1. The quantity $\sqrt{\dfrac{\hbar G}{c^5}}$ is well known to quantum gravity theorists. In that expression, $\hbar$ has the same units as angular momentum, G has units of $\dfrac{m^3}{kg \cdot s^2}$, and c is the speed of light. What is $\sqrt{\dfrac{\hbar G}{c^5}}$?

   a) a length   **b) a time**   c) a velocity   d) an area

2. Suppose you throw a rock **downward** from the top of the Empire State Building (a height of 381 m) with a speed of 10 m/s. Neglecting air resistance, when does the rock hit the ground?

   a) 7.85 s   b) 8.21 s   c) 8.93 s   d) 9.55 s

3. Suppose a rubber ball is dropped from a height of 100 ft and, after the bounce, rises to a height of 85 ft before momentarily coming to rest. What fraction of the ball's **speed** was lost in the collision with the ground?

   a) 8%   b) 12%   c) 19%   d) 27%

4. A man and his young son hit golf balls from an elevated pier into the water below. Both balls leave the tee with purely horizontal velocity, but the man's ball goes a horizontal distance of 200 yards, while the boy's ball travels a horizontal distance of only 100 yards before hitting the water.   Ignoring air resistance and the curvature of the earth, what can be said about the flight times of the balls?

   a) The boy's ball has a shorter flight time.
   b) The dad's ball has a shorter flight time.
   c) Both balls have the same flight time.
   d) The answer depends on whether the height of the pier is larger or smaller than the horizontal distance traveled by either ball.
   e) No general statement about the two flight times can be made.

5. An object is acted on by constant, external forces. At $t = 0$ s, the object is at (x=0 m, y=2 m) with a velocity of 3 m/s in the +x direction. A short time later, the object is at (x=2 m, y=0 m) with velocity $\vec{v} = 2\hat{i} - 5\hat{j}$ m/s. What can be concluded about the forces acting on the object?

   a) There is a force in the positive x-direction and in the positive y-direction.
   b) There is a force in the positive x-direction and in the negative y-direction.
   c) There is a force in the negative x-direction and in the positive y-direction.
   d) There is a force in the negative x-direction and in the negative y-direction.
   e) There is only a force along the x-axis.
   f) There is only a force along the y-axis.

6. A 1 kg mass is attached to one end of a light spring whose unstretched length is 0.5 m. If the other end of the spring is fixed and the mass revolves on a frictionless surface with constant speed in a horizontal circle of radius 1.5 m, making one revolution each second, what is the spring constant, k?

     a) 59 N/m   b) 69 N/m   c) 79 N/m   d) 89 N/m   e) 99 N/m

7. The mass density of material A is twice that of material B. If two wires are made with the same radius and length, one from material A and one from material B, and the two wires are held fixed at each end by the same tension, which wire has the **higher** fundamental frequency?

    a) wire A   **b) wire B**   c) both wires have the same fundamental frequency

8. A block slides up a rough incline with an initial velocity at the bottom of 10 m/s. The incline makes a 30° angle with the horizontal, and $\mu_k = 0.15$ (μ_k is the coefficient of kinetic friction between the block and the incline). How far up the incline (measured along the incline) has the block moved when its speed is 5 m/s?

    a) 2 m   b) 4 m   **c) 6 m**   d) 8 m   e) 10 m

9. An object is acted on by two conservative forces, causing the object to slow down. No other forces act. Which statement below must be true?

    a) The potential energy associated with at least one of the forces must have increased.
    b) The potential energy associated with at least one of the forces must have decreased.
    c) The potential energies associated with each of the individual forces must have increased.
    d) The potential energies associated with each of the individual forces must have decreased.
    e) No general statement about the potential energies associated with the forces can be made.

10. A man pulls a block up a rough incline at constant speed. Mark each statement below as T (true) or F (false).

    ____T_____ A. The kinetic energy of the block is conserved.

    ____F_____ B. The work done by the man is equal and opposite to the work done by friction.

    ____F_____ C. The total work done by all forces is positive.

    ____T_____ D. The potential energy of the block increases with time.

11. A rubber bullet ($m = 0.1$ kg, $v = 80$ m/s) hits a 5 kg bowling ball hanging at rest at the end of a 2 m long string. The bullet bounces backward with a speed of 20 m/s. What is the recoil velocity of the bowling ball?

