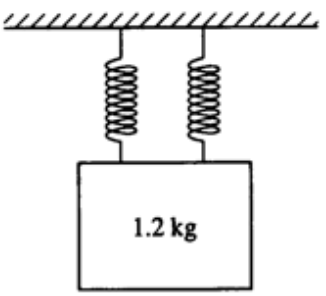
17. A rock is lifted for a certain time by a force F that is greater in magnitude than the rock's weight W. The change in kinetic energy of the rock during this time is equal to the
(A) work done by the net force (F - W) (B) work done by F alone
(C) work done by W alone (D) difference in the momentum of the rock before and after this time
(E) difference in the potential energy of the rock before and after this time.

10. During a certain time interval, a constant force delivers an average power of 4 watts to an object. If the object has an average speed of 2 meters per second and the force acts in the direction of motion of the object, the magnitude of the force is
(A) 16 N (B) 8 N (C) 6 N (D) 4N (E) 2N



Two identical massless springs are hung from a horizontal support. A block of mass 1.2 kilograms is suspended from the pair of springs, as shown above. When the block is in equilibrium, each spring is stretched an additional 0.15 meter.

23. The force constant of each spring is most nearly
(A) 40 N/m (B) 48 N/m (C) 60 N/m (D) 80 N/m (E) 96 N/m

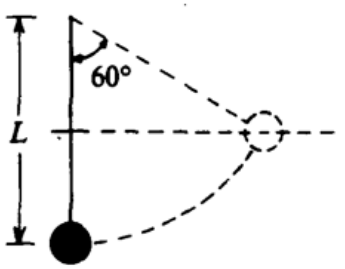
14. A weight lifter lifts a mass m at constant speed to a height h in time t How much work is done by the weight lifter? (A) mg (B) mh (C) mgh (D) mght (E) mgh/t

32. A 10-kilogram body is constrained to move along the x-axis. The potential energy U of the body in joules is given as a function of its position x in meters by

$U(x) = 6x^2 - 4x + 3$

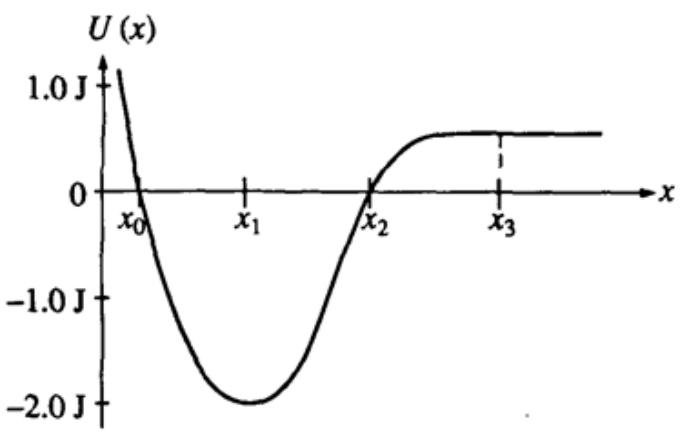
The force on the particle at x = 3 meters is

(A) 32 N in +x direction (B) 32N in -x direction (C) 45 N in +x direction (D) 45 N in -x direction (E) 98 N in +x direction



16. A pendulum consists of a ball of mass m suspended at the end of a massless cord of length L as shown above. The pendulum is drawn aside through an angle of 60. with the vertical and released. At the low point of its swing, the speed of the pendulum ball is

(A) $\sqrt{gL}$ (B) $\sqrt{2gL}$ (C) ½gL (D) gL (E) 2gL



15. A conservative force has the potential energy function U(x), shown by the graph above. A particle moving in one dimension under the influence of this force has kinetic energy 1.0 joule when it is at position x_1 Which of the following is a correct statement about the motion of the particle?

