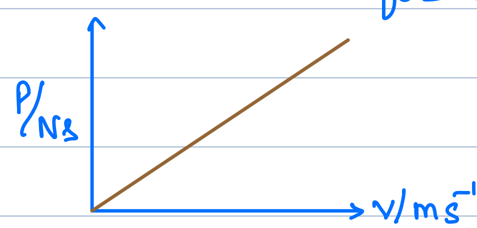


Gradient = velocity

i.e. difficult to stop a truck as compared to a cycle moving with same velocity due to greater momentum of truck.

(ii) Velocity:

$P \propto v$ for constant mass



Gradient = mass

i.e difficult to stop a cycle moving with greater velocity as compared to an identical cycle at lesser velocity.

Force:-

Def: Rate of change of momentum is force.

Symbol: F

Formula:

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

Dependance: $F = \dfrac{\Delta(mv)}{\Delta t}$

(a) Constant mass and change of velocity:

$F \neq 0$ if $\Delta m = 0$ but $\dfrac{\Delta v}{\Delta t} \neq 0$, for example

(i) a sphere fall freely in vacuum. $(a = g)$

(ii) a stone follows a circular path.

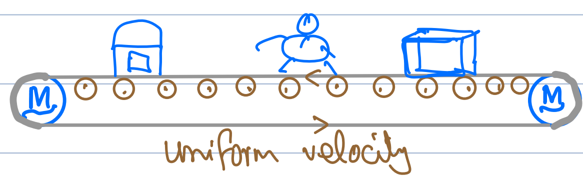
(iii) a sphere/cylinder move down along the inclined plane. $(a = g \sin\theta)$

(b) Constant velocity and change of mass:-

$F \neq 0$ if $\Delta v = 0$ but $\dfrac{\Delta m}{\Delta t} \neq 0$ for example

(i) fuel/petrol driven vehicle moving with uniform velocity but $\left(\frac{m}{t}\right)$ change due to consumption of fuel per unit time.

(ii) Conveyor belt used to transport luggage



Mass of luggage placed on it per unit time vary.

(c) Both mass and velocity changes:

$F \neq 0$ if $(\Delta m$ and $\Delta v) \neq 0$ per unit time ie

An accelerated$^{(v>u)}$ or decelerated$^{(v<u)}$ fuel driven vehicles.

(d) <u>Dependance on time:</u>

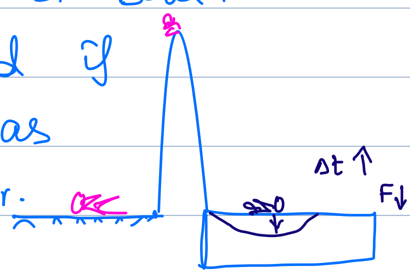
$$\uparrow F = \frac{\Delta P}{\Delta t \downarrow}$$

$F \uparrow$ if $(\Delta t)\downarrow$ for constant change of momentum

Example :-

(a) A fielder moves his hands in backward direction while catching a ball.

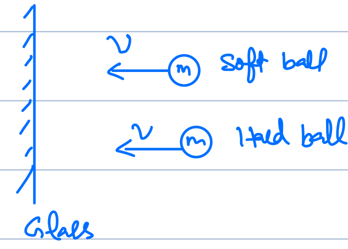
(b) A person is less injured if jump on soft mattress as compared to cemented floor.



(c) bumpers of modern vehicles are made of plastic or fibres.

(d) air bag inflates instantaneously when a vehicle hit a solid object.

(e) A hard ball can break glass while a soft ball can not if both hit glass with same momenta.



<u>Reason</u>. $F\downarrow$ as (Contact time, Δt) $\uparrow$ for constant change of momentum.

Impulse – change of momentum:

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

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

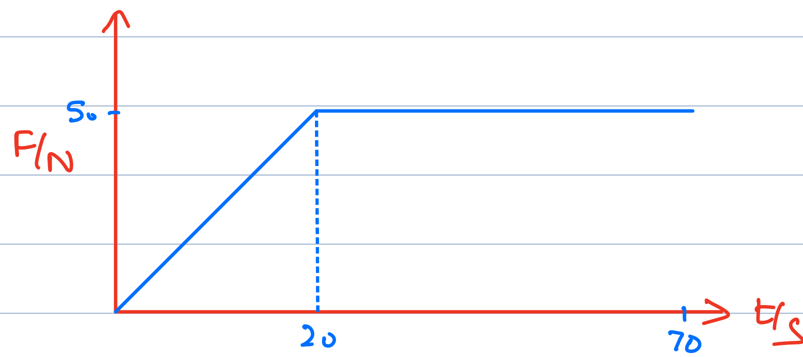
Impulse = change of momentum

Def. Product of force and time is impulse.

Units: $Ns = kg\,m\,s^{-1}$

Note:- Area under force against time graph provides impulse or change of momentum.

Q)



(a) Calculate impulse

Impulse = Area under graph

$= \frac{1}{2}(70 + 50)(50)$

$= 3000\ Ns$

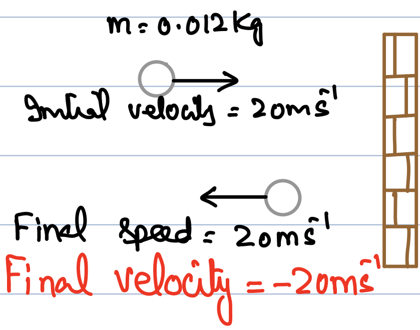
(b) State change in momentum

$= 3000\ Ns$

(c) Calculate change in velocity if mass is 2.0 kg.

$\Delta P = m \Delta V \Rightarrow 3000 = (2.0)(\Delta V) \Rightarrow \Delta V = 1500\ ms^{-1}$

Q)



contact time with wall

$t = 0.14s$

Calculate

i) Initial momentum of ball

$P_1 = mu = (0.012)(20) = 0.240\,Ns$

ii) Final momentum of ball

$P_2 = mv = (0.012)(-20) = -0.240\,Ns$

(iii) change in momentum of ball

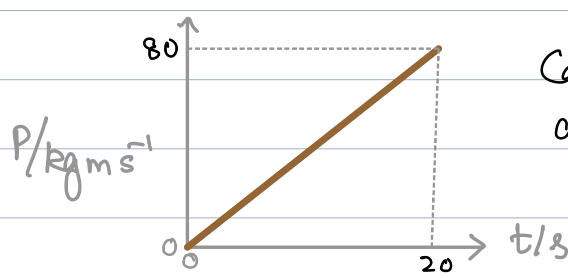
$\Delta P = P_2 - P_1 = -0.240 - 0.240 = -0.480\,Ns$

−ve sign shows direction towards left side.

iv) Force exerted <u>by wall on ball</u>.

$$F = \frac{\Delta P}{\Delta t} = \frac{-0.480}{0.14} = -3.4\,N$$

Q)

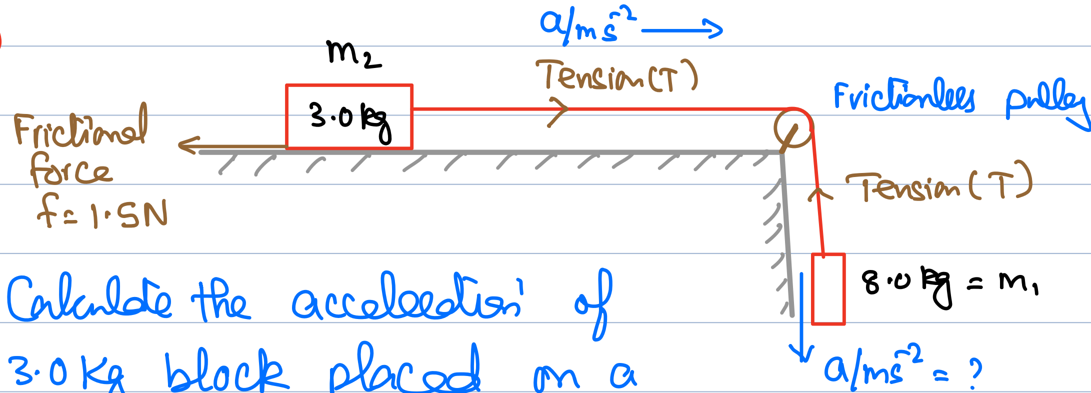


Calculate resultant force acting on 2.0kg mass.

$F = \frac{\Delta P}{\Delta t}$ = Gradient of P/kgms⁻¹ against time/s graph

$$F = \frac{80-0}{20-0} = 4.0\,N$$

Q)



Calculate the acceleration of 3.0 Kg block placed on a horizontal track having a frictional force of 1.5 N.

