A data sheet is provided. Table 10-2 from your text is assumed, and will be provided on the final exam.

1. A rock is thrown downward from the top of a building 175 m high with an initial velocity of 37.0 m/s. At the same time another rock of equal mass is projected upward from the bottom of the building with an initial speed of 30.0 m/s.

   (a) Calculate the height above the ground at which the two rocks meet.
   (b) If the rocks collide in a completely inelastic collision, calculate the time when they reach the ground. Let t = 0 be the time when the rocks are initially launched.

2. A small solid ball of mass m and radius r is started at rest and rolls without friction down the loop-the-loop shown. Assume r << R. (h = 4R).

   (a) Calculate the normal force of the track on the ball at point A, exactly opposite the center of the loop. (Your answer should be expressed as the weight of the ball times a number.)
   (b) Calculate the normal force on the ball at point B, exactly at the top of the loop. (Your answer should be expressed as the weight of the ball times a number.)

3. A small block of mass m is placed on a conical surface that is rotated about its symmetry axis. The coefficients of friction are 0.65 and 0.55. The block is initially a distance d up the cone as shown. (m = 0.750 kg, d = 0.374 m)

   (a) Calculate the maximum possible angular speed for rotation of the cone such that the block does not slide. Free body and force diagrams are an essential part of this problem.
   (b) At the instant before the block starts to slide, calculate the frictional force and the normal force.

4. (a) Two cylinders of mass m = 2.45 kg and radius R = 3.50 cm each, are connected by a massless rod of length 5.00 cm. This is shown in cross section. The system is rotated about an axis perpendicular to the paper and through the center of the rod. Find the moment of inertia of the system.

   (b) A grinding wheel, in the shape of a disc of thickness 1 inch and radius 12 inches, is slowed by friction with the tool being ground. The weight of the wheel is 55 pounds. If it slows from 25 rad/s to a full stop in 37 seconds, find the frictional force exerted by the tool.

   (c) Find the weight on Earth of an object whose mass on the moon is 2.70 kg.

   (d) If the coefficient of friction between skis and snow is 0.075, find the angle of slope at which a skier will move with constant velocity.

   (e) A 4.75 kg mass is rotated on a string. The string rotates in a cone, where the angle of the string from the vertical is 27.0°. Find the tension in the string.
5. A hollow cylinder is rotating about a vertical axis with angular velocity \( \omega \), as shown. A small block of mass \( m \) is on the inside of the cylinder. A string exerts a constant force \( P \) equal to 3 times the weight of the block in a direction of \( 30^\circ \) from the vertical, as shown. The coefficients of friction between the block and the wall are \( \mu_k = 0.60 \). The radius \( R \) is 1.25 m, and the block is very small. Find the minimum angular velocity of the cylinder such that the block does not slide up.

6. At \( t = 0 \) a rock is dropped from the top of a building 150 m high. Exactly 2.00 s later another rock is thrown down with an initial velocity of \( v_o \) m/s.

(a) Calculate the initial velocity for the second rock, such that both rocks arrive at the bottom at the same instant.

(b) Calculate the velocity of the thrown rock when it reaches the bottom.

7. A mass \( m \) is on the slope of a cone that rotates about its symmetry axis. There is a string attached to the mass and is fixed at the center. The string is parallel to the slope of the cone. The mass \( m \) does not move with respect to the cone. The tangential velocity of the mass (into the paper) is 2.55 m/s. Clear free body and force diagrams are a necessary part of this problem.

(a) If the string stretches slightly so that the maximum static friction occurs between the cone and the mass, calculate the tension in the string. The diagram shows the position and dimensions with the string stretched.

(b) Calculate the frictional force acting on the mass.

\[ m = 0.325 \text{ kg}; \theta = 25.0^\circ; R = 0.65 \text{ m}; \mu_s = 0.650; \mu_k = 0.550 \]

8. A car is traveling down a 15.0° slope as shown. The coefficients of friction are \( \mu_s = 0.65 \), \( \mu_k = 0.57 \).

(a) If the car is going at 55.0 mi/hr, how far would it skid before stopping with wheels locked?

(b) For the same initial conditions, how far would the car skid if it is initially going uphill?

(c) For part (a), calculate the time to reduce the speed of 1/2 of its initial value.