(A) It oscillates with maximum position x_2 and minimum position x_0.
(B) It moves to the right of x_3 and does not return.
(C) It moves to the left of x_0 and does not return.
(D) It comes to rest at either x_0 or x_2.
(E) It cannot reach either x_0 or x_2.

6. A ball is thrown upward. At a height of 10 meters above the ground, the ball has a potential energy of 50 joules (with the potential energy equal to zero at ground level) and is moving upward with a kinetic energy of 50 joules. Air friction is negligible. The maximum height reached by the ball is most nearly
(A) 10 m (B) 20 m (C) 30 m (D) 40 m (E) 50 m

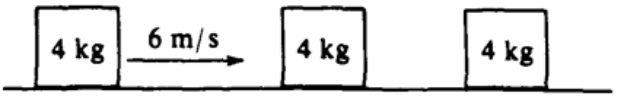
18. When an object is moved from rest at point A to rest at point B in a gravitational field, the net work done by the field depends on the mass of the object and
(A) the positions of A and B only
(B) the path taken between A and B only
(C) both the positions of A and B and the path taken between them
(D) the velocity of the object as it moves between A and B
(E) the nature of the external force moving the object from A to B

9. A piece of wire of uniform cross section is bent in the shape shown above. What are the coordinates $(\bar{x}, \bar{y})$ of the center of mass?
(A) (15/14, 6/7) (B) (6/7, 6/7) (C) (15/14, 8/7) (D) (1,1) (E) (1,6/7)

16. A balloon of mass M is floating motionless in the air. A person of mass less than M is on a rope ladder hanging from the balloon. The person begins to climb the ladder at a uniform speed v relative to the ground. How does the balloon move relative to the ground?
(A) Up with speed v (B) Up with a speed less than v (C) Down with speed v
(D) Down with a speed less than v (E) The balloon does not move.

17. If one knows only the constant resultant force acting on an object and the time during which this force acts, one can determine the
(A) change in momentum of the object (B) change in velocity of the object
(C) change in kinetic energy of the object (D) mass of the object
(E) acceleration of the object

Questions 2 and 3 **CONSERVATION OF MOMENTUM**



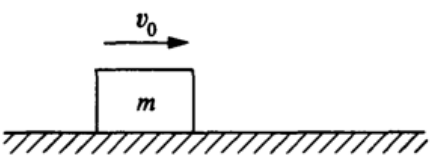
A 4-kilogram mass has a speed of 6 meters per second on a horizontal frictionless surface, as shown above. The mass collides head-on and elastically with an identical 4-kilogram mass initially at rest. The second 4-kilogram mass then collides head-on and sticks to a third 4-kilogram mass initially at rest.

2. The final speed of the first 4-kilogram mass is
(A) 0 m/s (B) 2 m/s (C) 3 m/s (D) 4 m/s (E) 6 m/s

3. The final speed of the two 4-kilogram masses that stick together is
(A) 0 m/s (B) 2 m/s (C) 3 m/s (D) 4 m/s (E) 6 m/s

8. A projectile of mass M_1 is fired horizontally from a spring gun that is initially at rest on a frictionless surface. The combined mass of the gun and projectile is M_2. If the kinetic energy of the projectile after firing is K, the gun will recoil with a kinetic energy equal to

(A) K (B) $\frac{M_2}{M_1}K$ (C) $\frac{M_1^2}{M_2^2}K$ D) $\frac{M_1}{M_2 - M_1}K$ (E) $\sqrt{\frac{M_1}{M_2 - M_1}K}$



21. An object of mass m is moving with speed v_0 to the right on a horizontal frictionless surface, as shown above, when it explodes into two pieces. Subsequently, one piece of mass 2/5 m moves with a speed $v_0/2$ to the left. The speed of the other piece of the object is
(A) $v_o/2$ (B) $v_o/3$ (C) $7v_o/5$ (D) $3v_o/2$ (E) $2v_o$