Sol. <u>Vertical forces</u>:

$$m_1 g - T = m_1 a \text{ -------- } (2)$$

<u>Horizontal forces</u>:

$$T - f = m_2 a \text{ ------ } (3)$$

$$m_1 g - \cancel{T} = m_1 a$$
$$\cancel{T} - f = m_2 a$$

$$m_1 g - f = (m_1 + m_2) a \implies a = \frac{m_1 g - f}{m_1 + m_2}$$

$$a = \frac{(8.0)(9.81) - 1.5}{8.0 + 3.0} \implies a = \qquad ms^{-2}$$

Principle of Conservation of momentum:

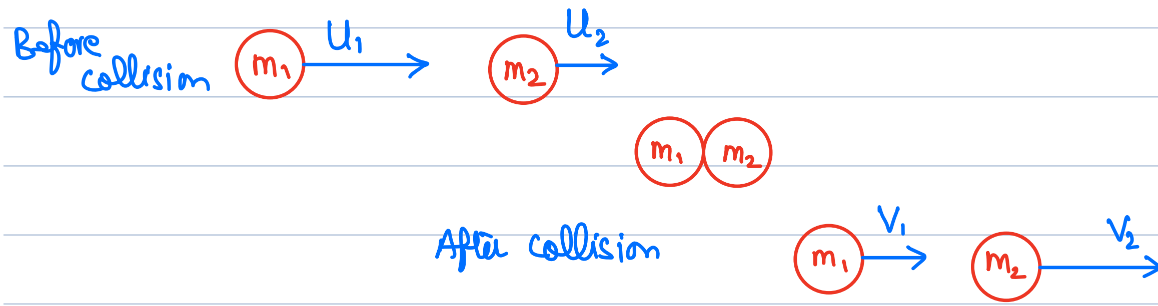
Statement:- Total momentum of all the bodies in an <u>isolated system</u> before and after interaction / collision remain conserved.

OR

Total momentum of all bodies before

and after collision remain constant provided no external force acts on them.

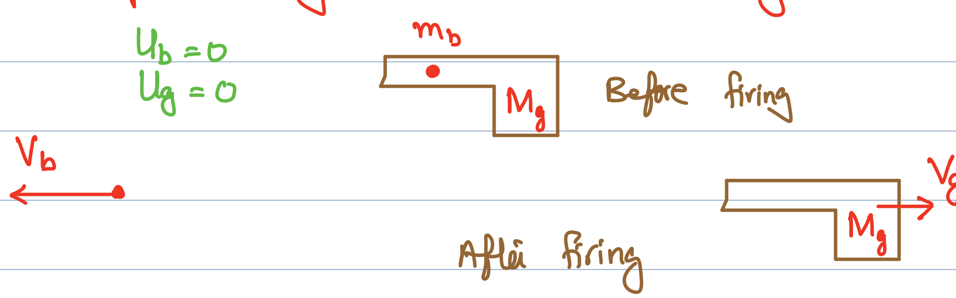
Mathematical form:



Total momentum before collision = Total momentum after collision

$$\boxed{m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2}$$

Q) Why the recoiling speed of Gun is lesser than speed of bullet on firing?



Total momentum before firing = Total momentum after firing

$$(m_b)(u_b) + (M_g)(u_g) = (m_b)(V_b) + (M_g)(-V_g)$$

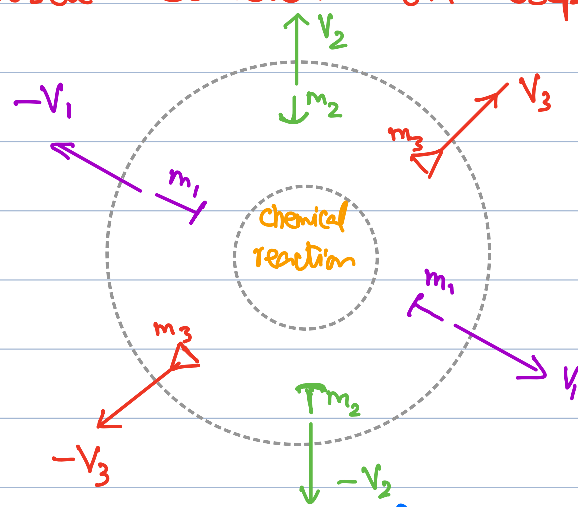
$$(m_b)(0) + (M_g)(0) = m_b V_b - M_g V_g$$

$$0 = m_b V_b - M_g V_g$$

$$m_b V_g = M_g V_g$$

Here $(V_g < V_b)$ because $(M_g > m_b)$ to keep momenta conserved.

Q) Why the metallic bearings/nails etc move in opposite direction on explosion/blast?



To keep momentum of the system conserved because total momentum of all bodies in a bomb before explosion is zero so they tend to move in opposite directions with same to keep final momentum to zero.

Types of Collision :-
→ Elastic collision
→ Inelastic collision

(a) Elastic Collision:- Interaction in which total momentum and kinetic energy of all the bodies before and after interaction remain conserved.

Note :- (1) For a perfect elastic collision, the relative speed of approach must be equal to relative speed of separation.

(2) In relative speed concept, speeds of both object are

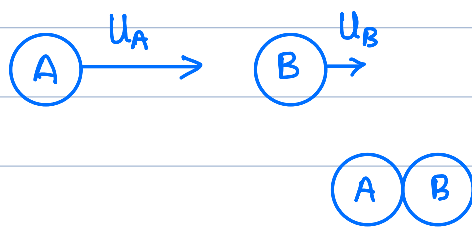
i) added if they move in opposite directions

and

(ii) subtracted if they move in same direction

Examples:

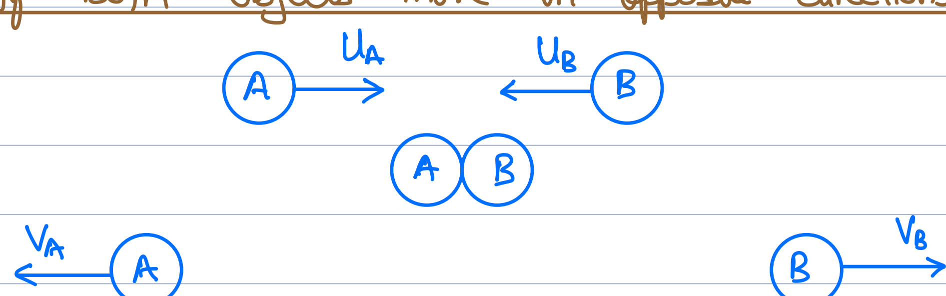
Ex.1: If both objects move in same direction:-



Relative speed of approach = separation

$$\boxed{u_A - u_B = V_B - V_A}$$

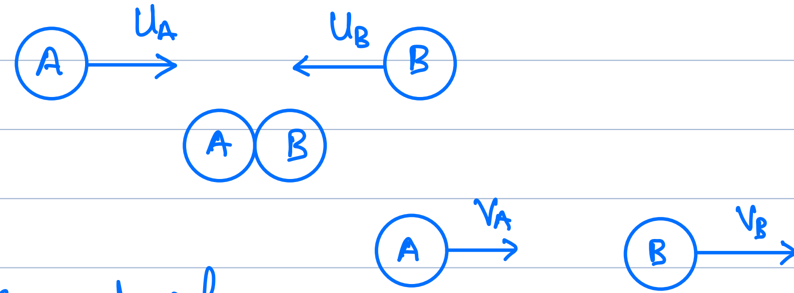
Ex.2: If both objects move in opposite directions:-



Relative speed of approach = Relative speed of separation

$$\boxed{u_A + u_B = V_A + V_B}$$

EX:3: If both objects move in same direction after collision:-

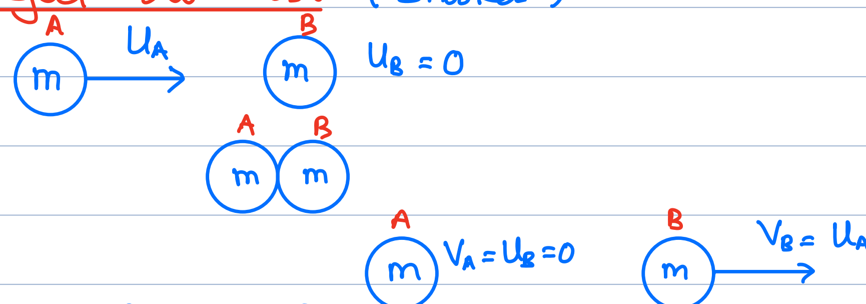


Relative speed of approach = separation

$$\boxed{u_A + u_B = V_B - V_A}$$

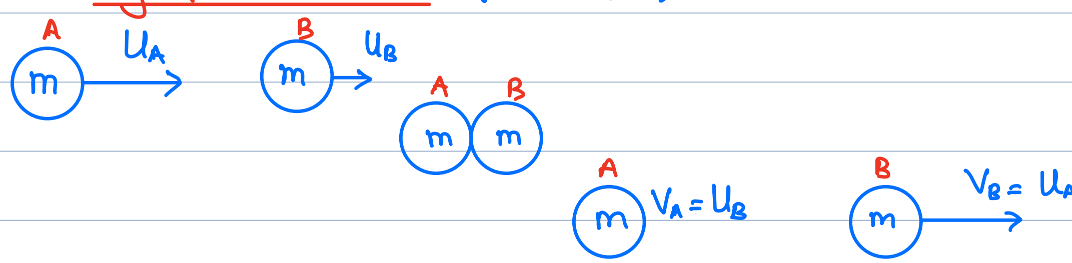
Special cases of Elastic collision in one dimension:-

Case 1:- If an object collide with an identical object at rest:- (Snooker)



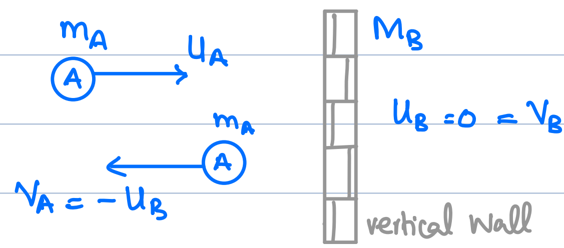
After collision, first object comes to rest and second object move with the initial velocity of first object.

