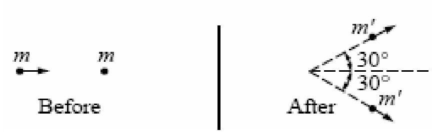
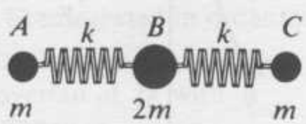
Problem 1:
A particle with rest mass *m* and momentum *mc*/2 collides with a particle of the same rest mass that is initially at rest. After the collision, the original two particles have disappeared. Two other particles, each with rest mass *m′*, are observed to leave the region of the collision at equal angles of 30° with respect to the direction of the original moving particle, as shown below.



What is the speed of the original moving particle?
(A) *c*/5
(B) *c*/3
(C) $c/(7^{1/2})$
(D) $c/(5^{1/2})$
(E) *c*/2

Problem 2:
What is the momentum of each of the two particles produced by the collision?
(A) *mc*/5
(B) $mc/(2(3^{1/2}))$
(C) $mc/(5^{1/2})$
(D) *mc*/2
(E) $mc/(3^{1/2})$

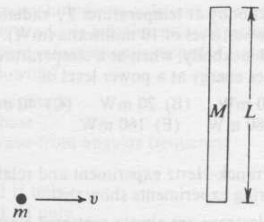
Problem 3:



Three masses are connected by two springs as shown above. A longitudinal normal mode with frequency $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ is exhibited by

(A) *A*, *B*, *C* all moving in the same direction with equal amplitude
(B) *A* and *C* moving in opposite directions with equal amplitude, and *B* at rest
(C) *A* and *C* moving in the same direction with equal amplitude, and *B* moving in the opposite direction with the same amplitude
(D) *A* and *C* moving in the same direction with equal amplitude, and *B* moving in the opposite direction with twice the amplitude
(E) none of the above

Problem 4:



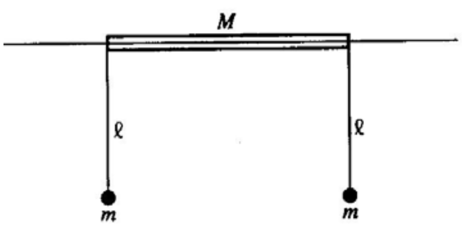
View from Above

A uniform stick of length L and mass M lies on a frictionless horizontal surface. A point particle of mass m approaches the stick with speed v on a straight line perpendicular to the stick that intersects the stick at one end, as shown above. After the collision, which is elastic, the particle is at rest. The speed V of the center of mass of the stick after the collision is

(A) $\frac{m}{M}v$ (B) $\frac{m}{M+m}v$ (C) $\sqrt{\frac{m}{M}}v$

(D) $\sqrt{\frac{m}{M+m}}v$ (E) $\frac{3m}{M}v$

Problem 5:



A cylindrical tube of mass M can slide on a horizontal wire. Two identical pendulums, each of mass m and length ℓ, hang from the ends of the tube, as shown above. For small oscillations of the pendulums in the plane of the paper, the eigenfrequencies of the normal modes of oscillation of this system are 0, $\sqrt{\frac{g(M+2m)}{\ell M}}$, and

(A) $\sqrt{\frac{g}{\ell}}$

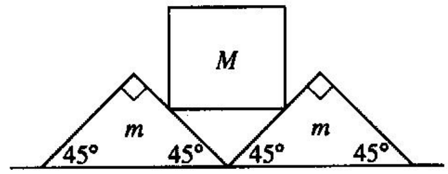
(B) $\sqrt{\frac{g}{\ell}\frac{M+m}{M}}$

(C) $\sqrt{\frac{g}{\ell}\frac{m}{M}}$

(D) $\sqrt{\frac{g}{\ell}\frac{m}{M+m}}$

(E) $\sqrt{\frac{g}{\ell}\frac{m}{M+2m}}$

Problem 6:



Two wedges, each of mass m, are placed next to each other on a flat floor. A cube of mass M is balanced on the wedges as shown above. Assume no friction between the cube and the wedges, but a coefficient of static friction $\mu < 1$ between the wedges and the floor. What is the largest M that can be balanced as shown without motion of the wedges?

(A) $\frac{m}{\sqrt{2}}$

(B) $\frac{\mu m}{\sqrt{2}}$

(C) $\frac{\mu m}{1-\mu}$

(D) $\frac{2\mu m}{1-\mu}$

(E) All M will balance.

Problem 7:

A rigid cylinder rolls at constant speed without slipping on top of a horizontal plane surface. The acceleration of a point on the circumference of the cylinder at the moment when the point touches the plane is

(A) directed forward
(B) directed backward
(C) directed up
(D) directed down
(E) zero

Problem 8:

A particle of mass m on the Earth's surface is confined to move on the parabolic curve $y = ax^2$, where y is up. Which of the following is a Lagrangian for the particle?

(A) $L = \frac{1}{2}m\dot{y}^2\left(1 + \frac{1}{4ay}\right) - mgy$

(B) $L = \frac{1}{2}m\dot{y}^2\left(1 - \frac{1}{4ay}\right) - mgy$

(C) $L = \frac{1}{2}m\dot{x}^2\left(1 + \frac{1}{4ax}\right) - mgx$

(D) $L = \frac{1}{2}m\dot{x}^2(1 + 4a^2x^2) + mgx$

(E) $L = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}m\dot{y}^2 + mgy$

Problem 9:

A ball is dropped from a height h. As it bounces off the floor, its speed is 80 percent of what it was just before it hit the floor. The ball will then rise to a height of most nearly

(A) 0.94 h
(B) 0.80 h
(C) 0.75 h
(D) 0.64 h
(E) 0.50 h

Problem 10:

A particle of mass M moves in a circular orbit of radius r around a fixed point under the influence of an attractive force $F = \frac{K}{r^3}$, where K is a constant. If the potential energy of the particle is zero at an infinite distance from the force center, the total energy of the particle in the circular orbit is

(A) $-\frac{K}{r^2}$

(B) $-\frac{K}{2r^2}$

(C) 0

(D) $\frac{K}{2r^2}$

(E) $\frac{K}{r^2}$