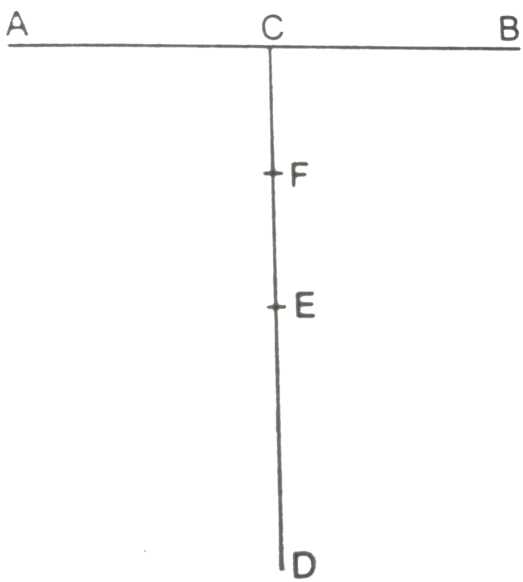
PHYSICS

BOOKS - HC VERMA PHYSICS (ENGLISH)

CENTRE OF MASS, LINEAR MOMENTUM, COLLISION

Example

1. Two identical uniform rods AB and CD, each of length L are jointed to form a T-shaped frame as shown in figure. Locate the centre of mass of the frame. The centre of mass of a uniform rod is at the middle point of the rod.



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2. Two charged particles of masses m and 2m are placed distance d apart on a smooth horizontal table. Because of their mutual attraction, they move towards each other and collide. Where will the collision occur with respect to the initial positions?

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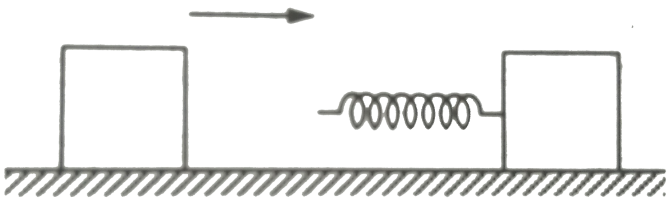
3. Each of the blocks shown in figure has mass 1 kg. The rear block moves with a speed of 2 m/s towards the front block kept at rest. The spring attached to the front block islight and has a spring constant 50 N/m. find the maximum compression of the spring.



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4. A cart A of mass 50 kg moving at a speed of 20 km/h hits a lighter cart B of mass 20 kg moving towards it at a speed of 10 km/h. The two carts cling to each other. Find the speed of the combined mass after the collision.

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5. A block of mass m moving at speed v collides with another block of mass 2 m at rest. The lighter block comes to rest after the collision. Find the coefficient of restitution.

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Worked Out Examples

1. Half of the recrtangular plate shown in figure is made of a material of density ρ_1 and the other half of density ρ_2. The length of the plate is L. Locate the centre of mass of the plate.

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2. The density of a rod of length L varies as $\rho = A + Bx$ where x is the distance from the left end. Locate the centre of mass.

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3. A cubical block of ice of mass m and edge L is placed in a large tray of mass M. If the ice melts, how far does the centre of mass of the system "ice plus tray" come down?

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4. Consider a two particle system with the particles having masses m_1 and m_2. If the first particles pushed towards the centre of mass through a distance d, by what distance should the second particle be moved so as the keep the centre of mass at the same position?

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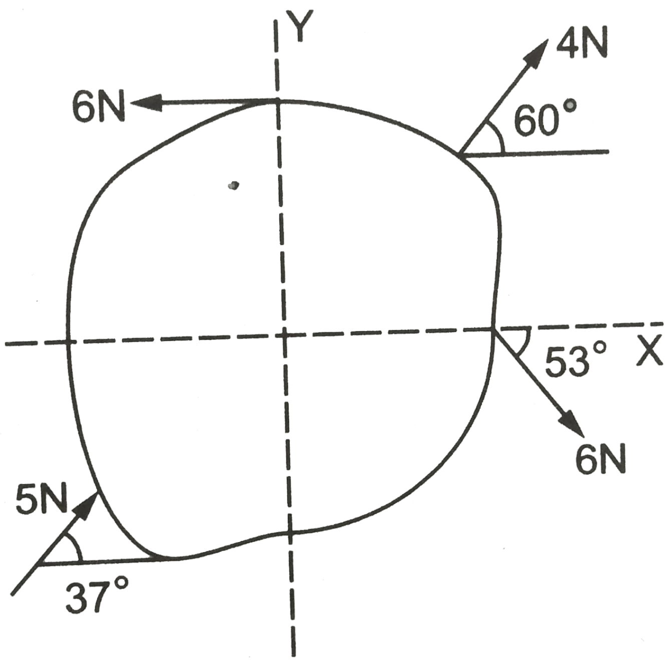
5. A body of mass 2.5 kg is subjected to the forces shown in figure. Find the acceleration of the centre of maas.



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6. Two block of equal mass m are connected by an unstretched spring and the sytem is kept at rest on a frictionless horizontal surface. A constant force F is applied on one of the blocks puling it away from the other as shown in figure. a.Find the positon of the centre of mass at time t. b.If the extansion of the spring is x_0 at time t find the displacement of the two blocks at this instant.

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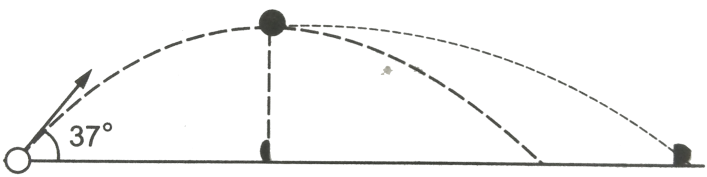
7. A projectile is fired at a spedd of 100 m/s at an angel of 37^0 above the horizontal. At the highest point, the projectile breaks into two parts of mass ratio 1:3 the smaller coming to rest. Findthe distance from the launching point to the where the heavier piece lands.



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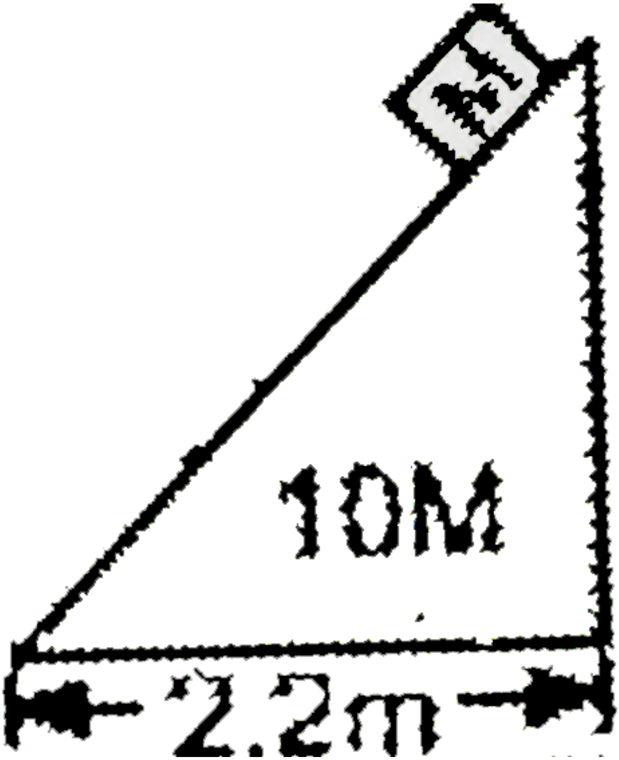
8. A block of mass M is placed on the top of a bigger block of mass 10 M as shown in figure. All the surfaces are frictionless. The system is released from rest, then the distance moved by the bigger block at the instant the smaller block reaches the ground :



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9. The hero of a stunt film fires 50 g bullets from a machine gun, each at a speed of 1.0

km/s. If he fires 20 bullets in 4 seconds. What average force does he exert against the machine gun during this period?