Case 2:- If an object collide with an identical object in motion:- (Snooker)



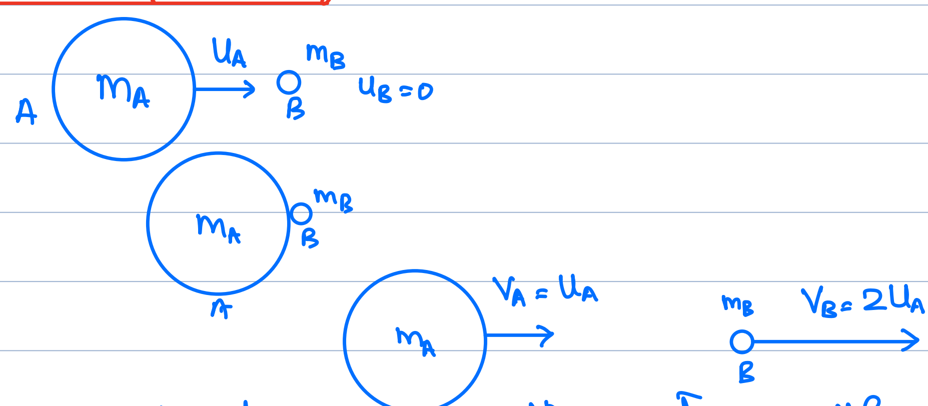
After collision, velocities are interchanged ie first object move with the velocity of 2nd object and second object move with an initial velocity of first object.

Case 3: If a light object collide with a massive object at rest:- (strike a ball on wall)



Massive object keeps its state of rest and light object bounces back with its same initial speed.

Case 4: If a massive object collide with a light object at rest (A train engine collide with a foot ball):-



Massive object continue its motion with same velocity while light object move with double the initial velocity of massive object.

(ii) **Inelastic collision – sticky collision:-**
Interaction in which total momentum is conserved while kinetic energy of all the bodies before and after interaction is not conserved.

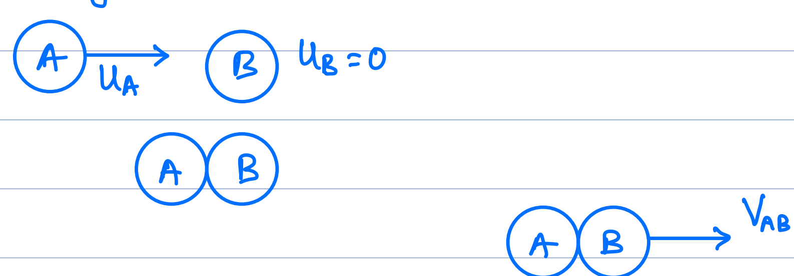
Note: If two object stick together on collision and move of with same velocity then relative speed of separation is zero and the collision is inelastic.

Examples

(1) Bullet is fired from a gun
(2) Bomb blast / explosion

} Kinetic energy is not conserved

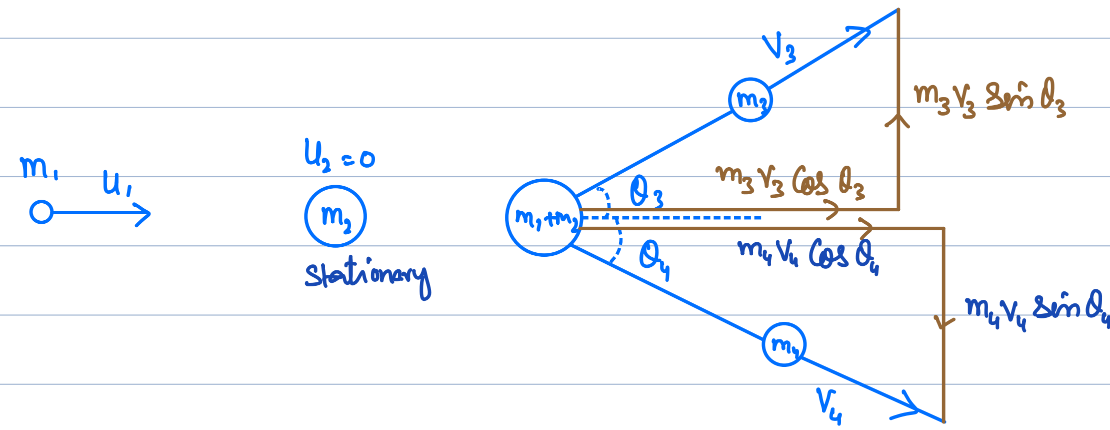
(3) Sticky collision



Relative speed of approach $= u_A$
Relative speed of separation $= 0$

Since relative speed of approach is not equal to relative speed of separation, so collision is inelastic.

Conservation of momentum in two dimensions:



Conservation of horizontal momentum:

Momentum before interaction = Momentum after interaction

$$m_1 u_1 + m_2(0) = m_3 V_3 \cos\theta_3 + m_4 V_4 \cos\theta_4$$

$$\boxed{m_1 u_1 = m_3 V_3 \cos\theta_3 + m_4 V_4 \cos\theta_4}$$

Conservation of vertical momentum:

Momentum before interaction = Momentum after interaction

$$0 + 0 = m_3 V_3 \sin\theta_3 + m_4(-V_4 \sin\theta_4)$$

$$0 = m_3 V_3 \sin\theta_3 - m_4 V_4 \sin\theta_4$$

$$\boxed{m_3 V_3 \sin\theta_3 = m_4 V_4 \sin\theta_4}$$

Note:

Type of collision	Conservation of momentum	Conservation of Kinetic energy	Total energy
Elastic	✓	✓	✓
Inelastic	✓	✗	✓

Q) Show that kinetic energy (E_k) is related to momentum by eq.

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

Sol. $P = mv \implies v = \frac{P}{m}$ ------ (1)

Also $E_k = \frac{1}{2} m v^2$ ------ (2)

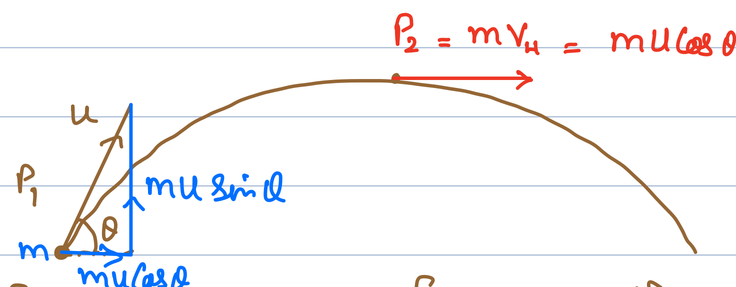
Put eq. (1) into eq. (2)

$$E_k = \frac{1}{2} m \left(\frac{P}{m}\right)^2$$

$$E_k = \frac{mp^2}{2m^2}$$

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

Q)



Drive the expression for momentum of the ball of mass m at the highest point in terms of P_1.

$$\frac{P_2}{P_1} = \frac{\cancel{mu}\cos\theta}{\cancel{mu}}$$

$$\boxed{P_2 = P_1 \cos\theta}$$

Statements of Newton's laws of motion

(1) Newton's first law of motion:

Every object continue its state of rest or of uniform motion in a straight line until no external resultant force acts on it

(2) Newton's second law of motion:

Rate of change of momentum is directly proportional to force and is the direction of force.

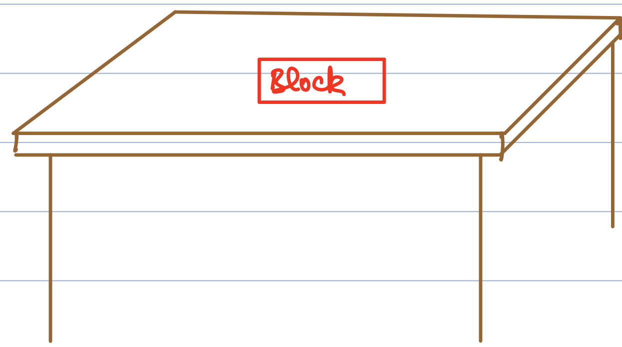
(3) Newton's third law of motion:-

Concept: Application of force → Two objects
Type of force → Same
magnitude of force → Same / equal
Direction of force → opposite
Time interval for application of force → Same

Statement 1: The forces between two interacting bodies are of same type and magnitude but act in opposite directions.

