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Dynamics

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Learning Objectives

- Understand Newton's laws of motion
- Understand Linear momentum and its conservation

Newton's Laws of Motion

1st Law:

$\sum F = 0$ → an object at **rest** will **remain at rest**, an object in **motion** will **remain in motion** with **constant speed** in **straight line**

2nd law:

$\sum F = ma$ → resultant force equal to **mass x acceleration** and both **resultant force** and **acceleration** have **same direction**

3rd law:

For a given force there is a **reaction force** with the **same magnitude** and **opposite direction** on **two different bodies**

Linear Momentum

- $p = mv$

p = momentum (N s or kg m s^{-1})

m = mass of the body (kg)

v = velocity (m/s)

- $\Delta p = Ft$

Δp = change in momentum (N s or kg m s^{-1})

F = net force (N)

t = time (s, how long the force acting to the body)

Conservation of Linear Momentum

Principal of conservation of momentum:

Momentum **conserved** when there’s **no net of external force**

$\sum F = 0 \rightarrow \sum p_0 = \sum p_1$

$\sum p_0$ = total initial momentum

$\sum p_1$ = total final momentum

Conservation of Linear Momentum

Elastic Collision

$\sum p_0 = \sum p_1$ and $\sum \mathrm{EK}_0 = \sum \mathrm{EK}_1$

Momentum and Kinetic Energy are conserved

$u_1 - u_2 = v_1 - v_2$

u_1 = initial velocity of body 1

u_2 = initial velocity of body 2

v_1 = final velocity of body 1

v_2 = final velocity of body 2

Conservation of Linear Momentum

Inelastic collision

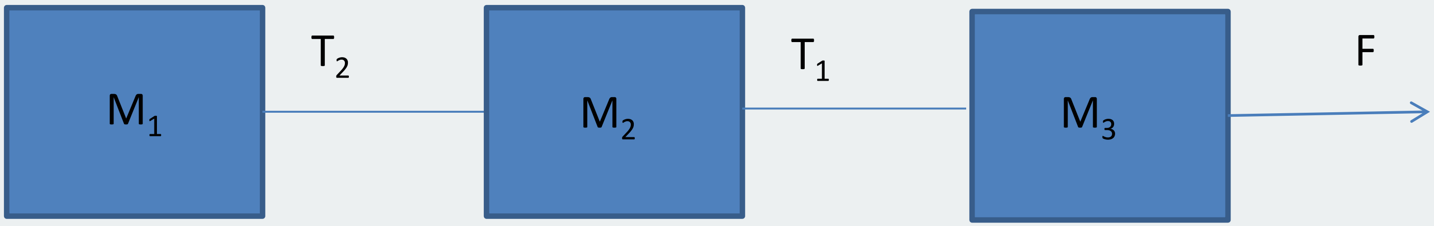
momentum is **conserved** but **total kinetic energy** is **not conserved**

There's corresponding value of *e* (coefficient of restitution), where $e = -\frac{v_1 - v_2}{u_1 - u_2}$

Perfectly inelastic collision

$m_1 u_1 + m_2 u_2 = (m + u)v$

Example 1



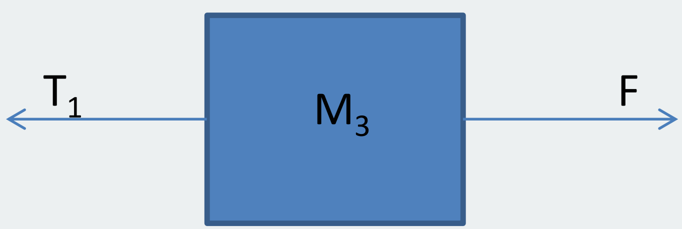
$F = 100$ N; $M_1 = 20$ kg; $M_2 = 30$kg; $M_3 = 50$kg; determine T_1 and T_2

Solution:

$\sum F = ma$; $F = (M_1 + M_2 + M_3)\, a$

$a = 1\ ms^{-2}$

Consider free body diagram for M_3



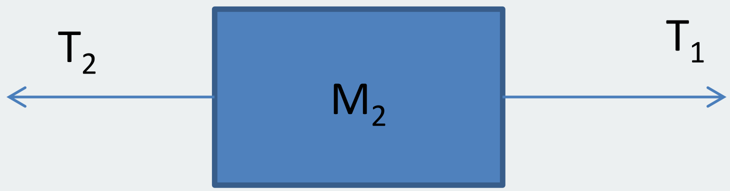
$F - T_1 = M_3a$

$T_1 = 100 – 50(1)$

$T_1 =$ **50 N**

Example 1

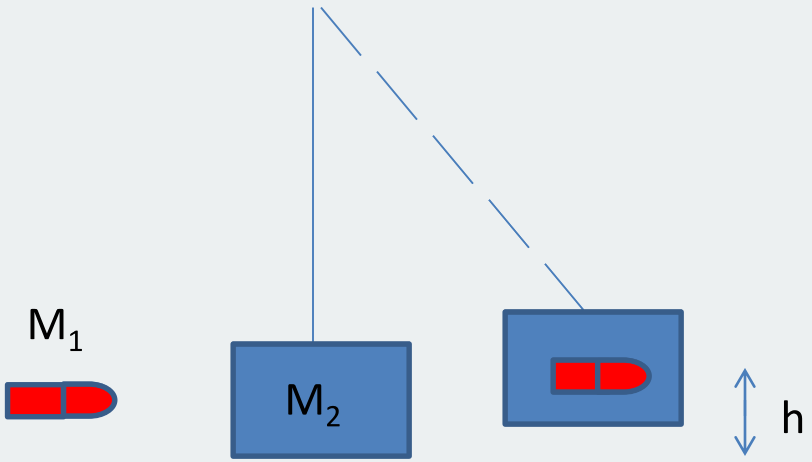
Now consider M_2



$T_1 - T_2 = M_2 a$

$T_2 = 50 – 30(1) =$ **20 N**

Example 2



Bullet M_1 fired into M_2 and embedded in the block ad make them rise by a vertical distance h.

a) Is the collision above elastic? Is linear momentum conserved? Justify your answer

b) If M_1 = 20 g, M_2 = 10 kg, and h = 0.01 m. Determine the initial velocity of the bullet. State any assumption you made

Example 2

Solution:

a) Perfectly inelastic, since the bullet and the block have the same final velocity. The linear momentum is conserved because there is no net of external force when the collision occur

b) Conservation of energy:

$0.5\ (M_1 + M_2)\ v^2 = (M_1 + M_2)\ gh$

$0.5\ (0.02 + 10)\ v^2 = (0.02 + 10)\ (9.81)(0.01)$

$v = 0.443\ m/s$

Conservation of momentum:

$M_1\ u_1 + M_2 u_2 = (M_1 + M_2)\ v$

$0.02\ u_1 = (0.02 + 10)(0.443)$

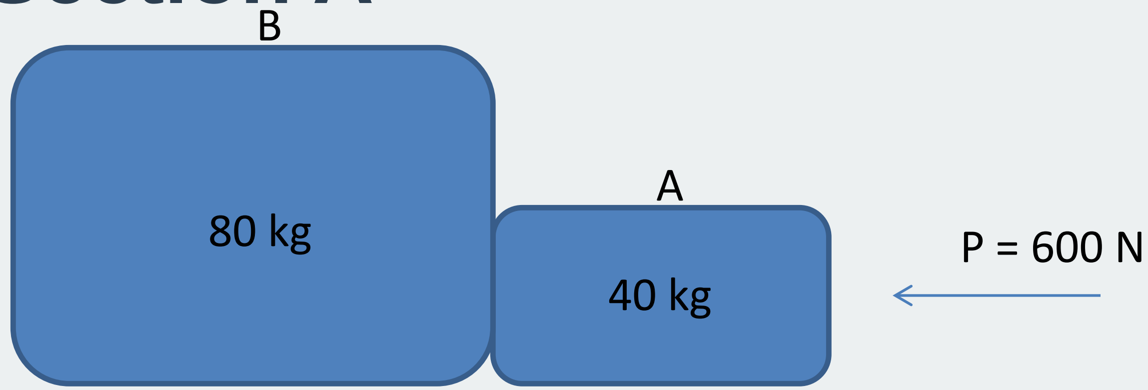
$u_1\ = 220\ m/s$

Conditions for conservation of momentum:

- The system is ideal with no lost of energy to the surroundings
- The effect of gravity is negligible (so there is no initial velocity of the bullet in vertical direction)
- The time taken for the bullet to be embedded is negligible
- The effect of uptrust is negligible