9. A cylinder of radius \( R \) (not small) and mass \( M \) rolls without sliding on a surface with the shape shown. It starts from rest.

(a) Calculate the largest possible value of \( h \), such that the cylinder does not leave the surface when it passes over the hump. \( h \) is measured to the center of mass of the cylinder. Express this in terms of \( R \) and \( A \) (the radius of the top of the hump). The top of the hump is 2\( A \) above the ground.

(b) For the starting value of \( h \) calculated in (a), the apparent weight of the cylinder at \( C \) is found to be 4 Mg. Find the radius of curvature at \( C \).
10. A wood block of mass \( m = 2.05 \text{ kg} \) is dropped from rest from the top of a 150 m cliff on Earth at \( t = 0 \). After it has fallen for 2.00 s, a bullet is fired upwards from the ground. The initial speed of the bullet is 115 m/s (at the ground). The mass of the bullet is 30.0 g.

(a) Find the height above the ground where the bullet strikes the block.
(b) If the bullet sticks in the block, find the time (measured from \( t = 0 \)) when the block hits the ground.

11. A cannon is set up at the base of a hill. The hill can be represented by a parabola of the form \( y = ax^2 \), as shown. If the angle at which the gun is pointed is \( \theta = 35.0^\circ \), calculate the value of the initial velocity if the shell is to strike the hill at point \( A \), where \( A \) is a height \( h \) above the horizontal. (Numerical answers.)

\[
a = 2.50 \times 10^{-6} \text{ m}^2\text{s}^{-1}
\]
\[
h = 150 \text{ m}
\]

12. A block is launched down the plane shown with initial velocity \( v_o \). The mass of the block is \( M \), and the coefficients of friction are given below. Calculate, USING ENERGY METHODS, how far along the plane the block moves before stopping. The plane is as long as needed.

\[
M = 2.77 \text{ kg} \quad v_o = 5.25 \text{ m/s}
\]
\[
\mu_k = 0.450 \quad \mu_s = 0.600
\]

13. The inclined plane shown is accelerated to the left with \( a = 17.0 \text{ m/s}^2 \). If the maximum static friction between the block and plane is used, what is the tension in the string? Correct free body and force diagrams are essential to this problem.

\[
M = 3.42 \text{ kg} \quad \theta = 25.0^\circ
\]
\[
\mu_s = 0.620 \text{ kg}
\]

14. A gun is fired horizontally from the top of a cliff. The initial velocity of the bullet, which has a mass of 0.050 kg, is 320 m/s. A block of wood is dropped at the exact time the bullet is fired, as in the "monkey shoot" demonstration. The bullet impacts the block of wood and sticks in it when the bullet is exactly half-way to the ground. The mass of the wood is 1.25 kg. \( h = 175 \text{ m} \).

(a) Calculate the velocity, magnitude and direction, of the bullet when it reaches the block.
(b) Find the velocity, magnitude and direction of the wood block just after the bullet impacts.
(c) Determine the distance \( R \) from the base of the cliff where the combined block and bullet land.
15. **[HARD]** Initially the system of masses shown is held motionless. All surfaces, pulley and wheels are frictionless. In this case let the force $F$ be zero and assume that $m_2$ can only move vertically with respect to the cart. At the instant after the system of masses is released find:

(a) the tension $T$ in the string;
(b) the acceleration of $m_1$ in the $y$ direction;
(c) the acceleration of $M$ with respect to the ground;
(d) the acceleration of $m_2$ with respect to the ground.

Note: The pulley accelerates along with the cart.

16. A point mass of mass $= 0.320$ kg is attached by a massless string to a fixed point $P$. It is released at rest. Directly below $P$, at a distance 1.10 m from $P$ is a peg. The string strikes the peg when the mass swings, and the string starts to wrap around the peg.

(a) Find the velocity of the mass when the lower point of the string is horizontal.
(b) What is the tension in the string when the lower part is horizontal?
(c) Calculate the tension in the string when it makes an angle of $45^\circ$ above the horizontal, as shown.

17. (a) Four cylinders are touching each in the arrangement shown. Calculate the moment of inertia for rotation about the axis $A$, at the exact center, and perpendicular to the paper. Take the mass of each cylinder as $M$, and the radius of each as $R$.