Statement 2: If an object A exert a force on object B then object also exert the same type and magnitude of force on A but in opposite direction.

Q)



Weight of the block is mg. Which statement is correct as per Newton's third law?

(A) Normal reactional force of table on block is mg.

(B) Block exert a force on Earth of magnitude mg in upward direction.

(C) Frictional force acting on block to prevent its motion is mg.

(D) None of above.

Momentum, Conservation of momentum and Collision

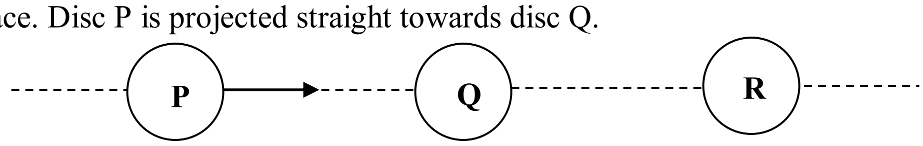
Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

1. The diagram shows two trolleys, X and Y, about to collide and gives the momentum of each trolley before the collision.

After the collision, the directions of motion of both trolleys are reversed and the magnitude of the momentum of X is then 2 Ns. What is the magnitude of the corresponding momentum of Y?

A 6 N s **B** 8 N s **C** 10 N s **D** 30 N s

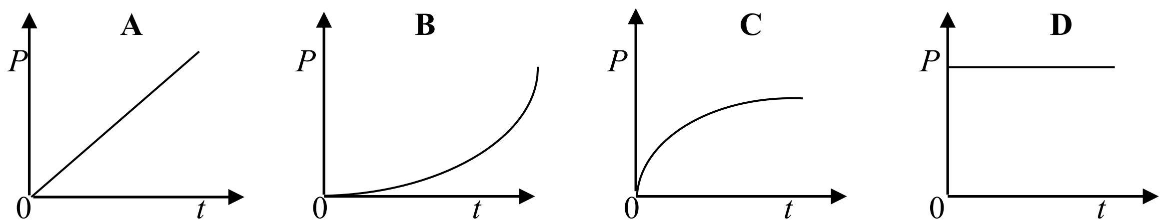
2. Three identical stationary discs, P, Q and R are placed in a line on a horizontal, flat, frictionless surface. Disc P is projected straight towards disc Q.



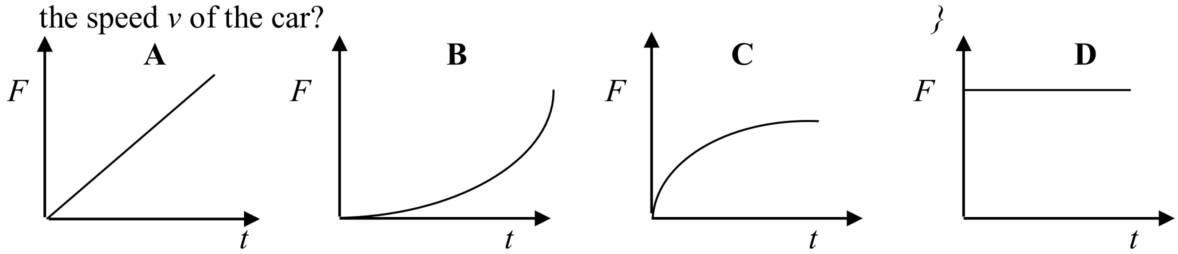
If all consequent collisions are perfectly elastic, what will be the final motion of three discs?

	P	Q	R
A	moving left	moving left	moving right
B	moving left	stationary	moving right
C	moving left	moving right	moving right
D	stationary	stationary	moving right

3. Which graph best shows the variation with time of the momentum of a body accelerated by a constant force?



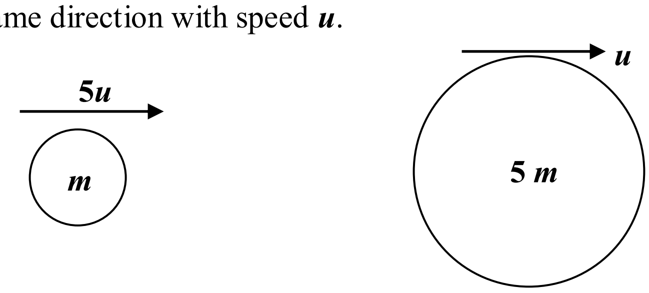
4. A car accelerates uniformly along a straight horizontal road.
Which graph best represents how the resultant horizontal force F acting on the car varies with the speed v of the car?



5. What is the **definition** of force?

A the mass of a body multiplied by its acceleration
B the power input to a body divided by its velocity
C the rate of change of momentum
D the work done on a body divided by its displacement

6. A body of mass ***m*** traveling with speed **5*u*** collides with and sticks to a body of mass **5*m*** travelling in the same direction with speed ***u***.

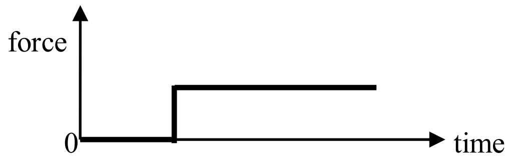


What is the speed with which the two travel after sticking together?

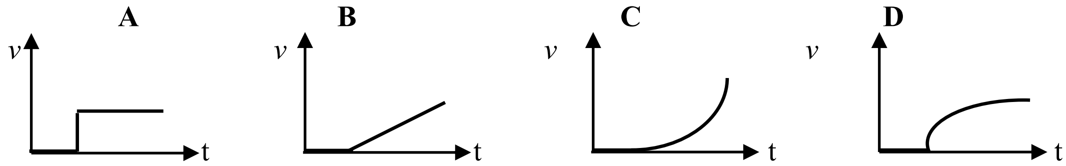
A $(3/10)u$ **B** u **C** $(6/5)u$ **D** $(10/6)u$

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

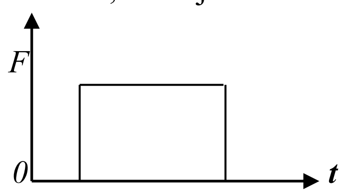
7. A car driver presses the accelerator sharply down when the traffic lights go green. The force on the car varies with time as shown.



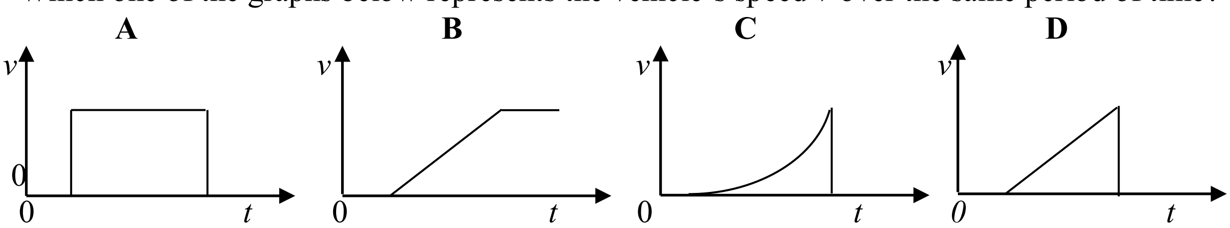
Which graph shows the variation of car's speed against time?



8. A vehicle, initially at rest on a horizontal road, is subject to a horizontal resultant force F which varies with time t as shown.



Which one of the graphs below represents the vehicle's speed v over the same period of time?



9. Two similar spheres, each of mass m and travelling with speed v, are moving towards each other.

The spheres have a head-on elastic collision. Which statement is correct?

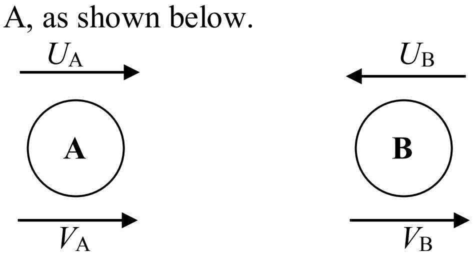
A The spheres stick together on impact. **B** The total kinetic energy after impact is mv^2
C The total kinetic energy before impact is zero. **D** The total momentum before impact is 2 mv

10. A body, initially at rest, explodes into two masses M_1 *and* M_2 that move apart with speeds V_1 and V_2 respectively. What is the ratio V_1 / V_2 ?

A M_1/ M_2 **B** M_2/ M_1 **C** $(M_1/ M_2)^{½}$ **D** $(M_2/ M_1)^{½}$

11. Two spheres **A** and **B** approach each other along the same straight line with speeds U_A and U_B. The spheres collide and move off with speeds V_A and V_B, both in the same direction as the initial direction of sphere A, as shown below.

Before collision



After collision

Which equation applies to an elastic collision?