Example 3

Section A

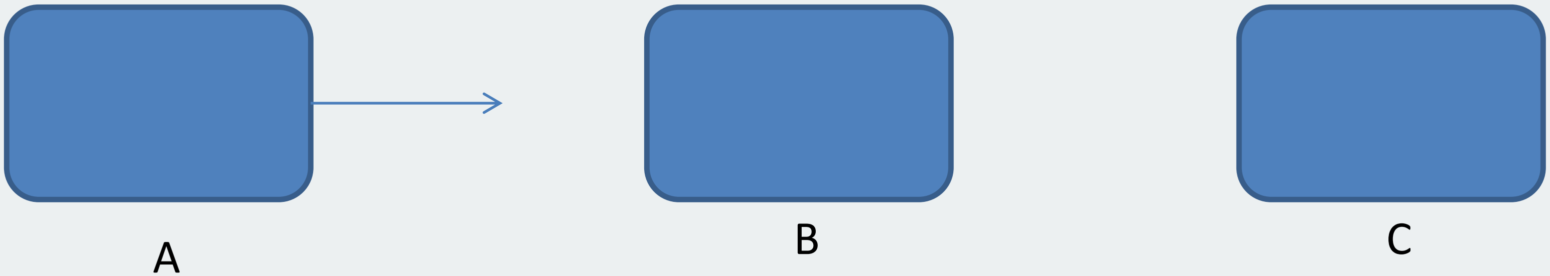


Force P (600N) is given to block A, determine the magnitude of force from block B to block A

a) 200 N
b) 300 N
c) 400 N
d) 500 N
e) 600 N

ANS: C

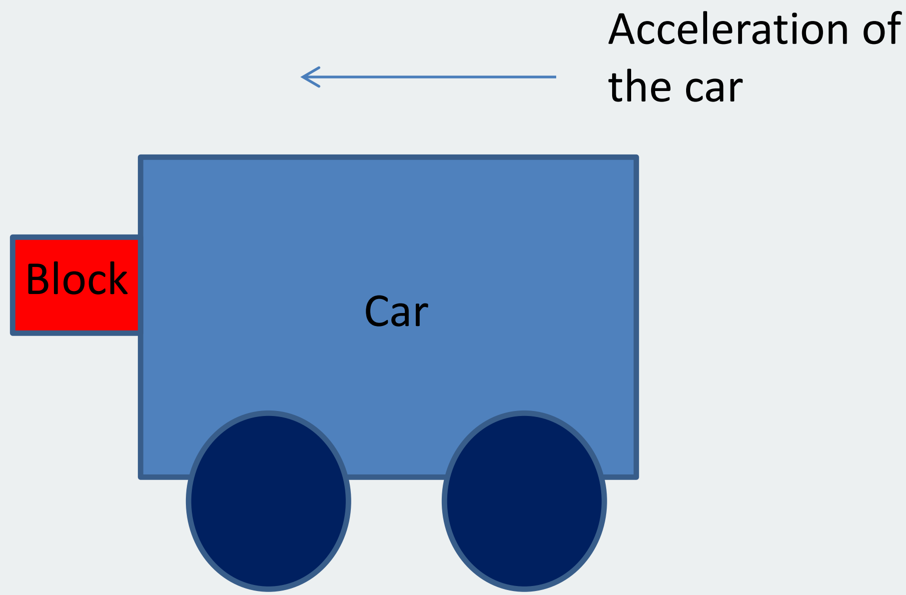
Example 4



Three identical blocks are placed in frictionless horizontal surface. In initial condition block A is moving to right. What will be the final condition of the three blocks, if all collision is elastic? **ANS: C**

	Block A	Block B	Block C
A	Moving left	Stationary	Moving right
B	Moving left	Moving left	Moving right
C	Stationary	Stationary	Moving right
D	Moving left	Moving right	Moving right

Example 4

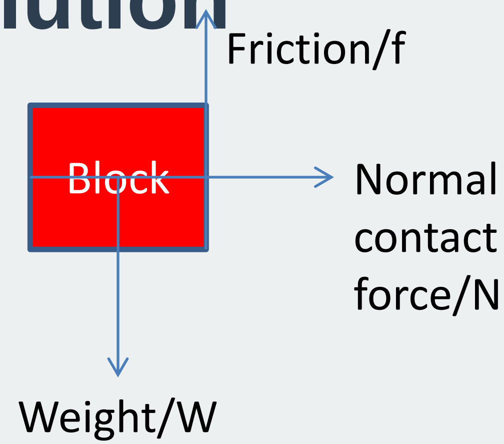


A car is accelerating with a block in front of it. The frictional force between the bodies is twice the normal reation between them

a) Show that the accelaration required to keep the block to not to fall is independent on the mass of the car and/or the block.
b) When the car come to a sudden stop describe the motion of the block

