1) An object initially at rest explodes in two fragments of masses $4.3\,\text{kg}$ and $1.6\,\text{kg}$ that move in diametrically opposite directions. If the speed of the first fragment is $8.4\,\text{m/s}$, find the internal energy of the explosion.

   A) 210 kJ   B) 210 J   C) 560 kJ   D) 560 J   E) 280 J

2) An object attached to a spring is pulled across a frictionless surface. If the spring constant is $45\,\text{N/m}$ and the spring is stretched by $0.88\,\text{m}$ when the object is accelerating at $2.0\,\text{m/s}^2$, what is the mass of the object?

   A) 22 kg   B) 26 kg   C) 20 kg   D) 17 kg   E) 19 kg

3.) The graphs below show the magnitude of the force on a particle as the particle moves along the positive x axis from the origin to $x = x_1$. The force is parallel to the x axis and is conservative. The maximum magnitude F_1 has the same value for all graphs. Rank the situations according to the change in the potential energy associated with the force, least (or most negative) to greatest (or most positive).
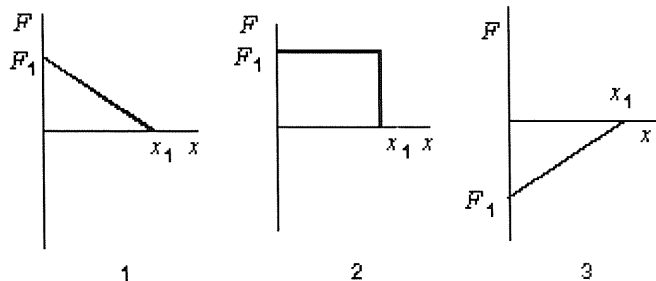
(A)   1, 2, 3   (B) 3, 1, 2   (C)   2, 3, 1   (D)   3, 2, 1   (E)   2, 1, 3

4) An object is moving with a constant velocity. Which statement(s) MUST be true?

   A) The net force on the object is zero.   B) A small net force is acting on the object, in the direction of motion.

   C) No forces are acting on the object.   D) Two of the above statements are true.   E) None of the above.

5) The figure shows two forces, each of magnitude 4.6 N, acting on an object. The angle between these forces is 40°, and they make equal angles above and below the horizontal. What third force will cause the object to be in equilibrium (acceleration equals zero)?


   A) 7.0 N pointing to the right   B) 8.6 N pointing to the right   C) 4.3 N pointing to the right

   D) 3.5 N pointing to the right   E) 9.2 N pointing to the right

6.) A 453 kg car moving at 13.9 m/s hits from behind another car moving at 13.3 m/s in the same direction. If the second car has a mass of 339 kg and a new speed of 13.9 m/s, what is the velocity of the first car after the collision?

(A)   13.1 m/s   (B)   14.3 m/s   (C)   -13.5 m/s   (D)   13.5 m/s   (E) 14.1 m/s

7) A ball is tossed vertically upward. When it reaches its highest point (before falling back downward),

   A) the velocity is zero, the acceleration is directed downward, and the force of gravity acting on the ball is directed downward.

   B) the velocity is zero, the acceleration is zero, and the force of gravity acting on the ball is directed downward.

   C) the velocity is zero, the acceleration is zero, and the force of gravity acting on the ball is zero.

   D) the velocity is not zero, the acceleration is zero, and the force of gravity acting on the ball is zero.

   E) None of the above

8) The figure shows a 100-kg block being released from rest from a height of 1.0 m. It then takes it 0.90 s to reach the floor. What is the mass m of the other block? The pulley has no appreciable mass or friction.
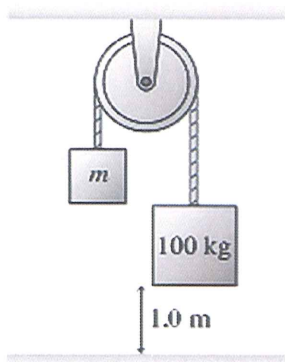

A) 42 kg   B) 60 kg   C) 48 kg   D) 54 kg   E) 63 kg

9) A 6.00-kg block is in contact with a 4.00-kg block on a horizontal frictionless surface as shown in the figure. The 6.00-kg block is being pushed by a horizontal 20.0-N force as shown. What is the magnitude of the force that the 6.00-kg block exerts on the 4.00-kg block?
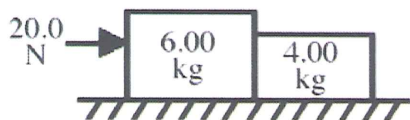
A) 20.00 N   B) 6.0 N   C) 10.0 N   D) 4.00 N   E) 8.00 N

10) A 4.00-kg block rests between the floor and a 3.00-kg block as shown in the figure. The 3.00-kg block is tied to a wall by a horizontal rope. If the coefficient of static friction is 0.800 between each pair of surfaces in contact, what horizontal force F must be applied to the 4.00-kg block to make it move?
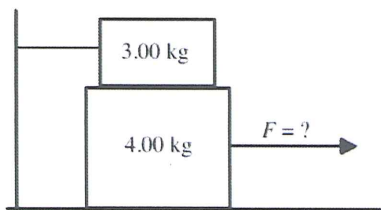

A) 16.2 N   B) 54.9 N   C) 78.4 N   D) 23.5 N   E) 21.1 N

11) In an INELASTIC collision between two objects
   A) the momentum of each object is conserved.
   B) the kinetic energy of each object is conserved.
   C) the momentum of the system is conserved but the kinetic energy of the system is not conserved.
   D) both the momentum and the kinetic energy of the system are conserved.
   E) the kinetic energy of the system is conserved, but the momentum of the system is not conserved.