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10. A block moving horizontally on a smooth surface with a speed of 20 m/s bursts into two equal parts continuing in the same direction. If one of the parts moves at 30 m/s, with what speed does the second part move and what is the fractional change in the kinetic energy?

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11. A car of mass M is moving with a uniform velocity v on a horizontal road when the hero of a Hindi film drops himself on it from above. Taking the mass of the hero to be m what will be the velocity of the car after the event?

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12. A space shuttle while travelling at a speed of 4000 km/h with respect to the earth disconnects and ejects a module backward, weighing one sixth of the residual part. If the shuttle ejects the disconnected module at a speed of 100 km/h with respect to the state of the shuttle before the ejection, find the final velocity of the shuttle.

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13. A boy of mass 25 kg stands on a board of mass 10 kg which in turn is kept on a frictionless horizontal ice surface. The boy makes a jump with a velocity component 5m/s in a horizontal direction with respect to the ice. With what velocity does the board recoil? With what rate are the boy and the board seperate from each other?

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14. A man of mass m is standing on a platform of mass M kept on smooth ice. If the man starts moving on the platform with a speed v relative to the platform with what velocity relative to the ice does the platform recoil?

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15. A ball of mass m moving with a velocity v along X-axis, strikes another ball of mass 2m kept at rest. The first ball comes to rest after collision and the other breaks into two equal pieces. One of the pieces starts moving along Y-axis with a speed v_1. what will be the velocity of the other piece?

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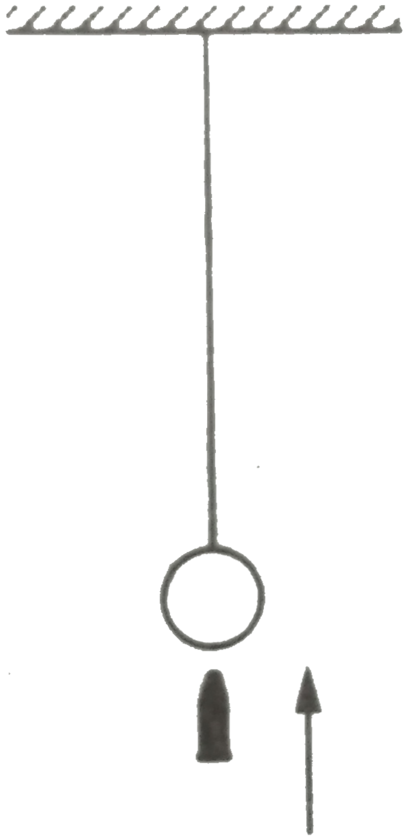
16. A bullet of mass 50g if fired from below into the bob of mass 450g of a long simple pendulum as shown in Fig. The bullet remains inside the bob and the bob rises through a height of 1.8m. Find the speed of the bullet.Take $g = 10\frac{m}{s^2}$



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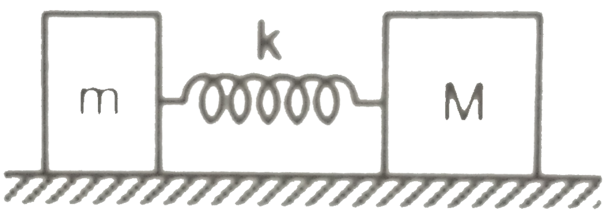
17. A light spring of spring constant k is kept compressed between two blocks of masses m and M on a smooth horizontal surface. When released, the blocks acquire velocities in opposite directions. The spring loses contact with the blocks when it acquires natural length. If the spring was initially compressed through a distance d find the final speeds of the two blocks.



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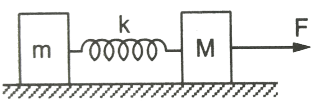
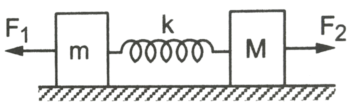
18. A block of mass m is connect to another block of mass M by a massless spring of spring constant k. The blocks are kept on a smooth horizontal plane. Initially the blocks are at rest and the spring is unsrtretched when a constnt force F starts acting on the block of mass M to pull it. Find the maximum extension of the spring.





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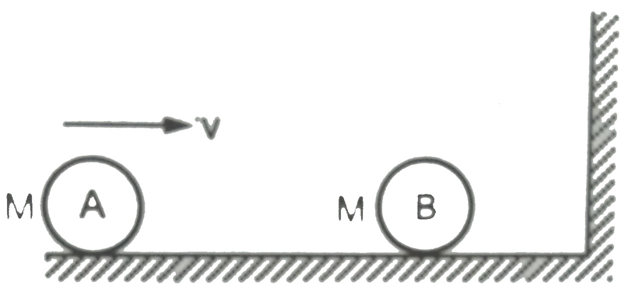
19. The two balls shown in figure are identical the first moving at a speed v towards right and the second staying at rest. The wall at the extreme right is fixed. Assume all collisions to be elastic. Show that the speeds of the balls remain unchanged after all the collisions have taken place.



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20. A block of mass m moving at a velocity v collides head on with another block of mass 2m at rest. If the coefficient of restitution is 1/2, find the velocities of the blocks after the collision.

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21. A block of mass 1.2 kg moving at a speed of 20 cm /s collides head on with a similar block kept at rest. The coefficient of restitution is 3/5. Find the loss of kinetic energy during the collision.

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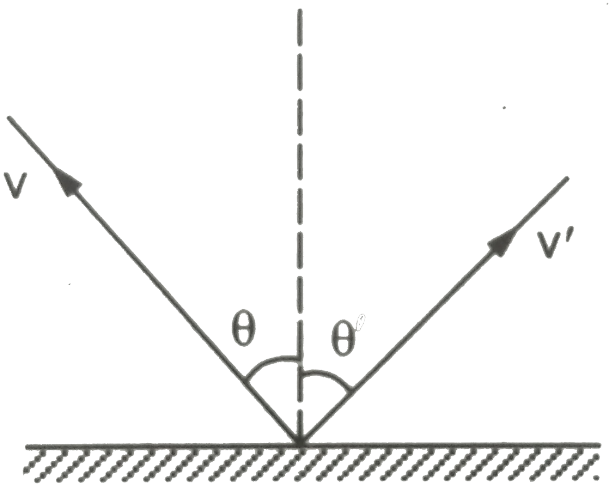
22. A ball of a mass m hits the floor with as speed v making an angle of incidence θ with the normal. The coefficient of restitution is e.

Find the speed of the reflected ball and the angle of reflection of the ball.



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23. A block of mass m and a pan of equal mass are connected by a string going over a smooth light pulley as shown in figure. Initially the system is at rest when a particle of mass m falls on the pan and sticks to it. If the particle strikes the pan with a speed v find the speed with which the system moves just after the collision.