A $U_A + U_B = V_B - V_A$ **B** $U_A - U_B = V_B - V_A$
C $U_A - U_B = V_B + V_A$ **D** $U_A + U_B = V_B + V_A$

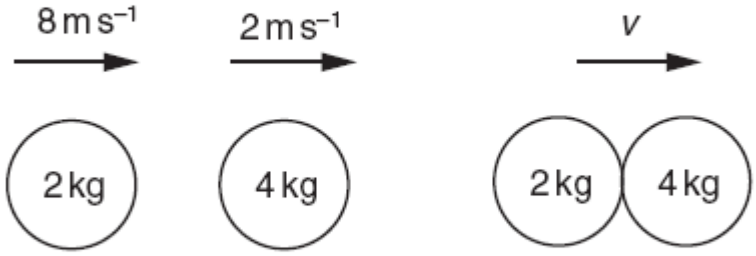
12. Two equal masses travel towards each other on a frictionless air track at speeds of 60 cm s^{-1} and 30 cm s^{-1}**.** They stick together on impact.

What is the speed of the masses after impact?

A 15 cm s^{-1} **B** 20 cm s^{-1} **C** 30 cm s^{-1} **D** 45 cm s^{-1}

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

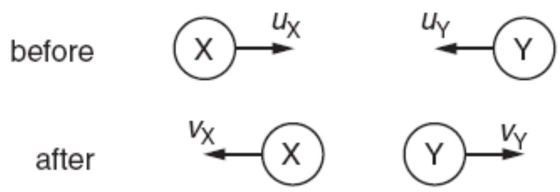
13. A ball of mass 2 kg travelling at $8ms^{-1}$ strikes a ball of mass 4 kg travelling at $2ms^{-1}$. Both balls are moving along the same straight line as shown.



After collision, both balls move at the same velocity v. What is the magnitude of the velocity v?

A $4ms^{-1}$ **B** $5ms^{-1}$ **C** $6ms^{-1}$ **D** $8ms^{-1}$

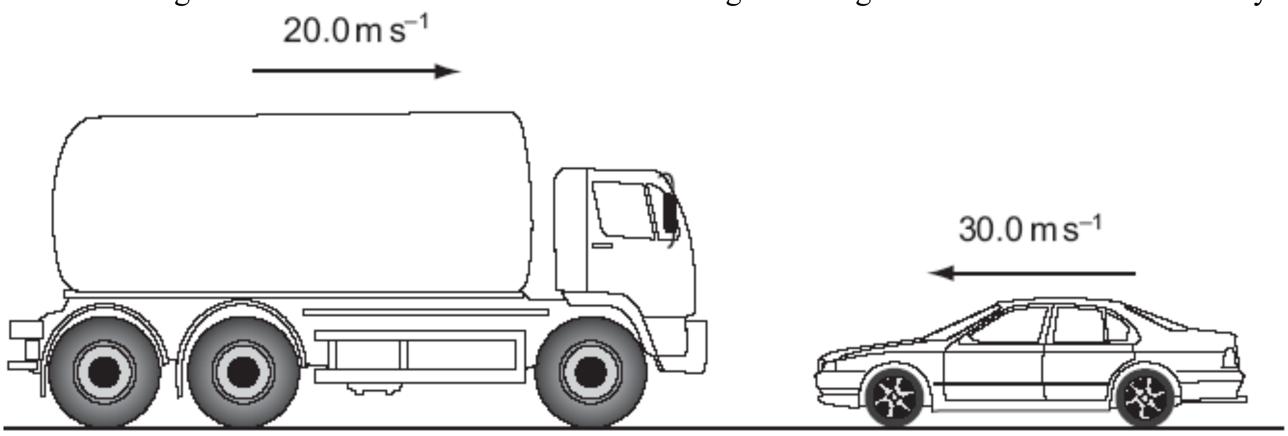
14. Two balls X and Y approach each other along the same straight line and collide elastically. Their speeds are u_X and u_Y respectively. After the collision they move apart with speeds v_X and v_Y respectively. Their directions are shown on the diagram.



Which of the following equations is correct?

A $u_X + u_Y = v_X + v_Y$ **B** $u_X + u_Y = v_X - v_Y$
C $u_X - u_Y = v_X + v_Y$ **D** $u_X - u_Y = v_X - v_Y$

15. The diagram shows a situation just before a head-on collision. A lorry of mass 20 000 kg is travelling at 20.0 m s^{-1} towards a car of mass 900 kg travelling at 30.0 m s^{-1} towards the lorry.

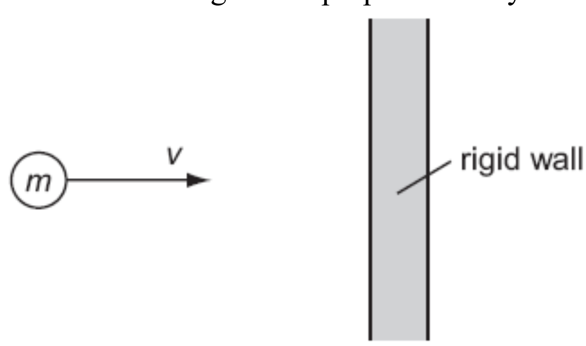


mass of lorry 20 000 kg **mass of car 900 kg**

What is the magnitude of the total momentum?

A 373 kN s **B** 427 kN s **C** 3600 kN s **D** 4410 kN s

16. A particle of mass m strikes a vertical rigid wall perpendicularly from the left with velocity v.



If the collision is perfectly elastic, the total change in momentum of the particle that occurs as a result of the collision is

A 2mv to the right. **B** 2mv to the left.
C mv to the right. **D** mv to the left.

Answers

1. C	**2. D**	**3. A**	**4. D**	**5. C**	**6. D**	**7. B**
8. B	**9. B**	**10. B**	**11. A**	**12. A**	**13. A**	**14. A**
15. A	**16. B**					

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

DYNAMICS

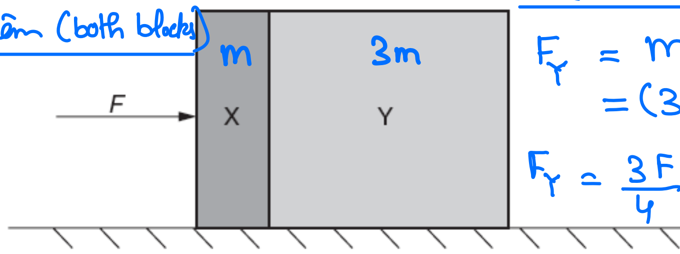
1. Two blocks X and Y, of masses *m* and 3*m* respectively, are accelerated along a smooth horizontal surface by a force *F* applied to block X as shown.

Acceleration of system (both blocks)

$F = (m_X + m_Y)a$

$F = (m + 3m)a$

$a = \frac{F}{4m}$



Force on Y by X

$F_Y = m_Y a$

$= (3\cancel{m})(\frac{F}{4\cancel{m}})$

$F_Y = \frac{3F}{4}$

Force exerted by Y on X:

$F_X = (m_X)(a)$

$= (\cancel{m})(\frac{F}{4\cancel{m}})$

$F_X = \frac{F}{4}$

What is the magnitude of the force exerted by block X on block Y during this acceleration?

A F / 4 **B** F / 3 **C** F /2 **D** 3 F / 4

Total Force F

$F = F_X + F_Y = \frac{F}{4} + \frac{3F}{4} = F$

2. Which is not one of Newton's laws of motion?

A The total momentum of a system of interacting bodies remains constant, providing no external force acts.

B The rate of change of momentum of a body is directly proportional to the external force acting on the body and takes place in the direction of the force. Newton's second law of motion

C If body A exerts a force on body B, then body B exerts an equal and oppositely-directed force on body A. N 3rd law

D A body continues in a state of rest or of uniform motion in a straight line unless acted upon by some external force. N 1st law

resultant

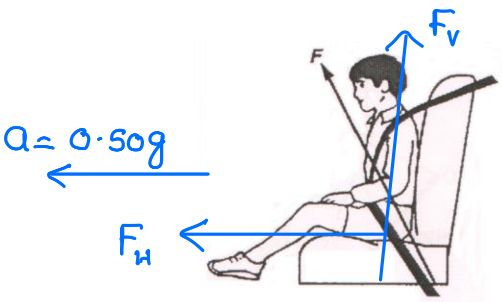
3. A motorist travelling at 10ms^{-1} can bring his car to rest in a distance of 10 m. If he had been travelling at 30ms^{-1}, in what distance could he bring the car to rest using the same braking force? Done in Kinematics chapter

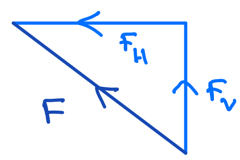
A 17 m **B** 30 m **C** 52 m **D** 90m

4. A child (mass *m*) sits on a car seat which is accelerating horizontally at 0.50 *g* (where *g* is the acceleration of free fall)

$F_V = mg$, $F_H = ma$

$= m(0.50g) = 0.50mg$





$F = \sqrt{(mg)^2 + (0.50mg)^2}$

$= 1.1mg$

What is the magnitude of the total force *F* exerted by the car seat on the child?