12) Figure shows the potential-energy diagram for a 500 g particle that is released from rest at A. What are the particle's speed at C ?
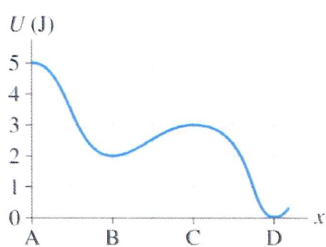
A)   3.46 m/s   B)   2.83 m/s   C)   2.53 m/s   D)   1.25 m/s   E)   4.47 m/s

13) Four identical particles, each with mass m, are arranged in the x, y plane as shown. They are connected by light sticks to form a rigid body. If $m = 2.0$ kg and
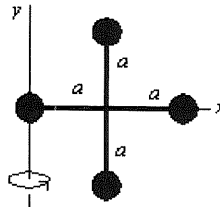
$a = 1.0$ m, the rotational inertia of this array about the y-axis is:

A) 12 kg · m^2 B) 7.2 kg · m^2 C) 4.8 kg · m^2 D) 4.0 kg · m^2 E) 9.6 kg · m^2

14) In the figure, determine the character of the collision. The masses of the blocks, and the velocities before and after are given, and no other unbalanced forces act on these blocks. The collision is

A) perfectly elastic.   B) partially inelastic.   C) completely inelastic.

D) characterized by an increase in kinetic energy.   E) not possible because momentum is not conserved.

15) $\tau = I\alpha$ for an object rotating about a fixed axis, where τ is the net torque acting on it, I is its rotational inertia, and α is its angular acceleration. This expression:

A) is the definition of torque.   B) is the definition of rotational inertia.   C) is the definition of angular acceleration.

D) follows directly from Newton's second law. E) depends on a principle of physics that is unrelated to Newton's second law.

16) Two objects are moving in the xy plane as shown. The magnitude of their total angular momentum (about the origin O) is:
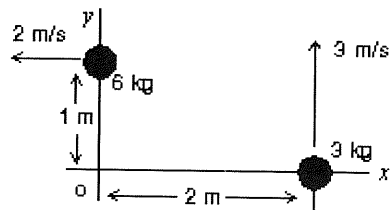
A) zero   B) 6 kg·m^2/s   C) 12 kg·m^2/s   D) 30 kg·m^2/s   E) 78 kg·m^2/s

17) A particle moves in simple harmonic motion according to $x = 5\cos(40t)$, where x is in meters and t is in seconds. Its maximum velocity in m/s is:

(A) 200sin(40t)   (B) 200cos(40t)   (C) 100   (D) 300   (E) 200

18) A simple pendulum of length L and mass M has frequency f. To increase its frequency to $2f$:

A) decrease its length by length to $L/4$ B) decrease its length by length to $L/2$ C) increase its length by length to $2L$

D) increase its length by length to $4L$ E) decrease its mass by length to $< M/4$

19.) The diagram shows a pipe of uniform cross section in which water is flowing. The directions of flow and the volume flow rates (in cm^3/s) are shown for various portions of the pipe. The direction of flow and the volume flow rate in the portion marked A are
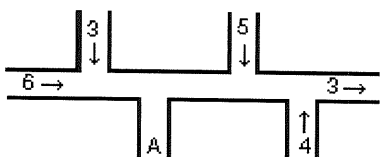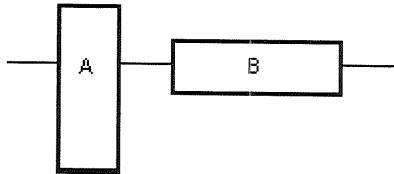
A) out and 15 cm^3/s   B) in and 11 cm^3/s   C) out and 9 cm^3/s   D) in and 15 cm^3/s   E) none of above

20.) 1 Pa is:

    A) 1 N/m   B) 1 m/N   C) 1 kg/m $\cdot$ s^2 D) 1 kg/m $\cdot$ s   E) 1 N/m $\cdot$ s

21) Two identical blocks of ice float in water as shown. Then:

  A)   block A displaces a greater volume of water since the pressure acts on a smaller bottom area

  B)   block B displaces a greater volume of water since the pressure is less on its bottom

  C)   the two blocks displace equal volumes of water since they have the same weight

  D)   block A displaces a greater volume of water since its submerged end is lower in the water

  E)   Block B displaces a greater volume of water since its submerged end has a greater area

22) An object hangs from a spring balance. The balance indicates 30 N in air, 20 N when the object is submerged in water. What does the balance indicate when the object is submerged in liquid with a density that is half of water?:

A) 40 N   B) 30 N   C) 20 N   D) 35 N   E) 25 N

23) A balloon is filled with cold air and placed in a warm room. It is NOT in thermal equilibrium with the air of the room until

A) it rises to the ceiling   B) it stops expanding   C) it sinks to the floor   D) it starts to contract

E) none of the above

24) The zeroth law of thermodynamics allows us to define

  A) temperature   B) pressure   C) work D) thermal equilibrium   E) internal energy

25)   When an ideal gas undergoes a slow isothermal expansion:

A) the increase in internal energy is the same as the work done by the gas

B) the work done by the environment is the same as the energy absorbed as heat

C) the increase in internal energy is the same as the heat absorbed

D) the work done by the gas is the same as the energy absorbed as heat

E) the increase in internal energy is the same as the work done by the environment