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Objective 1

1. Consider the following two equations

$$(A).\ \vec{R} = \frac{1}{M}\sum_i m_i \vec{r}_i$$

$$\text{and } (B).\ \vec{a}_{CM} = \frac{\vec{F}}{M}$$

IN a noninertial frame

A. both the correct

B. both are wrong

C. A is correct but B is wrong

D. B is correct but A is wrong

Answer: C

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2. Consider the following two statements:

A. Kinear momentum of the system remains constant.

B. Centre of mass of the system remains at rest

A. A implies B and B implies A

B. A does not imply B and B does not imply A.

C. A implies B but B does not imply A.

D. B implies A but A does not imply B.

Answer: D

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3. Consider the following two statements:

A. Linear momentum of a system of particles is zero.

B. Kinetic energy of a system of particles is zero.

A. A implies B and B implies A.

B. A does not imply B and B does not imply A.

C. A implies B but B does not imply A.

D. B implies A but A does not imply B.

Answer: D

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4. Consider the following two statements:

A The linear momentum of a particle is independent of the frame of reference.

B. The kinetic energy of a particle is independent of the frame of reference

A. both A and B are true

B. A is true but B is false

C. Ais false but B is true

D. both A and B are false

Answer: D

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5. All the particles of a body are situated at a distance R from the origin. The distance of the centre of mass of the body from the origin is

A. $= R$

B. $\leq R$

C. $> R$

D. $\geq R$

Answer: B

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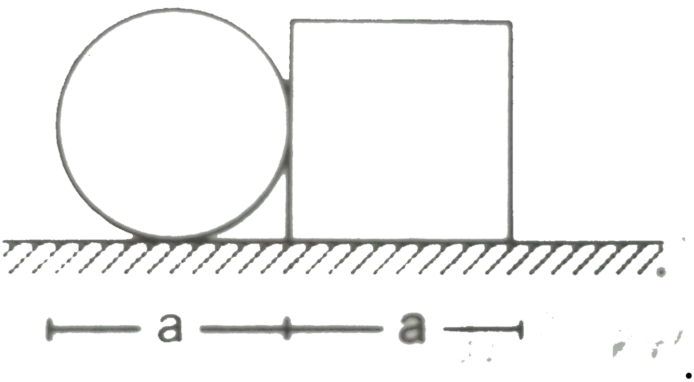
6. A circular plate of diameter d is kept in contact with a square plate of edge d as shown in figure. The densit of the material and the thickness are same



Everywhere. The centre of mass of the composite system will be

A. inside the circular plate

B. inside the squre platee

C. at the point of contact

D. outside the system

Answer: B

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7. Consider a system of two identical particles. One of the particles is at rest and the other has an acceleration. The centre of mass has an acceleration.

A. zero

B. $\frac{1}{2}\overrightarrow{a}$

C. $\overrightarrow{a}$

D. $2\overrightarrow{a}$

Answer: B

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8. Internal forces can change

A. the linear momentum but not the kinetic energy

B. the kinetic energy but not the liear momentum

C. linear momentum as well as kinetic energy

D. neigher the linear momentum nor the kinetic energy.

Answer: B

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9. A bullet hits a lock kept at rest on a smooth horizontal surface and gets embedded into it. Which of the following does not change?

A. a linear momentum of the block

B. kinetic energy of the block

C. gravitational potential energy of the block

D. temperature of the block

Answer: C

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10. A uniform sphere is place on a smooth horizontal surface and as horizontal force F is appied on it at a distance h above the surface. The acceleratioin of the centre

A. is maximum when h=0

B. is maximum when h=R

C. is maximum when h=2R

D. is independent of h

Answer: D

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11. A body falling vertically downwards under gravity breaks in two parts of unequal masses. The centre of mass of the two parts taken together shifts horizontally towards

A. heavier piece

B. lighter piece

C. does not shift horizontally

D. depends on the verical velocity at the tiem of breaking

Answer: C

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12. A ball kept in a close box moves in the box making collisions with the walls. The box is kept on a smooth surface. The velocity of the centre of mass

A. of the box remains constant

B. of the box plus the ball sytem remains constant

C. of the ball remains constant

D. of the ball relative to the box remains constant.

Answer: B

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13. A body at rest breaks into two pieces of equal masses. The parts will move

A. in same direction

B. along different lines

C. in opposite directions with equal speeds

D. in opposite directions with unequal speeds.

Answer: C

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14. A heavy ring fo mass m is clamped on the periphery of a light circular disc.A small particle having equal mass is clamped at the centre of the disc. The system is rotated in such a way that the centre of mass moves in a circle of radius r with a uniform speed v. We conclude that an external force :

A. $\frac{mv^2}{r}$ must be acting on the central particle

B. $\frac{2mv^2}{r}$ must be acting on the central particle

C. $\frac{2mv^2}{r}$ must be acting on the system

D. $\frac{2mv^2}{r}$ must be acting on the ring

Answer: C

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15. The quantities remaining constant in colision are

A. momentum, kinetic energy and temperature

B. momentum and kinetic energy but not temperature

C. momentum and temperature but not kinetic energy

D. momentum but neither kinetic energy nor temperature

Answer: D

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16. A shell is fired from a cannon with a velocity V at an angle θ with the horizontal direction. A the highest point i its path, it explodes into two pieces of equal masses. One of the pieces retraces its path to the cannon. The speed of the other piece immediately after the explosion is

A. $3V\cos\theta$

B. $2V\cos\theta$

C. $\frac{3}{2}V\cos\theta$

D. $V \cos \theta$

Answer: A

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17. In an elastic collision

A. the initial kinetic energy is equal to the final kinetic energy

B. thefinal kinetic energy is les than the initial kinetic energy

C. the kinetic energy remains constnt

D. the kinetic energy first increases then decreases

Answer: A

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18. In an inelastic collision

A. the initia kinetic energy is equal to the finl kineitc energy

B. the final kinetic energy is less than the initial kineitc energy

C. the kinetic energy remains the constant

D. the kinetic energy first increases then decreases

Answer: A

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Exercises

1. Three particles of masses 1.0 kg 2.0 kg and 3.0 kg are placed at the corners A,B and C respectively of an equilateral triangle ABC of edge 1m. Locate the centre of mass of the system.

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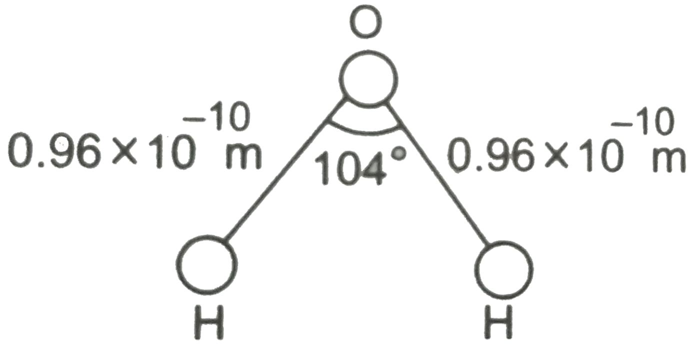
2. The structure of a water molecule is shown in figure. Find the distance of the distance of the centre of mass of the molecule from the centre of the oxygen atom.



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3. Seven homogeneous bricks, each of length L are arranged as shown in figure. Each brick is displaced with respect to the one in contact by $\frac{L}{10}$. Find the x-coordinate of the centre of mass relative to the origin shown.

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4. A uniform disc of radius R is put over another unifrom disc of radius 2R of the same thickness and density. The peripheries of the two discs touch each other. Locate the centre of mass of the system.