A 0.50 *mg* **B** 1.0 *mg* **C** 1.1 *mg* **D** 1.5 *mg*

5. Which is a statement of the principle of conservation of momentum?

A A force is equal to the rate of change of momentum of the body upon which it acts. Def of force

B In a perfect elastic collision, th e relative momentum (speed) of the bodies before impact is equal to their relative momentum (speed) after impact. ✗

C The momentum of a body is the product of the mass of the body and its velocity. Def of momentum

D The total momentum of a system of interacting bodies remains constant, providing no external force acts.

6. A mass accelerates uniformly when the resultant force acting on it $F \propto a$

A is zero. **B** is constant but not zero.

C increases uniformly with respect to time. **D** is proportional to the displacement from a fixed point.

8. A molecule of mass *m* travelling horizontally with velocity *u* hits a vertical wall at right angles to the wall. It then rebounds horizontally with the same speed. What is its change in momentum?

A zero **B** *mu* **C** –*mu* **D** –2*mu*

$\Delta P = -mu - mu = -2mu$

9. A force *F* is applied to a freely moving object. At one instant of time, the object has velocity *v* and acceleration *a*. Which quantities **must** be in the same direction?

A *a* and *v* only **B** *a* and *F* only **C** *v* and *F* only **D** *v*, *F* and *a*

Q (a) Distinguish between mass and weight. [3]

(b) State two situations where a body of constant mass experience a change in its apparent weight. [2]

(i) In water due to upthrust acting on it

(ii) due to variation in g by w = mg

(iii) Accelerated lift either rise up or descend down.

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

Newton's Second Law of Motion and Applications

1. A resultant force of 100 N is applied to an object placed on a roof whose weight is 500 N as shown in fig.1.

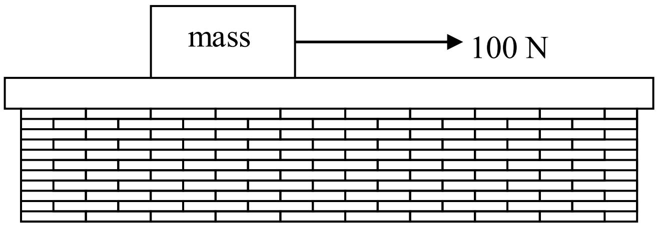


Fig 1

What is the acceleration of the mass?

2. A net force of 10 N is applied to a 2.0 kg mass, initially at rest for a time of 10 s.

(a) What is the speed of the mass after the interval of acceleration.

(b) What distance does the mass move during the period of acceleration.

3. In fig. 3, find the acceleration of the system and the tension in the string between the two masses if m = 1.0 kg and F = 12 N

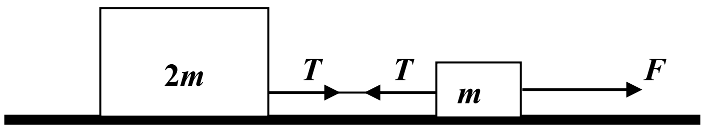


Fig 3

4. In fig. 4, find the acceleration of the system and the tension in the string between the two masses if m = 1.o kg and F = 12 N.

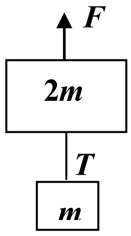


Fig. 4

5. In fig. 5, the surface and pulley are ideal. Let m_1 = 1.0 kg and m_2 = 4.0 kg.

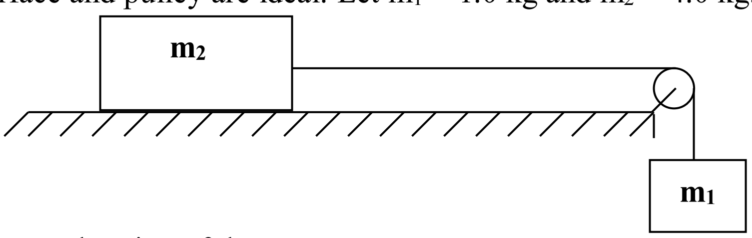
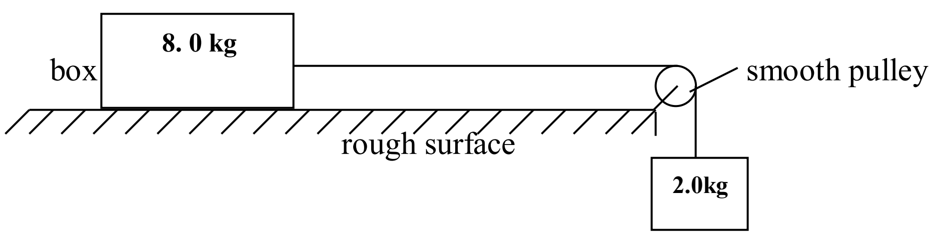


Fig. 5

(a) Calculate the acceleration of the system;

(b) Calculate the tension in the string connecting the masses.

6. A box of mass 8.0 kg rests on a horizontal, rough surface. A string attached to the box passes over a smooth pulley and supports a 2.0 kg mass at its other end.



When the box is released, a friction force of 6.0 N acts on it. What is the acceleration of the box?

A 1.4 ms^{-2} **B** 1.7 ms^{-2} **C** 2.0 ms^{-2} **D** 2.5 ms^{-2}

7. In fig. 7, calculate the acceleration of the system and the tension in the connecting strings. Take m = 2.0 kg.(neglect friction and mass of the pulley)

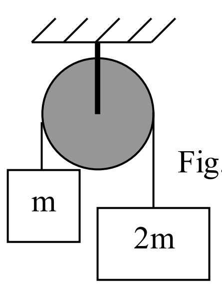


Fig. 7

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

Newton's Second Law of Motion and Applications

Answers

1. *given :* $F = 100\ N$; $W = 500\ N$

first find the mass : $W = mg$; $500 = m\,(9.81)$; $m = 51.0\ kg$

now use Newton's 2nd law: $F = ma$; $100 = (51.0)\,a$; $\boldsymbol{a = 1.96\ ms^{-2}}$

2 . *given :* $F = 10\ N$; $m = 2.0\ kg$

first find the acceleration : $F = ma$; $10 = (2.0)\,a$; $a = 5.0\ ms^{-2}$

constant force produce constant acceleration ;

(a) $v = u + a\,t$; $v = 0 + (5.0)(10)$; $\boldsymbol{v = 50\ ms^{-1}}$

(b) $S = u\,t + (1/2)\,a\,t^2$; $S = 0 + (1/2)(5.0)(10)^2$; $\boldsymbol{S = 2.5 \times 10^2\ m}$

3. *Note: Only forces in the horizontal direction should be considered*

For m : $F - T = ma$

For 2m : $T = 2ma$

Adding both these equations

$ma + 2ma = F$; $3ma = F$; $3\,(1.0)\,a = 12$; $a = 4.0\ ms^{-2}$

To find T, substitute $a = 4.0\ ms^{-2}$ *in any equation.*

$2\,(1.0)(4.0) = T$; $\boldsymbol{T = 8.0\ N}$

4. *For* ***top mass****, one upward force and two downward forces*

$F - T - 2\,m\,g = 2\,m\,a$

For ***bottom mass****, one upward force and one downward force*

$T - mg = ma$

Adding both these equations,

$F - 3mg = 3ma$

$12 - 3(1.0)(9.81) = 3\,(1.0)\,(a)$

$\boldsymbol{a = -\,5.8\ m\,s^{-2}}$

Note: The negative sign means the system is accelerating downward instead of upward. The upward force is less than the total weight of the system.

5. *Since the surface is frictionless, the mass* m_1 *moves downward and* m_2 *to the right.*

For $\boldsymbol{m_1}$: $m_1\,g - T = m_1\,a$

For $\boldsymbol{m_2}$: $T = m_2\,a$

Adding these equations:

$m_1\,g = m_1\,a + m_2\,a$

$(1.0)(9.81) = (1.0)\,a + (4.0)\,a$

$a = 2.0\ ms^{-2}$

To find T, substitute $a = 2.0\ ms^{-2}$ *in equation for mass* m_2*.*

$T = m_2\,a$; $T = (4.0\,(2.0)$; $\boldsymbol{T = 8.0\ N}$

6. *Vertical forces on* ***2 kg*** *mass*

downward weight – upward tension = ma ; $mg - T = ma$; $2g - T = 2a$

Horizontal forces on box of mass ***8 kg***

Rightward tension – Leftward friction = ma ; $T - f = ma$; $T - 6 = 8a$

Adding both these equations,

$2g - 6 = 10\,a$; $2\,(9.81) - 6 = 10\,(a)$; $\boldsymbol{a = 1.36\ ms^{-2}}$

So Answer is option ***A***

7. *Vertical force on* ***2 m*** *mass :*

downward weight – upward tension = ma ; $2\,mg - T = 2\,ma$; $2(2)\,g - T = 2(2)a$

Vertical force on ***m*** *mass :*

upward tension - downward weight = ma ; $T - mg = ma$; $T - (2)g = (2)\,a$

Adding both these equations,

$4g - 2g = 4a + 2a$; $2\,g = 6\,a$; $2(9.81) = 6\,a$; $a = 3.27 \approx \boldsymbol{3.3\ m\,s^{-2}}$

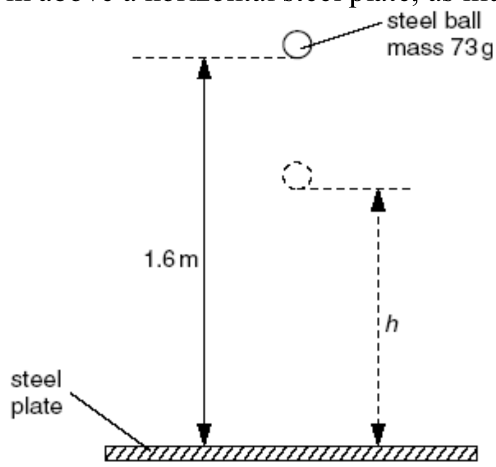
To find T, substitute $a = 3.3\ ms^{-2}$ *in any equation.*

$T - 2\,g = 2\,a$; $T - 2(9.81) = 2(3,3)$; $T = 6.6 + 19.6$; $\boldsymbol{T = 26.2\ N}$

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

DYNAMICS

Q. A steel ball of mass 73 g is held 1.6 m above a horizontal steel plate, as illustrated in Figure.



The ball is dropped from rest and it bounces on the plate, reaching a height *h*.