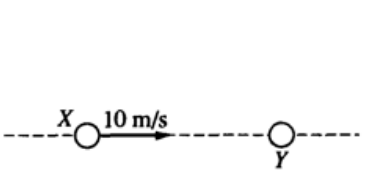


Figure I

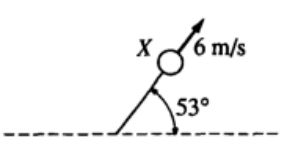
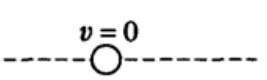


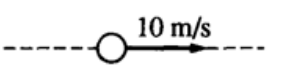
Figure II

11. Two balls are on a frictionless horizontal tabletop. Ball X initially moves at 10 meters per second, as shown in Figure I above. It then collides elastically with identical ball Y. which is initially at rest. After the collision, ball X moves at 6 meters per second along a path at 53^0 to its original direction, as shown in Figure II above. Which of the following diagrams best represents the motion of ball Y after the collision?

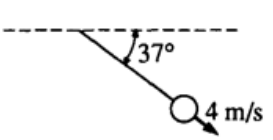
(A)



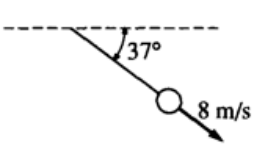
(B)



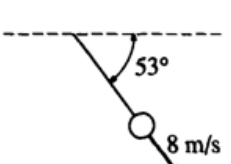
(C)



(D)

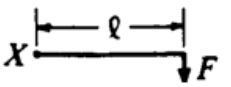


(E)

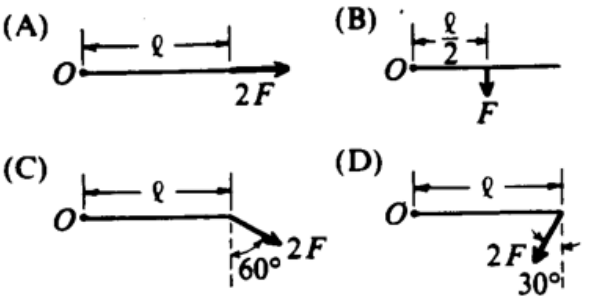


20. A turntable that is initially at rest is set in motion with a constant angular acceleration α. What is the angular velocity of the turntable after it has made one complete revolution?

(A) $\sqrt{2\alpha}$ (B) $\sqrt{2\pi\alpha}$ (C) $\sqrt{4\pi\alpha}$ (D) 2α (E) $4\pi\alpha$

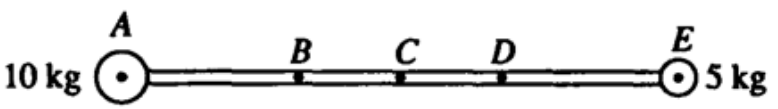


31. In which of the following diagrams is the torque about point O equal in magnitude to the torque about point X in the diagram above? (All forces lie in the plane of the paper.)



(E) None of the above

Questions 29 - 30



A 5-kilogram sphere is connected to a 10-kilogram sphere by a rigid rod of negligible mass, as shown above.

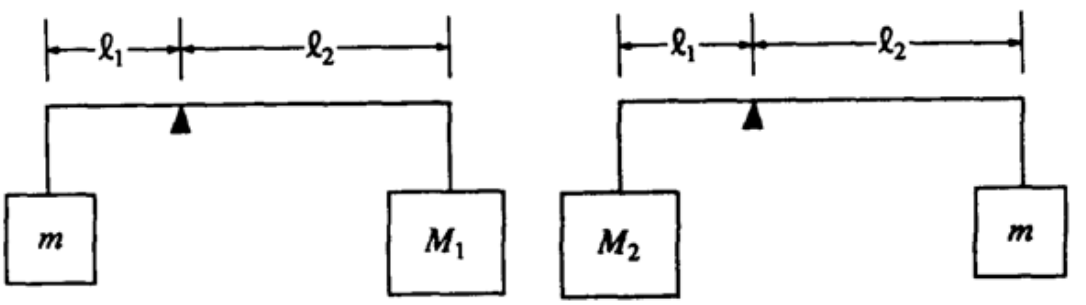
29. Which of the five lettered points represents the center of mass of the sphere-rod combination?
(A) A (B) B (C) C (D) D (E) E