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5. A disc of radis R is cut out from a larger disc of radius 2R in such a way that the edge of the hole touches the edge of the disc. Locate the centre of mass of the residual disc.

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6. A square plate of edge d and a circular disc of diameter d are placed toucing ech other at the midpoint of san edge of th plate as shown in figure. Locate the centre of mass of the combination assuming same mass per unit area for the two plates.

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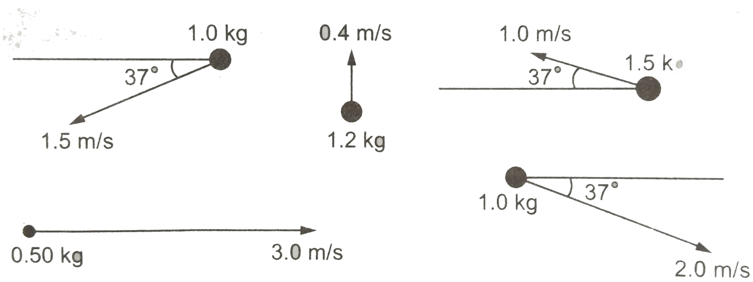
7. Calculate the velocity of the centre of mss of the system of particles shown in figure.



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8. Two bocks of masses 10 g and 20 kg are plced on the X-axis. The first mass is moved on the axis by a distance of 2 cm. By what distance should the second mass be moved to keep the position of the centre of mass unchanged?

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9. Two blocks of msses 10 kg and 30 kg are placed along a vertical line. The first block is raised through a height of 7 cm. By what distance should the second mass be moved to raise the centre of mass by 1 cm?

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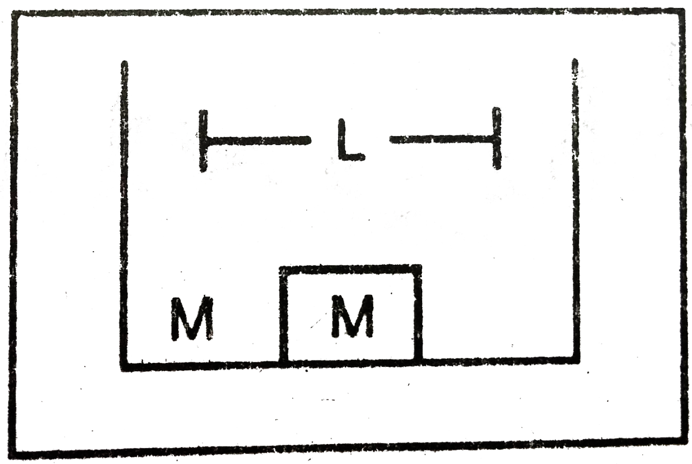
10. Consider a gravity free hall in which a tray of mas M, carrying a cubical block of ice of mass m and edge L, is at rest in the middle.. If the ice melts, by what distance does the centre of mass of the tray plus the ice system descend?



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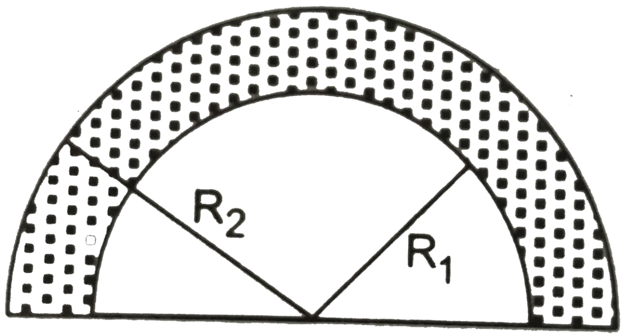
11. Find the centre of mass of a uniform plate having semicircular inner and outer boundaries of radii R_1 and R_2.



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12. Mr. Verma (50kg) and Mr. Mathur (60kg) are sitting at the two extremes of a 4 m long boat (40 kg) standing still in water. To discuss a mechanics problem, they come to the middle of the boat. Neglecting frictioin with water

how far does the boat move on the water during the process?

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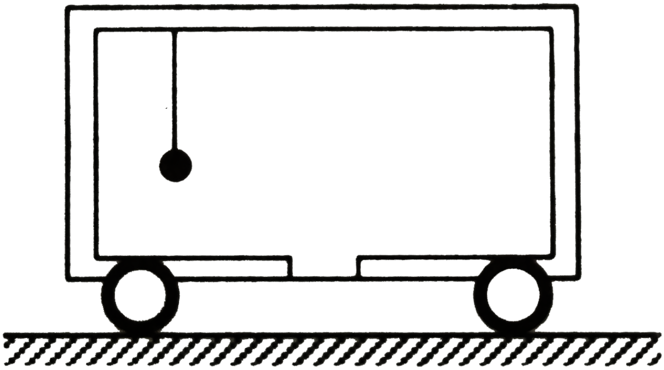
13. A cart of mas M is at rest on a frictionless horizontal surface and a pendulum bob of mass m hangs from the roof of the cart figure. The string breaks, the bob falls on the floor, makes several collision on the floor and finally lands up in a small slot made in the floor. The horizontal distance between the string and the slot is L. Find the displacement of the cart during this process



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14. The ballon the light rope and the monkey shown in figure are at rest in the air. If the monkey reaches the top of the rope, by what distnce does the ballon descend? Mass of the ballon =M mass of the monkey =m and the length of the rope ascended by the monkey =L

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15. Find the ratio of the linear momenta of two particles of masses 1.0 kg and 4.0 kg if their kinetic energies are equal.

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16. A uranium 238 nucleus, initially at rest emits n alpha particle with a speed of $1.4 \times 10^7 \frac{m}{s}$. Calculate the recoil speed of the residual nucleus thorium 234. Assume that the mass of a nucleus is proportional to the mass number.

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17. A man of mass 50 kg starts moving on the earth and acquires speed of 1.8 m/s. with what speed does the earth recoil? Mass of earth = $6 \times 10^{24} kg.$

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18. A neutron initially at rest, decays into a proton, an electron and an antineutrino. The ejected electron has a momentum of 1.4×10^{-26} kg-m/s and that of antineutrino 6.4×10^{-27} kg-m/s. Find the recoil speed of the proton a. if the electron and the antineutrino are ejected along the same direction and b. if they are ejected along perpendicular directions. Mass of the proton 1.67×10^{-27}kg.

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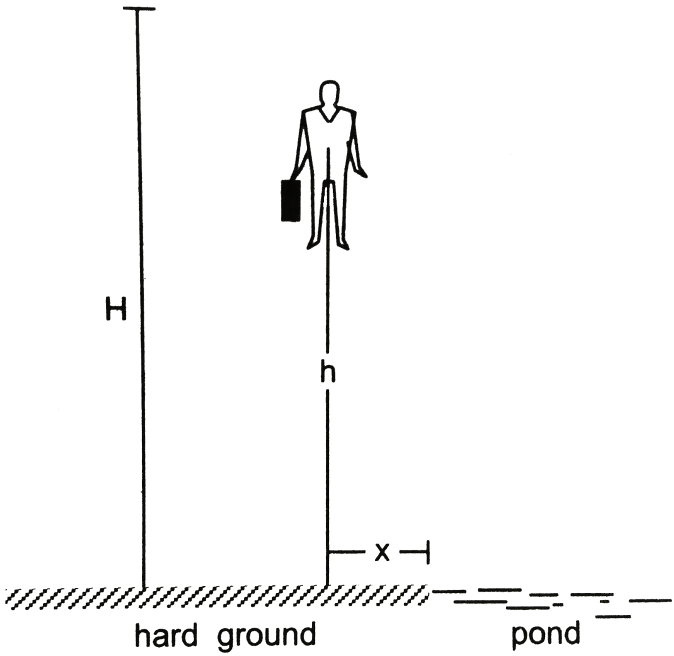
19. A man of mass m having a bag ofmas m slips from the roof of atall building of height H and starts falling vertically figure. When at a height h from the ground, he notices that the ground below him is pretty hard but there is a pond at a horizontal distnce x from the line of fall. In order to save himself he throws the bag horizontally (with respect to himself) in the direction opposite to the pond. Calculate the minimum horizontal velocity imparted to the bag so that the man lands in the water. If the man just suceeds toavoid the hard ground, where will the bag land?