    a) 1 m/s   **b) 2 m/s**   c) 3 m/s   d) 4 m/s   e) 5 m/s

12. Through what angle does the bowling ball swing before momentarily coming to rest in the previous problem?

    a) 12°   b) 18°   **c) 26°**   d) 31°   e) 37°

13. A solid uniform disk ($M = 2$ kg, $R = 3$ m) rolls from rest down a 45° incline without slipping. When the disk has made one complete revolution, what is the velocity of the disk's center of mass? The moment of inertia of a disk about an axis through its center of mass is $\frac{1}{2}MR^2$.

a) 3 m/s   b) 7 m/s   **c) 13 m/s**   d) 17 m/s   e) 24 m/s

14. Hagrid is helping a Hogwarts first-year student onto the merry-go-round. The stationary merry-go-round has a radius of 3 m and a moment of inertia of 200 kg•m². Hagrid picks up the 40 kg student and tosses him onto the edge of the merry-go-round so that he lands there moving tangential to the edge of the merry-go-round with a speed of 4 m/s. What is the final angular velocity of the merry-go-round with the student on board?

a) 0.21 rad/s   b) 0.47 rad/s   c) 0.62 rad/s   **d) 0.86 rad/s**

15. The man holding the bicycle wheel is at rest on the stool (the stool is free to rotate). The bicycle wheel is spinning clockwise when viewed from above (so as you view the picture, the left hand side of the wheel is moving away from you). If the man now rotates the wheel's axis 90° so that his arms are now held straight out from his shoulders, the wheel/man/stool system will

a) rotate clockwise when viewed from above.
b) rotate counterclockwise when viewed from above.
c) slide to the left (from the viewer's perspective).
d) slide to the right (from the viewer's perspective).
e) not rotate or slide.

16. Consider a mass attached to a spring undergoing simple harmonic motion on a horizontal, frictionless surface. Mark each statement below as T (true) or F (false).

____T_____   A. The position and velocity of the mass are 90° out of phase with each other.

____F_____   B. The acceleration is zero when the displacement is maximum (positive or negative).

____T_____   C. Maximum velocity occurs when the acceleration is zero.

____T_____   D. Position and acceleration are never both positive (or negative) at the same time.

17. A 1 kg block attached to a spring (k = 50 N/m) executes simple harmonic motion on a horizontal, frictionless surface. As the block passes through the unstretched position of the spring at t = 0, its velocity is 2 m/s in the negative direction. The amplitude of the motion is

a) 0.28 m   b) 0.34 m   c) 0.41 m   d) 0.55 m

18. In problem 17, what is the shortest time after t = 0 at which the block's velocity is zero?

a) 0.11 s   **b) 0.22 s**   c) 0.33 s   d) 0.44 s

19. Suppose the velocity of waves in a wire fixed at both ends is 320 m/s. If the tension in the wire is reduced by a factor of three, the velocity of waves in wire will then be

      a) 185 m/s   b) 273 m/s   c) 320 m/s   d) 375 m/s   e) 410 m/s

20. An ambulance siren has a frequency of 600 Hz. If you are traveling northward at 20 m/s and the ambulance is traveling southward at a speed of 35 m/s, what maximum change in frequency do you observe when the ambulance passes you? The speed of sound in air is 343 m/s.

      a) 47 Hz   b) 82 Hz   c) 131 Hz   d) 165 Hz   **e) 194 Hz**

21. A transverse wave travels in a string in the +x direction. The speed of the waves is 14 m/s and the period of oscillation is 2 s. At t = 0, a point on the string at x = 0 is 0.05 m below y = 0 and has a vertical velocity of +3 m/s. Assuming that $y(x,t) = A\sin(kx - \omega t + \phi)$, the amplitude A is

      a) 0.96 m   b) 1.27 m   c) 2.83 m   d) 4.99 m   e) 8.06 m

22. The phase constant ϕ in problem 22 is

      a) 0.24 rad   b) 0.58 rad   c) 1.51 rad   d) 2.37 rad   **e) 3.19 rad**

23. The lowest resonant frequency of an organ pipe (closed at one end, open at the other) is f. If both ends of the pipe are opened without changing the length of the pipe, its lowest resonant frequency becomes

      a) $f/4$ b) $f/3$ c) $f/2$ **d) $2f$**   e) $3f$ f) $4f$

24. As you listen to two flute players play a B-flat note (nominal frequency of 466 Hz), you notice that the intensity of the combined sound waves produces 2 beats per second. If one of the flutes is tuned to the correct frequency (466 Hz), what is a possible frequency for the other flute?

      a) 461 Hz   b) 462 Hz   c) 463 Hz   d) 464 Hz   **e) 465 Hz**