(a) Calculate the speed of the ball as it reaches the plate.

$2as = v^2 - u^2$

$2(9.81)(1.6) = v^2 - (0)^2$

$E_p = E_k$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$v = \sqrt{2gh}$

$v = \sqrt{2(9.81)(1.6)}$

$v = 5.6$

speed = ...5.6.......... ms–1 [2]

(b) As the ball loses contact with the plate after bouncing, the kinetic energy of the ball is 90% of that just before bouncing. Calculate

(i) the height *h* to which the ball bounces,

90% of Kinetic energy = Gravitational potential energy

$\frac{90}{100}\left(\frac{1}{2}\cancel{m}v^2\right) = \cancel{m}gh$

$\frac{0.45v^2}{g} = h \Rightarrow h = \frac{(0.45)(5.6)^2}{9.81}$

h = ...1.44.......... m

(ii) the speed of the ball as it leaves the plate after bouncing.

$2aS = v^2 - u^2$

$2(9.81)(1.44) = 0 - u^2$

$E_k = E_p$

$u = \sqrt{(19.6)(1.44)}$

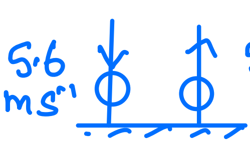
speed = ...5.30.......... ms^{-1}[4]

(c) Using your answers to **(a)** and **(b)**, determine the change in momentum of the ball during the bounce.

$\Delta P = mv - mu$

$= (73\times10^{-3})(-5.30) - (73\times10^{-3})(5.6)$

$=$ ________ $kg\,ms^{-1}$



change = ... Ns [3]

(d) With reference to the law of conservation of momentum, comment on your answer to **(c)**.

The loss of momentum of ball is gained by the steel plate but in opposite direction.

....[3]

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

Q. A ball falls from rest onto a flat horizontal surface. Fig. 1.1 shows the variation with time *t* of the velocity *v* of the ball as it approaches and rebounds from the surface.

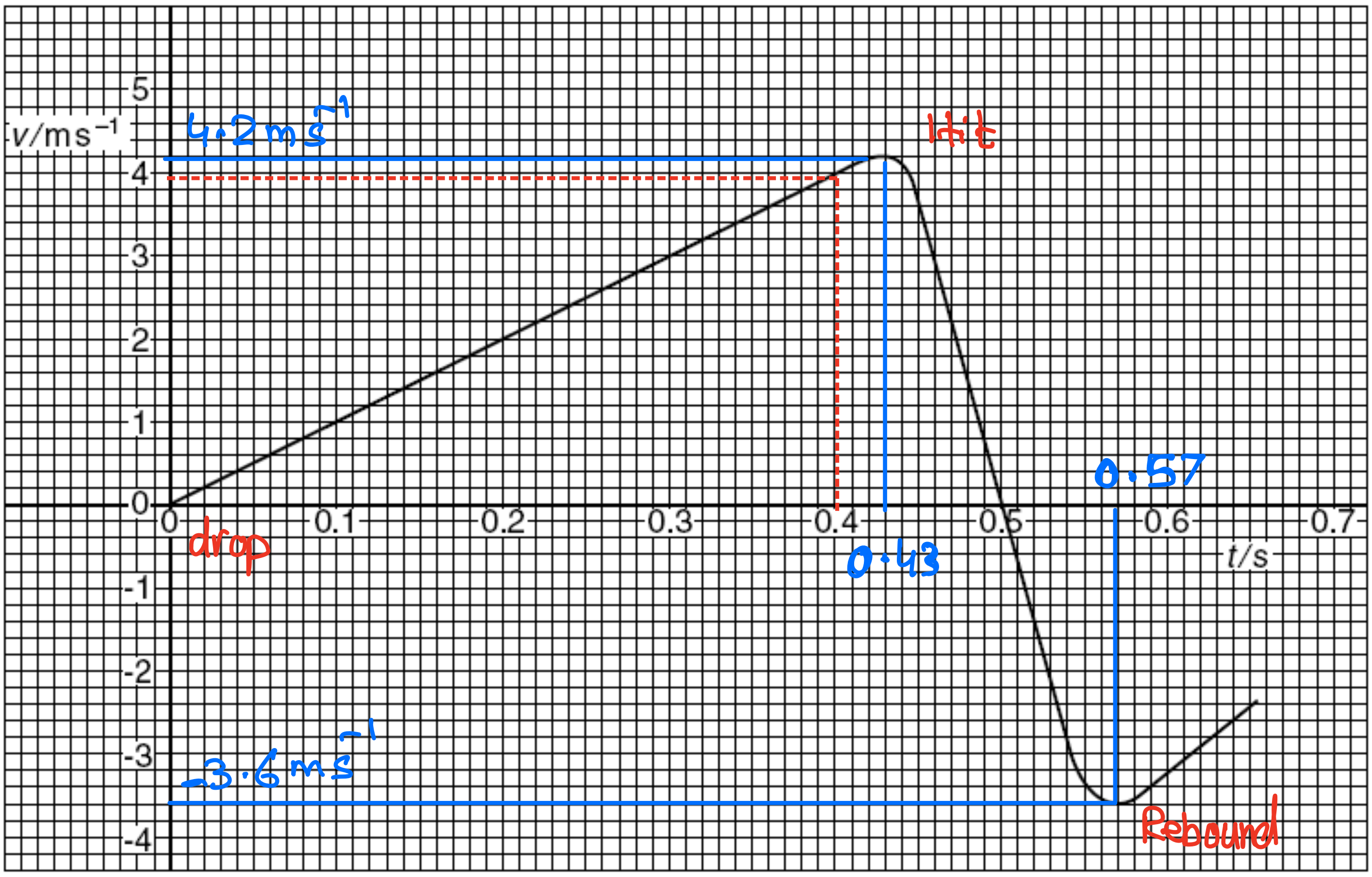


Fig. .1.1

Use data from Fig. 1.1 to determine

(a) the distance travelled by the ball during the first 0.40 s,

distance = Area under graph

$= \frac{1}{2}(0.40)(4.0)$

distance = ...0.80.... m [2]

(b) the change in momentum of the ball, of mass 45 g, during contact of the ball with the surface,

$\Delta P = mv - mu$

$= (45\times10^{-3})(-3.6) - (45\times10^{-3})(4.0)$

$= -0.342\,Ns$

change = …………………………………….. Ns [4]

(c) the average force acting on the ball during contact with the surface.

$F = \frac{\Delta P}{\Delta t} = \frac{0.342}{0.57-0.43} = 2.44\,N$

force = ……………………………………… N [2]

Akhtar Mahmood (0333-4281759)
M.Sc.(Physics), MCS, MBA-IT, B.Ed.
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

Q. An experiment is carried out to determine the speed of a bullet. The bullet, of mass 15 g and speed v, is fired horizontally at a box of sand of mass 6000 g, suspended by strings as shown in Fig. 1.1.