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20. A ball of mass 50 g moving at a speed of 2.0 m/s strikes a plane surface at an angle of incidence 45^0. The ball is reflected by the plane at equal angle of reflection with the same speed. Calculate a. the magnitude of the change in momentum of the ball b. the change in the magnitude of the momentum of the wall.

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21. Light in certain cases may be considered as a stream of paerticles called photons. Each photon has a linear momentum $\frac{h}{\lambda}$ where h is the Planck's constant and λ is the wavelength

λ is incident on a plane mirror at an angle of incidene θ. Calculate the change in the linear momentum of a photon as the beam is reflected by the mirror.

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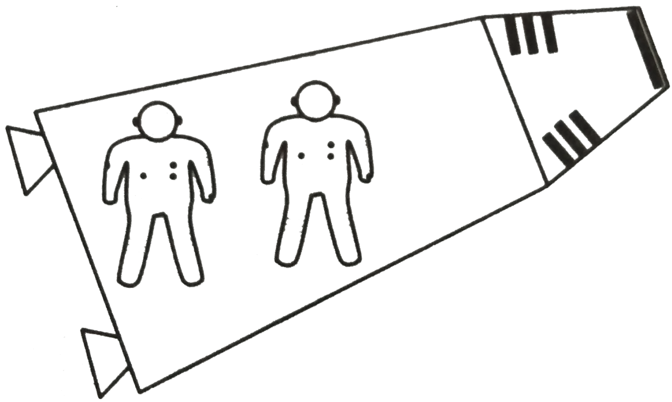
22. A block at rest explodes into three equal parts. Two parts start moving along X and Y axes respectively with equal speeds of 10 m/s.

Find the initial velocity of the third part.



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23. Two fat astronauts each of mass 120 kg are travelling in a closed spaceship moving at a speed of 15 km/s in the outer space far removed from tall other material objects. The

total mass of the spaceship and its contents including the astronauts is 660 kg. If the astronauts do slimming exercise and thereby reduce their masses to 90 kg each, with what velocity will spaceship move?

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24. During a heavy rain hailstones of average size 1.0 cm in diameter fall with an average speed of 20 m/s. Suppose 2000 hailstones strike every square meter of a $10m \times 10m$

roof perpendicularly in one second and assume that the hailstones do not rebound. Calculate the average force exerted by the falling hailstones on the roof. Density of a hailstone is $900k\frac{g}{m^3}$

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25. A ball of mass m is dropped onto a floor from a certain height. The collision is perfectly elastic and the ball rebounds to the same height and again falls. Find the average force exerted by the ball on the floor during a long time interval.

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26. A rail road car of mass M is at rest on frictionless rails when a man of mass m starts moving on the car towards the engine. If the car recoils with a speed v backward on the rails, with what velocity is the man aproaching the engine?

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27. A gun is mounted on a railroad car. The mass of the car, the gun, the shells and the operator is 50m where m is the mass of one shell. If the velocity of het shell with respect to the gun (in its state before firing) is 200 m/s, what is the recoil speed of the car after the second shot? Neglect friction.

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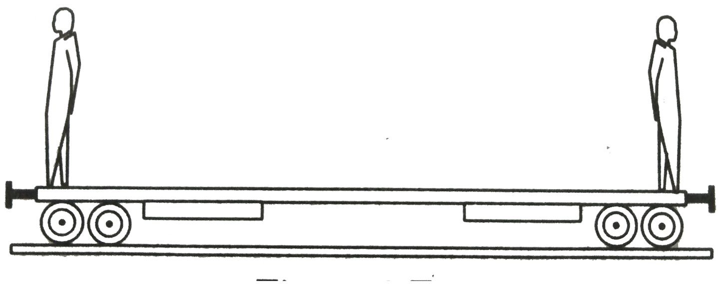
28. Two persns each of mass m are standing at the two extremes of a railroad car of mas M resting on a smooth track figure. The person on left jumps to the left with a horizontal speed u with respect to the state f the cr before the jump. Threafter, the other person jumps to the right, again with the same horizontl speed u with respect to teg state of the car before his jump. Find the vellcity of the car after both the person hae jumped off.



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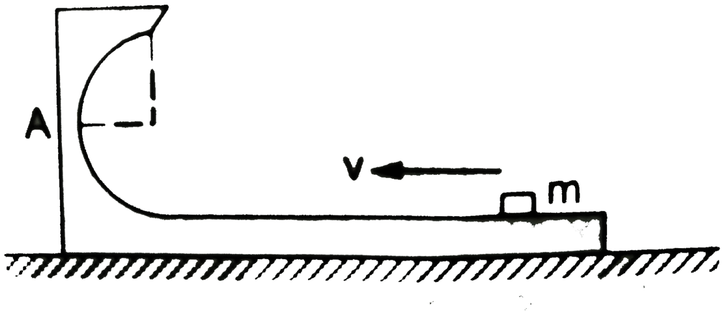
29. Figure shows a small block of mass m which is started with a speed v on the horizontal part of the bigger block of mas m placed on a horizontal floor. The curved part of the surface shown is semicircular. All the surfaces are frictionless. Find the speed of the bigger block when the smaller block reaches the point A of the surface.



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30. IN a typical Indian Bugghi(a luxury cart drawn by horses), a wooden plate is fixed on the rear on which one person can sit. A bugghi of mass 200 kg is moving at a speed of 10 km/h. As it overtakes a school boy walking at a speed of 4 km/h,. the boy sits on the wooden plate. If the mass of the boy is 25 kg, what will be the new velocity of the bugghi?

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31. A ball of mass 0.50 kg moving at a speed of 5.0 m/s collides with another ball of mas 1.0 kg. After the collision the balls stick together ane remain motionless. What was the velocity of the 1.0 kg block before the collision?

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32. A 60 kg man skating with a speed of 10 m/s collides with a 40 kg skater at rest and they cling to each other. Find the loss of kinetic energy during the collision.

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33. consider a head on collision between two particles of masses m_1 and m_2. The initial speeds of the particles are u_1 and u_2 in the same direction. The collision starts at t=0 and the particles interact for a time interval $\triangle t$. during the collision the speed of the first particle varies as

$v(t) = u_1 + t / \ t(v_1 - u_1)$ Find the speed of the second particle as as function of time during the collision.

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34. A bullet of mass m moving at a speed v hits a ball of mass M kept at rest. A small part having mass m ' breaks from the ball and sticks to the bullet. The remaining ball is found to move at a speed v 1 , in the direction of the bullet. Find the velocity of the bullet after the collision.