30. The sphere-rod combination can be pivoted about an axis that is perpendicular to the plane of the page and that passes through one of the five lettered points. Through which point should the axis pass for the moment of inertia of the sphere-rod combination about this axis to be greatest?
(A) A (B) B (C) C (D) D (E) E

23 A bowling ball of mass M and radius R. whose moment of inertia about its center is (2/5)MR^2, rolls without slipping along a level surface at speed v. The maximum vertical height to which it can roll if it ascends an incline is (A) $\frac{v^2}{5g}$ (B) $\frac{2v^2}{5g}$ (C) $\frac{v^2}{2g}$ (D) $\frac{7v^2}{10g}$ (E) $\frac{v^2}{g}$

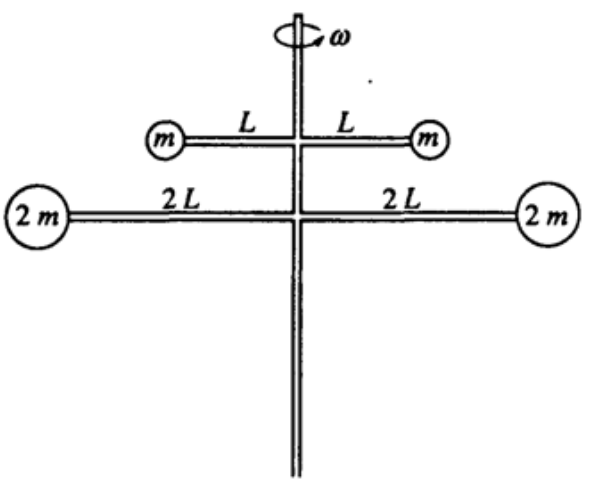
12. A figure skater is spinning on frictionless ice with her arms fully extended horizontally. She then drops her arms to her sides. Which of the following correctly describes her rotational kinetic energy and angular momentum as her arms fall?

	Rotational Kinetic Energy	Angular Momentum
(A)	Remains constant	Remains constant
(B)	Decreases	Increases
(C)	Decreases	Decreases
(D)	Increases	Decreases
(E)	Increases	Remains constant



35. A rod of negligible mass is pivoted at a point that is off-center, so that length l_1 is different from length l_2. The figures above show two cases in which masses are suspended from the ends of the rod. In each case the unknown mass m is balanced by a known mass, M_1 or M_2, so that the rod remains horizontal. What is the value of m in terms of the known masses?

(A) $M_1 + M_2$ (B) $\frac{1}{2}(M_1 + M_2)$ (C) $M_1 M_2$ (D) $\frac{1}{2}M_1M_2$ (E) $\sqrt{M_1 M_2}$



26. The rigid body shown in the diagram above consists of a vertical support post and two horizontal crossbars with spheres attached. The masses of the spheres and the lengths of the crossbars are indicated in the diagram. The body rotates about a vertical axis along the support post with constant angular speed ω. If the masses of the support post and the crossbars are negligible, what is the ratio of the angular momentum of the two upper spheres to that of the two lower spheres?

(A) 2/1 (B) 1/1 (C) 1/2 (D) 1/4 (E) 1/8

Work & KE
17. A
10. E
23. A
14. C

Conservation of E
32. B
16. A
15. E
6. B
18. A

Momentum & Systems
9. A
16. D
17. A

Conservation of M
2. A
3. C
8. D
21. E
11. D

Rot Motion (Torque)
20. C
31. C
29. B
30. E
23. D

Rot Dynamics
12. E
35. E
26. E