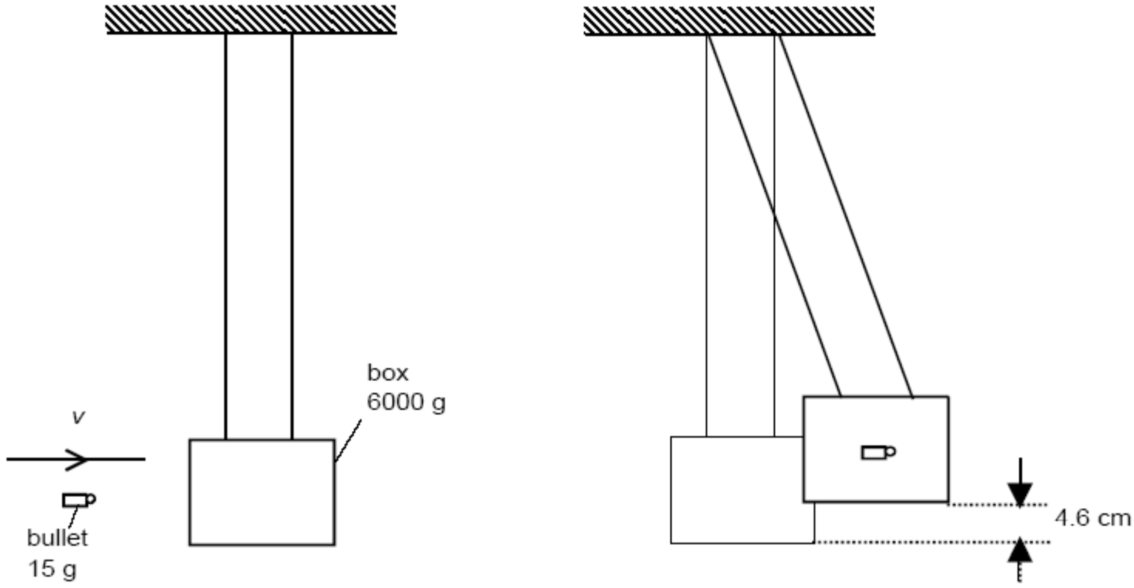


Fig. 1.1 Fig. 1.2

The bullet becomes embedded in the sand in the box and causes the box to rise to a maximum height of 4.6 cm, as shown in Fig. 1.2.

(a) State with a reason whether the collision is elastic or inelastic.

Inelastic because relative speed of separation is zero [1]

(b) Use the principle of conservation of energy to show that the initial speed of the box, immediately after the bullet has become embedded, is 0.95 m s^{-1}. [3]

Loss of E_k of bullet = Gain in E_p of bullet and box

$\frac{1}{2}\cancel{m}v^2 = \cancel{m}gh \Rightarrow v = \sqrt{2gh}$

$v = \sqrt{2(9.81)(4.6\times10^{-2})} = 0.95\,ms^{-1}$

(c) Calculate the initial speed of the bullet. Use of conservation of momentum principle

$(15)(v) + (6000)(0) = (15 + 6000)(0.95)$

$15v = (6015)(0.95)$

$v = 381$

speed = 381 m s^{-1} [3]

Q.(a) Collisions can be described as *elastic* or *inelastic*.
State what is meant by an inelastic collision.

Interaction in which momentum is conserved but kinetic energy before and after collision is not conserved.

(b) A ball of mass 0.12 kg strikes a stationary cricket bat with a speed of $18ms^{-1}$. The ball is in contact with the bat for 0.14 s and returns along its original path with a speed of $15ms^{-1}$. Calculate

(i) the momentum of the ball before the collision,

$P_1 = mu = (0.12)(18)$ 2.16 Ns

(ii) the momentum of the ball after the collision,

$P_2 = mv = (0.12)(-15)$ −1.8 Ns

(iii) the total change of momentum of the ball,

$\Delta P = -1.8 - 2.16$ −3.96 Ns

(iv) the average force acting on the ball during contact with the bat,

$F = \frac{\Delta P}{\Delta t} = \frac{3.96}{0.14}$ 28.3 N

(v) the kinetic energy lost by the ball as a result of the collision.

$\Delta E = \frac{1}{2}m[v^2 - u^2] = \frac{1}{2}(0.12)[(15)^2 - (18)^2] = -5.94J$ 5.94J

−ve sign shows that energy is lost by ball

2 (a) State the principle of conservation of momentum.

Total momentum of all the bodies in an isolated system before and after interaction remain conserved.

.... [2]

(b) A stationary firework explodes into three different fragments that move in a horizontal plane, as illustrated in Fig. 2.1.

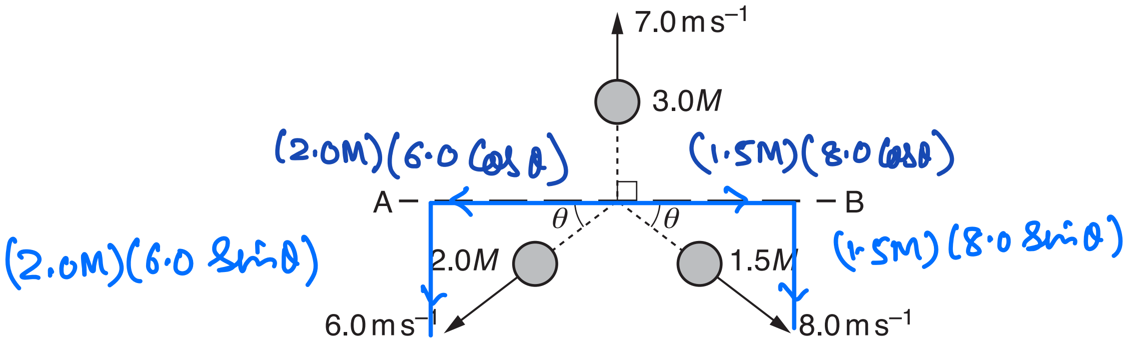


Fig. 2.1

The fragment of mass $3.0M$ has a velocity of $7.0\,\mathrm{m\,s^{-1}}$ perpendicular to line AB.
The fragment of mass $2.0M$ has a velocity of $6.0\,\mathrm{m\,s^{-1}}$ at angle θ to line AB.
The fragment of mass $1.5M$ has a velocity of $8.0\,\mathrm{m\,s^{-1}}$ at angle θ to line AB.

(i) Use the principle of conservation of momentum to determine θ.

Consider vertical conservation of momentum

$$(3.0M)(7.0) = (2.0M)(6.0 \sin\theta) + (1.5M)(8.0 \sin\theta)$$

$$\theta = 61°$$

θ = ... ° [3]

(ii) Calculate the ratio

$$\frac{\text{kinetic energy of fragment of mass } 2.0M}{\text{kinetic energy of fragment of mass } 1.5M}.$$

$$= \frac{\frac{1}{2}(2.0M)(6.0)^2}{\frac{1}{2}(1.5M)(8.0)^2}$$

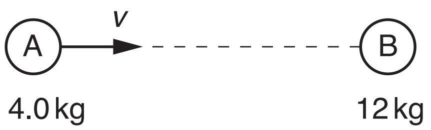
ratio = ... 0.75 .... [2]

[Total: 7]

3 **(a)** State the principle of conservation of momentum.

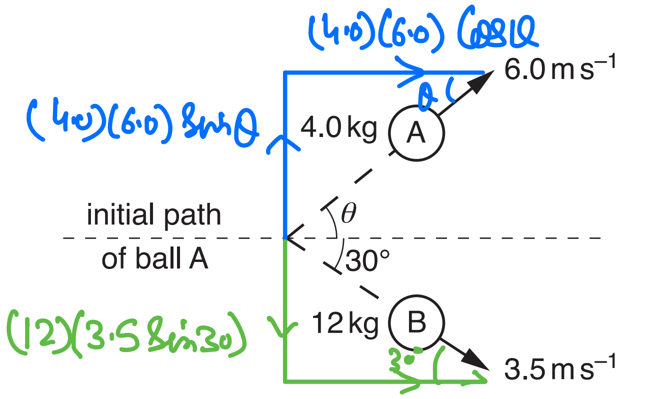
Total momentum of all the bodies in an isolated system before and after interaction remain conserved. [2]

(b) Ball A moves with speed v along a horizontal frictionless surface towards a stationary ball B, as shown in Fig. 3.1.



before collision

Fig. 3.1



after collision (12)(3.5 Cos 30)

Fig. 3.2 (not to scale)

Ball A has mass 4.0 kg and ball B has mass 12 kg.
The balls collide and then move apart as shown in Fig. 3.2.
Ball A has velocity $6.0\,\mathrm{m\,s^{-1}}$ at an angle of θ to the direction of its initial path.
Ball B has velocity $3.5\,\mathrm{m\,s^{-1}}$ at an angle of 30° to the direction of the initial path of ball A.

(i) By considering the components of momentum at right-angles to the direction of the initial path of ball A, calculate θ.

Before interaction = After interaction

$0 + 0 = (4.0)(6.0 \sin\theta) + (12)(-3.5 \cos 30)$

$\theta = 61°$

$\theta =$ 61 ° [3]

(ii) Use your answer in **(i)** to show that the initial speed v of ball A is 12 m s^{-1}. Explain your working.

Consider horizontal conservation of momentum

$(4.0)(v) + (12)(0) = (4.0)(6.0\cos 61) + (12)(3.5\cos 30)$

$v = 12\,\text{ms}^{-1}$

[2]

(iii) By calculation of kinetic energies, state and explain whether the collision is elastic or inelastic.

Initial kinetic energy before interaction

$= \frac{1}{2}(4.0)(12)^2 + \frac{1}{2}(12)(0) = 288\text{J}$

Final kinetic energy after interaction

$= \frac{1}{2}(4.0)(6.0)^2 + \frac{1}{2}(12)(3.5)^2$

$= 145\text{J}$

[3]

Since kinetic energy is not conserved

so collision is inelastic

[Total: 10]

[Turn over