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35. A ball of mass m moving at a speed v makes a head-on collision with an identical ball at rest. The kinetic energy of the balls after the collision is three fourths of the original. Find the coefficient of restitution.

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36. A block of mass 2.0 kg moving at 2.0 m/s collides head on with another block of equal mass kept at rest. a. Find the maximum possible loss in kinetic energy due to the collision. b.If the actual loss in kinetic energy is half of this maximum, find the coefficient of restitution.

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37. A particle of mass 100 g moving at an initial speed u collides with another particle of same mass kept initially at rest. If the total kinetic energy becomes 0.2 J after the collision what could be minimum and the maximum value of u.

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38. Two friends A and B (each weighing $40kg$) are sitting on a frictionless platform some distance d apart. A rolls a ball of mass $4kg$ on the platform towards B which B catches. Then B rolls the ball towards A and A catches it. The ball keeps on moving back and forth between A and B. The ball has a fixed speed of $5m / s$ on the platform.

a. Find the speed of A after he rolls the ball for the first time.

b. Find the speed of A after he catches the ball for the first time.

c. Find the speed of A and B after the ball has made five round trips and is held by A.

d. How many times can A roll the ball?

e. Where is the centre of mass of the system $A + B +$ ball at. the end of the nth trip?

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39. A ball falls on the ground fro a height of 2.0 m and rebounds up to a height of 1.5 m. Find the coefficient of restitution.

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40. In a gamma decay process, the internal energy of a nucleus of mass M decreases, a gamma photon of energy E and linear momentum E/c is emitted and the nucleus recoils. Find the decrease in internal energy.

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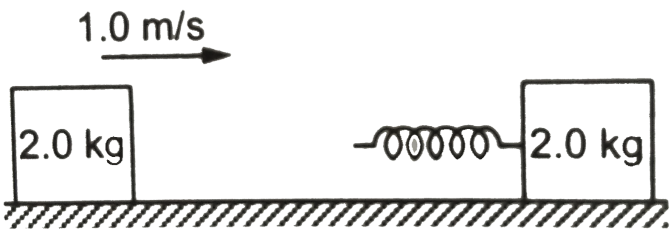
41. A block of mass 2.0 kg is moving on a frictionless horizontal surface with a velocity of 1.0 m/s figure towards another block of equal mass kept at rest. The spring constant of the spring fixed at one end is 100 N/m. Find the maximum compression of the spring.



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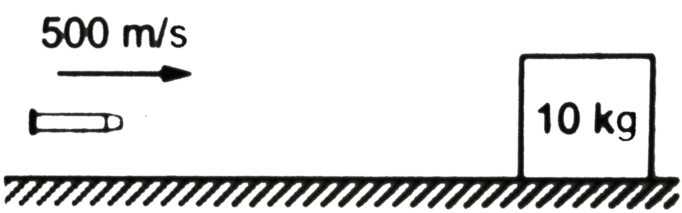
42. A bullet of mass 20 g travelling horizontally with a speed of 500 m/s passes through a wooden block of mass 10.0 kg initially at rest on a level surface. The bulet emerges with speed of 100 m/s and the block slides 20 cm on the surface before coming to rest. Find the friction cioefficient between the block and the surface figure.



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43. A projectile is fired with a speed u at an angle θ above a horizontal field. The coefficient of restitution of collision between the projectile and the field is e. How far from the starting point does the projectile makes its second collision with the field?

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44. A ball falls vertically on an inclined plane of inclination α with speed v_0 and makes a perfectly elastic collision. What is angle of velocity vector with horizontal after collision.

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45. Solve tehh previous problem if the coefficient of restitution is e. Use $\theta = 45^0, e = \frac{3}{4} ndh = 5m$

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46. A block of mass $180g$ is suspended by a massless spring. The spring extends by $1.8cm$ due to the weight of block. A particle of mass $20g$ is dropped from a height $80cm$ on the block. The collision is completely inelastic . Find the maximum elongation of the spring.

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47. A bullet of mass 25 g is fired horizontally into a ballistic pendulum of mas 5.0 kg and gets embedded in it figure. If the centre of the pendulum rises by a distance of 10 cm, find the speed of the bullet.

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48. A bullet of mass 20 g moving horizontally at a speed of 300 m/s is fired into a wooden block of mass 500 g suspended by a long string. The bullet crosses the block and emerges on the other side. If the centre of mass of the block rises through a height of

20.0 cm, find the speed of the bullet as it emerges from the block.

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49. Two masses m_1 and m_2 re connected by a spring of spring constant k and are placed on as frictionless horizontal surface. Initially the spring is stretched through a distance x_0 when the system is released from rest. Find the distance moved by the two masses before they again come to rest.

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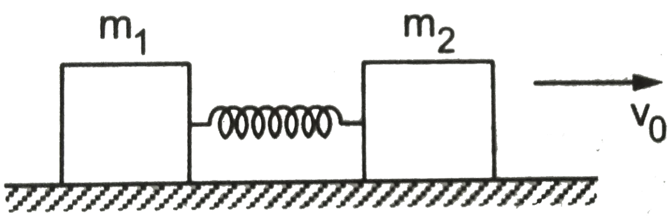
50. Two blocks of masses m_1 and m_2 are connected by a spring of spring constant k figure. The block of mass m_2 is given a shape impulse so that it acquires a velocity v_0 towards right. Find a. the velocity of the centre of mass b. the maximum elongation that the spring will suffer.



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51. Cionsider the situation of the previous problem. Suppose each of tbe blocks is pulled by a constant foerce F instead of any impulse. Find the maximum elongation that the spring will suffer and the distancews moved by the two blocks in the process.

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52. consider the situastion of the previous problem. Suppose the block of mass m_1 is pulled by a constant force F_1 and the other block is pulled by a constant force F_2. Find the maximum elongation that the spring will suffer.

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53. Consider a gravity-free hall in which an experimenter of mass 50 kg is resting on a 5 kg pillow, 8 ft above the flooe of the hall. He pushes the pillow down so that it starts falling at a speed of 8ft/s. The pillow makes a perfectly elastic collision with the floow, rebounds and reaches the experimenter's head. Find the time elaspsed in the process.

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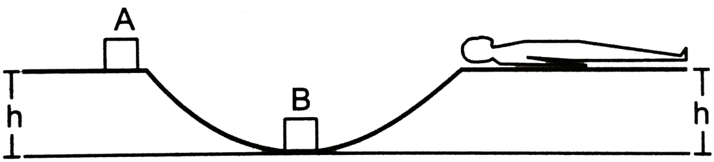
54. The track shown in figure is frictionless. The block B of mass 2 m is lying at rest and the block A of mass m is placed along the track with some speed. The collision between A and B is perfectly elastic. With what velocity should the block A be started to get the sleeping man awakened ?



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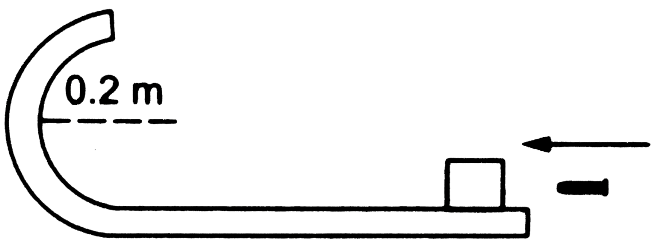
55. A bullet of mass 10g moving horizontally at a speed of 50 7 m/s strikes a block of mass 490g kept on a frictionless track as shown in figure. The bullet. remains inside the block and the system proceeds towards the semicircular track of radius 0.2m. Where will the block strike the horizontal part after leaving the semicircular track?



