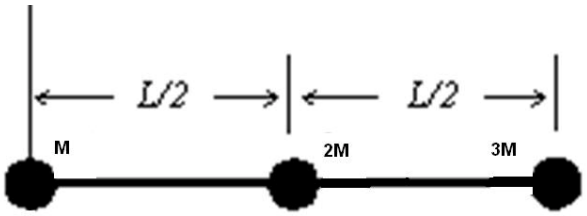
1. A wheel initially has an angular velocity of 36 rad/s. During the next six seconds the wheel turns through 126 radians. What is its angular speed in rad/s at the end of this time period?
   A) 6.00
   B) 11.00
   C) 4.49
   D) 17.20
   E) none of these

2. Three point-sized objects, of mass M, 2M, and 3M, are fastened to a rod of length L. The mass of the rod is 5M. Note: the rotational inertia of a uniform rod of length x and mass m, with respect to an axis through the center of the rod is $(1/12)\ mx^2$. The rotational inertia about the *center* of the rod, through the 2M object is:



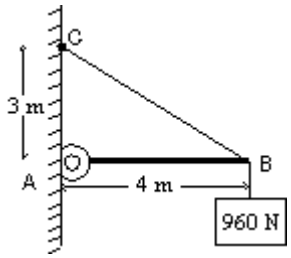
   A) $17ML^2/12$
   B) $ML^2/12$
   C) $13ML^2/12$
   D) ML^2
   E) none of these

3. The linear density (mass per length) of a straight rod is given by the equation, $\lambda(x) = 2x\ln(x+1)$, where λ is in kg/m, and x is in meters, and x = 0 marks the left end of the rod, whose length is 1.2 m. What is the rotational inertia of this rod, in kg-m^2?
   A) 0.43
   B) 0.69
   C) 0.92
   D) 1.23
   E) none of these

4. An 80-N uniform plank leans against a frictionless wall as shown. The ladder is 5 m long. The coefficient of static friction between ladder and floor is 0.24. How far (in m) from the edge of the wall may the bottom of the ladder be placed without the ladder slipping?

A) 2.16
B) 2.34
C) 2.41
D) 2.89
E) none of these

5. A 960-N block is suspended as shown. The beam AB is uniform and has a weight of 600 N and is hinged to the wall at A. The tension in the wire BC (in N) is



A) 720
B) 1240
C) 1280
D) 2100
E) none of these

6. The position vector of a 2 kg object is r = <t, $2t^3$, t^2>, where r is in meters, and t is in seconds. What is the angular momentum of the object at time t = 1.0 s, in m^2-kg/s ?

A) <-12, 4, 11>
B) <-9, 0, 15>
C) <9, -12, 27>
D) <-4, -2, 8>
E) none of these

7. A spherical shell has an outer radius of 3.00 m, and an inner radius of 2.00 m. It consists of metal of uniform density 9000 kg/m^3. What would be the force on a 0.50 kg point-sized object placed 2.60 m from the sphere's center, in units of micro-newtons (1 micro-newton = 1.0 x 10^{-6} N)
   A) 4.63
   B) 1.63
   C) 3.79
   D) 7.93
   E) none of these

8. A hoop ($I = MR^2$) rolls with constant velocity v = 6.0 m/s and without sliding along level ground, it climbs a hill that is 2.6 m high. What is the hoop's speed (in m/s) at the top of the hill?
   A) 1.98
   B) 2.78
   C) 3.24
   D) 4.12
   E) none of these

9. What additional pressure (in Pa) must be applied to a solid metal sphere with a radius of 1.3000 m, and a bulk modulus of 2.5 $\times 10^{10}$ N/m^2, if its radius is to be reduced to 1.2999 m?
   A) 4.50 x 10^4
   B) 8.90 x 10^6
   C) 4.56 x 10^7
   D) 5.77 x 10^6
   E) none of these

10. A raft floats in a swimming pool. An oar floating in the pool beside the raft is lifted out of the water and placed on the raft. The water level in the pool
    A) rises
    B) falls
    C) remains the same
    D) not enough information to answer
    E) none of these