Example 4

Solution



a) $\sum F_y = 0$

$f - W = 0 \rightarrow 2N = mg$

$\sum F_x = ma$

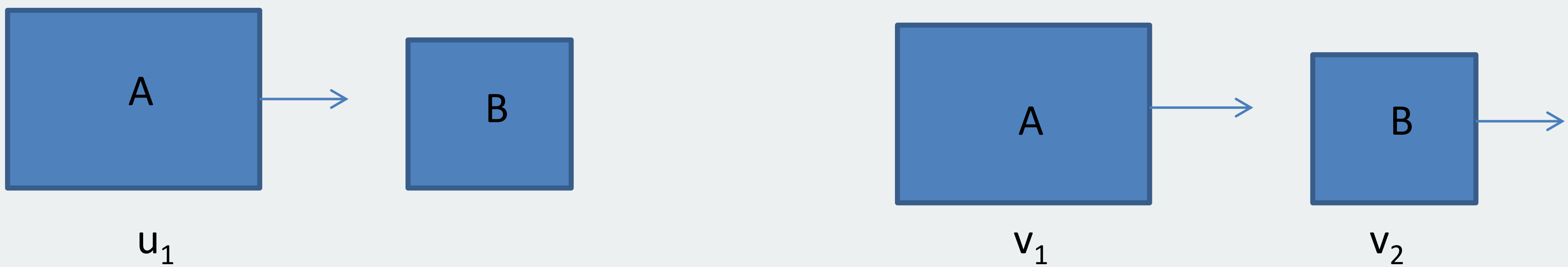
$N = ma$

$mg/2 = ma \rightarrow a = 0.5g$ (shown)

hence acceleration is independent of mass

b) After a sudden stop, the only force acting on the block is gravitational force, hence the block will have parabolic motion.

Example 5



Before collision

After collision

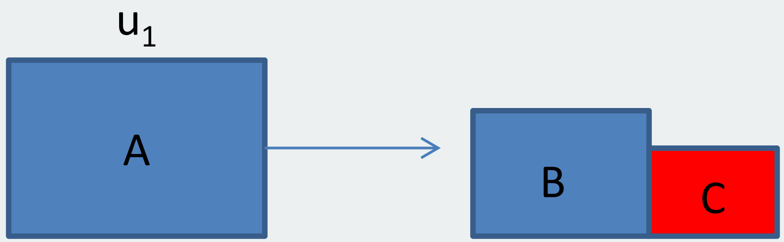
Block A is moving with initial velocity u_1 and perform ellastic collision with Block B

a) In the case where M = m, describe the movement of block A and B after the collision

b) If $M_A \neq M_B$ determine the expression for the fraction of initial kinetic energy of A which is transferred to block B (in terms of M_A and M_B)

Example 5

b) now additional block is placed next to block b, by considering the ellastic collision between all the blocks, determine the expression for the fraction of the initial kinetic energy of block A which is transferred to block C (in terms of M_A , M_b and M_c)



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Example 5

Solution

a) Because the collision is ellastic, after the collision block A will stop and block B will move with velocity equal to u_1

b) $M_A u_1 = M_A v_1 + M_b v_2$

$$v_1 = \frac{M_A u_1 - Mbv_2}{M_A}$$

$$\tfrac{1}{2} M_A u_1^2 = \tfrac{1}{2} M_A v_1^2 + \tfrac{1}{2} M_b v_2^2$$

$$\tfrac{1}{2} M_A u_1^2 = \tfrac{1}{2} M_A \left(\frac{M_A u_1 - Mbv_2}{M_A}\right)^2 + \tfrac{1}{2} M_b v_2^2$$

$$2M_A M_b u_1 v_2 = M_b^2 v_2^2 + M_A M_b v_2^2$$

$$\frac{v_2}{u_1} = \frac{2MA}{M_A + M_b}$$

$$\text{Fraction transferred} = \frac{\text{kinetic energy of block B}}{\text{initial kinetic energy of block A}}$$

$$\tfrac{1}{2} M_b v_2^2 \div \tfrac{1}{2} M_A u_1^2 = \frac{M_b}{M_A}\left(\frac{v_2}{u_1}\right)^2$$

$$\frac{M_b}{M_A}\left(\frac{2MA}{M_A + Mb}\right)^2 = \frac{4M_A M_b}{(MA + Mb)^2}$$

Example 5

From (b) Fraction transferred from b to c =

$$\frac{\text{kinetic energy of block } C}{\text{initial kinetic energy of block } B} = \frac{4M_bM_c}{(Mb + Mc)^2}$$

Fraction transferred from a to c = $\frac{KE_C}{KE_A}$ =

$$\frac{KE_C}{KE_B} + \frac{KE_B}{KE_A} = \frac{4M_bM_c}{(Mb + Mc)2} \text{ x } \frac{4M_AM_b}{(MA_+ Mb)2} =$$

$$\frac{16M_AM_b{}^2M_c}{(MA_+ Mb)2(Mb + Mc)2}$$

References

A level complete guide, Themis Publisher,

www.xtremepapers.com,

Physics MCQ with helps (topical).