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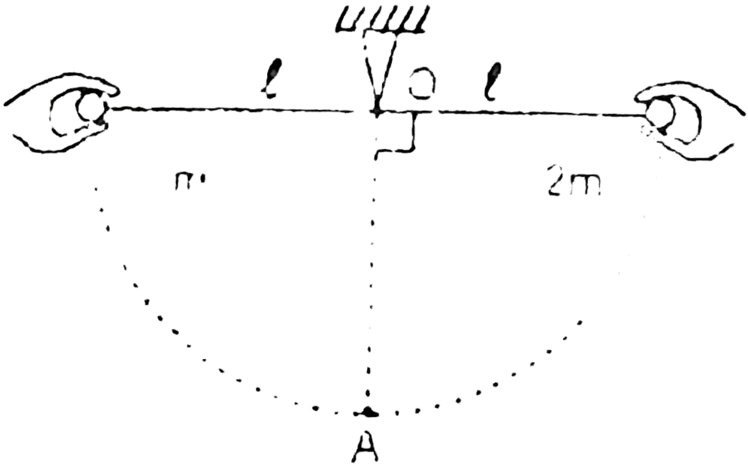
56. Two balls having masses m and 2m are fasrtened to two light strings of same length (figure). The other ends of the strings are fixed at O. The strings are kept in the same horizontal line and the system is released from rest. The collision between the balls is elastic. Point A is the lowest point at which either ball can reach



The speed of ball of mass 2m just after collision (for the first time) is over

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57. A uniform chain of mass M and length L is held verticallyi in such a way that its lower end just touches the horizontal floor. The chain is released from rest in this position. Any portion that strikes the floor comes to rest. Assuming that the chain does not form a heap on the floor, calculate the force exerted by it on the floor when a length x has reached the floor.

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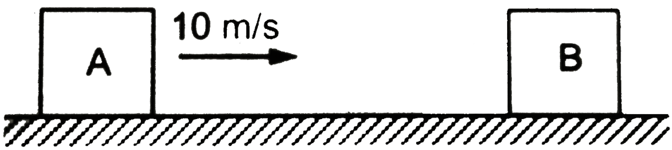
58. The blocks shown in figure have equal masses. The surface of A is smooth but that of B has a friction coefficient of 0.10 with the floor. Block A is moving at a speed of 10 m/s towards B which is kept at rest. Find the distance travelled by B if a. the collision is perfectly elastic and b. the collision is perfectly inelastic. Take $g = 10\frac{m}{s^2}$.



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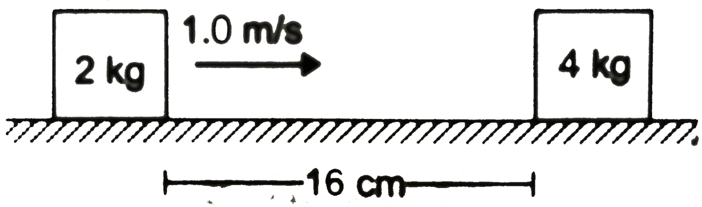
59. The friction coefficient between the horizontal surfce and ech of the blocks shown in figure is 0.20. The collision between the blocks is perfectly elastic. Find the separation between the two blocks when they come to rest. Take $g = 10\frac{m}{s^2}$.



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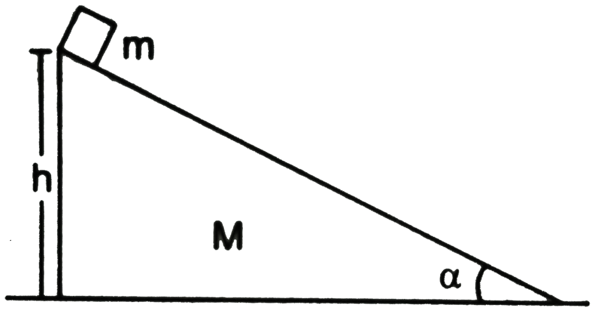
60. A block of mas m is placed on a triangular block of mas m, which in tunis placed on a horizontal surface as shown in figure. Assuming frictionless surfaces find the velocity of the triangular block when the smaller block reaches the bottom end.



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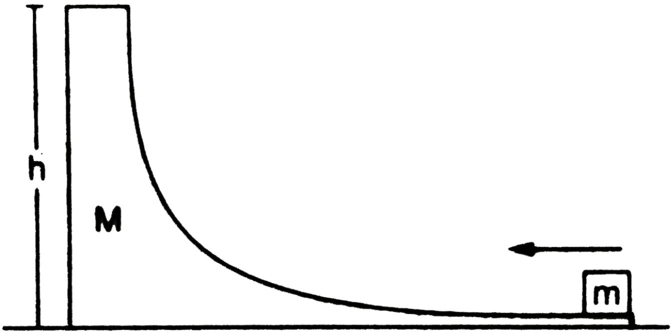
61. Figure shows a small body of mass m placed over a larger mass M whose surface is horizontal near the smaller mass and gradually curves to become verticle. The

smaller mass is pushed on the longer on at a speed v and the system is left to itself. Assume thast all the surfaces are frictionless. a. find teh 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 mas at height h. c. find the maximum height (from the ground) that the smaller mass seconds. d show that the smaller mass will again land on the bigger one. Find the distane traversed by the bigger block during the time when the smaller block was in its flight under gravity.



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62. A small block of superdennse material has a mass of 3×10^{24} kg. It is situated at a height h (much smaller than the earth's radius) from where it falls on the earth's surface. Find its speed when its height from the earth's surface has reduced to $\frac{h}{2}$. The mass of the earth is $6 \times 10^{24} kg$

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63. A body of mass m makes an elastic collision with another identical body at rest. Show that if the collisionis not head on the bodiese to at right to each other after the collision.

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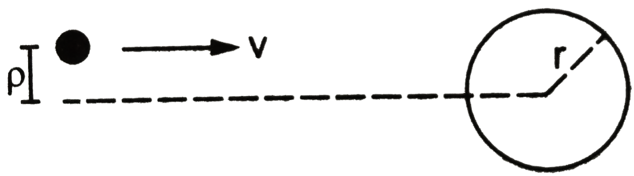
64. A small particle travelling with a velocity v collides elastically with a spbereical body of equal masss and of radius r initially kept at rest. The centre of this spherical body is located a distnce $\rho(<r)$ away from the direction of motion of the particle figure. Find the final velocities of the two particles.



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Question For Short Answer

1. Can the centre of mass of a body be at a point outside the body?

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2. If all the particle of a system lie in X-Y plane is it necessary that the centre of mass be in X-Y plane?

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3. If all the particle of a system lie in a cube is it necessary that the centre of mass be in the cube?

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4. The centre of mass is defined as $\overrightarrow{R}=\frac{1}{M}\sum_{i}m_{i}\overrightarrow{r}_{i}$. Suppose we define centre of charge as $\overrightarrow{R}_{c}=\frac{1}{Q}\sum_{i}q_{I}\overrightarrow{r}_{i} where q_{i}$ represents the ith charge placed at $\overrightarrow{r}_{i}$ and Q is the total charge of the sytem

a. Can a centre of charge of two charge system be outside the line segment joining the charges?

b. If all the charges of a system are in X-Y plane?

c. If all the charges of a system lie in a cube, is it necessary that the centre of charge be in the cube?