11. A narrow water pipe enters a house 1.2 m above ground. The pipe widens and becomes a larger diameter pipe that carries water to a basement faucet 1.6 m below ground. Water flows at 3.0 m/s in the above-ground pipe and at 1.1 m/s in the wider portion of the pipe in the basement. Take the density of water to be 1000 kg/m^3. The difference in pressure between the basement line and the main line (in kPa, kilo-pascal) is approximately:
    A) 3.6
    B) 6.6
    C) 5.9
    D) 8.3
    E) none of these

12. An object is oscillating horizontally on the end of a spring at an angular frequency ω and with amplitude *A*. The amount by which the spring is stretched (or compressed) when its speed $\omega A/2$ is:
    A) $3^{1/2}A$
    B) A/2
    C) $2^{1/2}$ A
    D) $3^{1/2}A/2$
    E) None of these

13. An object of mass m = 1 kg is oscillating horizontally on a frictionless surface at the end of a spring whose spring constant is 900 N/m. Its equation of motion is given by $x = A \cos(\omega t + \phi)$. At time t = 1.5 seconds, the object is observed to have a speed of 1.7 m/s, and is moving to the left; at that same instant, it is 0.16 m to the right of the object's equilibrium position (at x = 0). What is the phase constant, ϕ, in radians ?
    A) 2.3
    B) -0.8
    C) 1.2
    D) 4.9
    E) none of these

14. A string is clamped at both ends. The speed of waves on this string is 9.00 m/s. The *third*-lowest frequency of vibration of standing waves on this string is 450 Hz. What is the wavelength (in m) of the *fundamental* mode of oscillation?
    A) 0.12
    B) 0.06
    C) 0.09
    D) not enough information to answer
    E) none of these

15. An organ pipe open at one end, closed at the other end, 0.85 m long. Assuming that the speed of sound is 340 m/s, the frequency (in hertz) of the mode of vibration that has two antinodes is:
    A) 200 Hz
    B) 300 Hz
    C) 400 Hz
    D) 600 Hz
    E) none of these

16. A source emits sound with a frequency of 800 Hz. It is moving at 20 m/s toward an observer that is moving away from the sound source at a certain speed. If the speed of sound is 340 m/s, and the observer hears a frequency 700 Hz, what is the speed of the observer, in m/s?
    A) 50
    B) 60
    C) 70
    D) 80
    E) none of these

17. About how much force (in N) would be required to lift a 120-N ball, of radius 12 cm, that's initially at rest at the bottom of a pool of water?
    A) 22
    B) 28
    C) 49
    D) 56
    E) none of these

18 What is the angle in degrees between the vectors A = <3, 2, 1> and B = <-2, -1, 4>?

(a) 65.74
(b) 77.21
(c) 70.09
(d) 103.49
(e) none of these

19. A ball is revolving in a circular path at the end of a string 2.1 meters long. It is making 24 revolutions per minute. What is the ball's centripetal acceleration, in m/s^2?

(a) 13.26
(b) 17.34
(c) 22.98
(d) 12.02
(e) none of these

20. An object initially moving at 30 m/s accelerates at 4.0 m/s^2, reaching a speed of 140 m/s. How far (in m) did the object travel during this time?

(a) 1895.92
(b) 2111.23
(c) 2337.50
(d) 1442.24
(e) none of these

21. At time t = 0, an object is at x = 12 m, and its velocity is 17.50 m/s. At that instant, it begins accelerating according to the equation, a(t) = 5t, where a(t) is in m/s^2, and t is in seconds. What will be the object's x-coordinate (in meters) at time t = 2.98 seconds?

(a) 33.82
(b) 77.58
(c) 88.22
(d) 86.20
(e) none of these

22. Given A = <4, -1, 2> and B = <-3, 2, -1>. What is the length of A x B?

(a) 9.56
(b) 6.16
(c) 7.80
(d) 9.84
(e) none of these

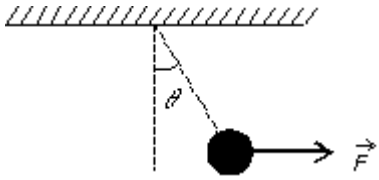
23. A jet flying at 200 m/s is climbing above level ground at an angle of 25º relative to the horizontal. When it reaches an altitude of 1000 meters it drops a bomb. About how far (in meters) horizontally from its point of release does the bomb strike the ground?

(a) 4587
(b) 2857
(c) 1976
(d) 813
(e) none of these

24. Relative to the ground, air is moving at 33 m/s on a heading of 228º. An airplane's heading is 48º, and it is flying level at a speed of 90 m/s relative to the air. Inside the airplane a bullet is fired perpendicularly toward the left side of the plane at a speed of 70 m/s relative to the plane. Which of the numbers below is the closest to the heading of the bullet relative to the ground, in degrees? Hint: drawing a picture and estimating might be quicker than other methods.

(a) 0
(b) 110
(c) 140
(d) 170
(e) 60

25. A 7-N pendulum bob is held at an angle θ from the vertical by a 4-N horizontal force F as shown. The angle θ (in degrees) is:



A) 21.23
B) 23.45
C) 26.78
D) 29.74
E) none of these

26. A 200 kg crate resting on a rough horizontal floor is to be moved horizontally. The coefficient of static friction is 0.24. To start the crate moving by pulling at an angle of 22º above the horizontal, what force (in N) must be applied?
A) 462.50
B) 324.56
C) 564.81
D) 734.32
E) none of these

27. An object is orbiting a planet in a circular orbit at a speed of 10,000 m/s. A second object orbiting the same planet is five times as far from the center of the planet as the first object. What is its speed, in m/s?
A) 2,000
B) 4,472
C) 3,189
D) 1,329
E) none of these

28. One end of a 1.6-m string is fixed, the other end is attached to a 2.0-kg stone. The stone swings in a vertical circle at constant speed. If the maximum tension the string can withstand without breaking is 80 N, what is the maximum speed (in m/s) the stone can have without breaking the string?
    A) 4.13
    B) 5.67
    C) 6.95
    D) 7.89
    E) none of these

29. A 0.60-kg block attached to an ideal spring with a spring constant of 80 N/m oscillates on a horizontal frictionless surface. When the spring is 0.04 m longer than its equilibrium length, the speed of the block is 0.70 m/s. The speed (in m/s) of the block when the spring is 0.03 m shorter than its equilibrium length is
    A) 0.81 m/s
    B) 0.32 m/s
    C) 0.55 m/s
    D) 0.76 m/s
    E) 0.93 m/s

30. A 74-kg man is marooned at rest on level frictionless ice. In desperation, he hurls his shoe to the right at 15 m/s. If the man moves to the left at a speed of 0.24 m/s, what is the mass of the shoe, in kg?
A) 0.24
B) 0.45
C) 0.86
D) 1.18
E) none of these

31. Blocks A and B are moving toward each other along the *x* axis. A has a mass of 2.0 kg and a velocity of 50 m/s, while B has a mass of 4.0 kg and a velocity of –20 m/s. They suffer an elastic collision and move off along the *x* axis. The speed (in m/s) of Block B after collision is:
    A) 14.56
    B) 17.45
    C) 19.75
    D) 26.67
    E) none of these

32. A 1200-kg car is traveling at 11 m/s along a horizontal road when the brakes are applied. The car skids to a stop in 4.0 s. What is the magnitude of the work done on the car in this time?
    A) 4.8×10^4 J
    B) 5.9×10^4 J
    C) 1.2×10^5 J
    D) 7.3×10^4 J
    E) none of these

33. A 4-kg object at x = 0.70 m is moving to the right at 6 m/s along the x-axis at time t = 0. At that time, a force $F(x) = 3x^2 e^x$ begins to act on the object, where F is measured in newtons, and x is in meters. What will be the object's speed (in m/s) when x = 1.40 m?
    A) 2.01
    B) 6.31
    C) 8.45
    D) 4.58
    E) none of these