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5. The weight Mg of an extended body is generally shown in a diagram to act through the centre of mass. Does it mean that the earth does not attract other particles?

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6. A bob suspended from the ceiling of a car which is accelerating on a horizontal road. The bob stays t rest with respect to the car when the string is making an angle θ with the vertical.The linear momentum of the bob as seen from the road is increasing with momentum? If not, where is the external force which changes the linear momentum?

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7. You are waiting for a train on a railway platform. Your three year old niece is standin on your iron trunk containing the luggage. Why does the trunk not recoil as she jumps off on the platform?

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8. IN a headon collision between two particles, is it necessary that the particles will acquire a common velocity at least for one instant?

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9. A collision experiment is done on a horizontal table kept in an elevator. Do you expect a change in the results if the elevator is accelerated up or down because of the noninertial character of the frame?

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10. Two bodies make an elastic head on colision on a smooth horizontal table kept in a car.Do you expect a change in the result if the car is accelerated on a horizontal road because of the noninertial character of the frame? Does the equation velocityof separation = velocity of approach remain valid in n accelerating car? Does the equation final momentum =initial momentum remain valid in the accelerating car?

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11. If the total mechanical energy of a particle is zero is its linear momentum necessarily zero? Is it necessarily nonzero?

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12. If the linear momentum of a prticle is known can you find its kinetic energy? If the kinetic energy of a particle is known can you find its linear momentum?

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13. What can be said about the centre of mass of a uniform hemisphere without making any calculation? Will its distance from the centre be more than r/2 or less than r/2?

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14. You are holding a cage containing a bird. Do you have to make less effort if the bird flies from its position in the cage and manages to stay in the middle without touching the walls of he cage? Does it make a difference whether the cage is completely closed or it has rods to let air pass?

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15. A fat person is standing on light plank floating on a calm lake. The person walks from one end to the other on the plank. His friend sitting on the shore watches him and finds that the person hardly moves any distance because the plank moves basckward about the same distance as the person moves on the plank. Explain.

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16. A high jumper successfully clears the bar. Is it possible that his centre of mass crossed the bar from below it? Try it with appropriate figures.

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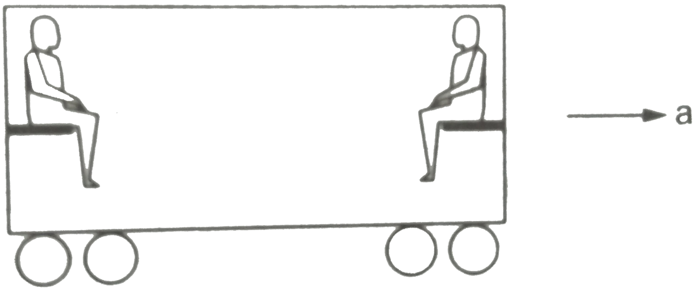
17. Which of the two persons show in figure is more likely to fall down? Which external force is responsible for his falling down?



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18. Suppose we define a quantity Linear Momentum as linear momentum =mass x speed.

The linear momentum of a system of particles is the sum of linear momentum of the individual particles. Can we state a principle of conservation of linear momentum as linear momentum of a system remains constant if no external force acts on it?

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19. Use the definition of linear pometum form the previous qestion. Can we state the principle of conservation of linear pomentum for a single particle?

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20. To accelerate a car we ignite petrol in the engine of the car. Since only an external force can accelerate the centre of mass, is it proper to sasy that the fore generated by the engine accelerates the car?

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21. A ball is moved on a horizontal table with some velocity. The ball stops after moving some distance. Which external force is responsible for the change in the momentum of the ball?

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22. Consider the situation of the previous problem. Take the table and the ball as a system friction is then an internal force. As the ball slows down the momentum of the system decreases. Which external force is responsible for this change in the momentum?

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23. When a nucleus at rest emits a beta particle, it is found that the velocities of the recoiling nucleus and th beta particle ae not along the same straight line. How can this be possible in view of the principle of conservation of momemtum?

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24. A van is standing on a frictionless portion of a horizontal road. To start the engine, the vehicle must be set in motion in theforward direction. How can the persons sitting inside the van do it without coming out and pushing from behind?

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25. In one dimensional elastic collision of equal masses, the velocities are interchanged. Can velocities in one dimensional collision be interchanged if the masses are not equal?

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Objective 2

1. The centre of mass of a system of particles is at the origin. It follows that:

A. the number of particle to the righ of the the origin is equal to the number of particles to the left

B. the total mass of the particles to the right of the origin is same as the total mass to the left of theorigin

C. the number of particles on X-axis should be equal to the number of particles on Y-axis

D. if there is a particle on the positive X-axis, there must be at least one particle on the negative X-axis.

Answer:

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2. A body has its centre of maas at the origin. The x-coordinates of the particles

A. may be all positive

B. may be all negative

C. may be all non negative

D. may be positive for some case and negative in other cases.

Answer: C::D

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3. In which of the following cases the centre of mass of a rod is certainly not at its centre?

A. the density continuously increases from left to right

B. the density continuously decreases from left to right

C. the density decreases from let to right upto the centre and then increases

D. the density increases from left to right upto the centre and then decreases.

Answer: A::B

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4. If the external forces acting on a system have zero resultant, the centre of mass

A. must not move

B. must not accelerate

C. may move

D. may accelerate

Answer: B::C

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5. A nonzero external force on a system of particles. The velocity and the acceleration of the cente of mass are found to be v_0 and a_0 at an instant t. It is possible that

A. $v_0 = 0, a_0 = 0$

B. $v_0 = 0, a_0 \neq 0$

C. $v_0 \neq 0, a_0 = 0$

D. $v_0 \neq 0, a_0 \neq 0$

Answer: B::D

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6. Two balls are thrown simultaneously in air. The acceleration of the centre of mass of the two balls while in air

A. depends on the direction of the motion of the balls

B. depends on the masses of the two balls

C. depends on the speeds of the two balls

D. is equla to g

Answer: D

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7. A block moving in air breaks in two parts and the parts separate

A. the total momentum must be conserved

B. the total kinetic energy must be conserved

C. the total momentum must charge

D. the total kinetic energy must charge

Answer: A::D

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8. In an elastic collision

A. the kinetic energy remains constant

B. the linear momentum remains constant

C. the final kinetic energy is equal to the initial kinetic energy

D. the final linear momentum is equal to the initial linear momentum

Answer: B::C::D

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9. A ball hits a floor and rebounds after an inelastic collision. In this case

A. the momentum of the ball just after the collision is same as that just before the collision

B. the mechanical energy of the ball remains the same during the collision

C. the total momentum of the ball and the earth is conserved

D. the total energy of theball and the earth remains the same

Answer: C::D

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10. A body moving towards a finite body at rest collides with it. It is possible that

A. both the bodies come to rest

B. both the bodies move after collision

C. the moving body comes to rest and the stationary body starts moving

D. the stationary body remains stationary, the moving body changes its velocity

Answer: B::C

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11. In a head on elastic collision of two bodies of equal masses

A. the velocities are interchanged

B. the speeds are interchanged

C. the momenta are interchanged

D. the faster body shows down and the slower body speeds up

Answer: A::B::C::D

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