(b) A wheel is accelerated from rest at an angular acceleration of $3.75 \, \text{r/s}^2$. Calculate the total angular displacement after $8.90 \, \text{s}$.
(c) For the wheel in (b), calculate the magnitude of the angular velocity when the total angular displacement is $18.0 \, \text{rad}$.
(d) A car is traveling at 60 mi/hr. If the wheels have a radius of 15 inches, what is the magnitude of their angular velocity in rad/s?
(e) A bowling ball has a weight of 16.0 pounds. If it is rolling without sliding and the radius is 4.00 inches, calculate the rotational kinetic energy if its translational speed is 30.0 ft/s.
(f) Calculate magnitude of the angular momentum of a baseball of mass 0.145 kg if it rotates at 1600 RPM (revolutions per minute). Assume a uniform mass distribution. Take the radius as 4.00 cm.

18. Car A passes the point $x = 0$ at a steady speed of 75.0 mi/hr. After A has traveled 250 feet a police car, P, starts from rest, and uniformly accelerates. Car P catches car A at point $x = 2000$ ft.

(a) Calculate the acceleration of P.
(b) Calculate the velocity of P when P catches A.
19. Mass 1 rests on a rotating turntable (like our green lazy susan) a distance \( d \) from the axis of rotation. A string from 1 passes over a massless, frictionless pulley, and is attached to mass 2. By means of a mechanism not shown, and not relevant to the problem, \( m_1 \) is constrained to move only in the vertical direction. (It rotates around with the lazy susan also.)

\[ d = 0.300 \text{ m}; \ m_1 = 1.27 \text{ kg}; \ m_2 = 0.300 \text{ kg}; \ \mu_s = 0.650 \]

(a) Calculate the maximum value of the tangential velocity due to rotation of \( m_1 \), into the paper, such that \( m_1 \) does not slide.

(b) Calculate the maximum value of \( m_2 \) for which this is a sensible problem. (Find an analytic expression for the velocity in a, and see what values of \( m_2 \) do not work.)

20. A block of mass \( m \) is given an initial velocity by the spring. The spring has a spring constant \( k \), and is squeezed 0.200 m when the block is at A. Between A and B the slope has friction coefficients \( \mu_s = 0.75 \) and \( \mu_k = 0.65 \). After point B the system is frictionless. The block goes around the circular loop of radius \( R \) and is in contact with the loop all the way. The distance between A and B is 2.40 m. Assume the size of the block is small compared to \( R \). The vertical position of B is the same as the center of the loop.

\[ m = 0.175 \text{ kg}; \ k = 120.0 \text{ N/m}; \ R = 0.500 \text{ m}; \ \Theta = 27.0^\circ \]

(a) Calculate the speed of the block at the exact top of the loop.

(b) Find the normal force of the loop on the block at the exact top.

(c) Determine the normal force on the block at C, directly opposite the center of the loop.

21. Block A is launched up a frictionless inclined plane with an initial velocity \( v_0 \). At the same instant, block B is released from rest at a point a distance \( d \) up the plane.

\[ m_A = 3.50 \text{ kg}; \ m_B = 2.00 \text{ kg}; \ \Theta = 40.0^\circ; \ v_0 = 6.00 \text{ m/s}; \ d = 3.00 \text{ m} \]

(a) Calculate the distance \( x \) up the plane to the point where they meet.

(b) If they collide in a completely inelastic collision, find the time that elapses from the collision until they are back at the initial position of A.

22. A sled of mass \( m \) is pulled with a constant force \( F \) down the incline shown. The coefficients of friction are \( \mu_s = 0.25 \) and \( \mu_k = 0.30 \) (on snow). The sled starts at zero velocity. Clear labeled free-body and force diagrams are necessary for full credit.

\[ m = 17.2 \text{ kg}; \ F = 15.0 \text{ N} \]

(a) Find the speed of the sled after it has traveled \( d = 4.72 \text{ m} \) down the incline.

(b) Determine the energy dissipated due to friction during this activity.

23. Block 2 is resting on a frictionless horizontal table. The force \( F \) is applied to block 1 in the direction shown. The coefficients of friction between block 1 and block 2 are \( \mu_s = 0.60 \) and \( \mu_k = 0.50 \).

\[ m_1 = 1.25 \text{ kg} \]

\[ m_2 = 2.75 \text{ kg} \]

\[ \Theta = 25.0^\circ \]
24. A cannon is set up on a cliff at an elevation angle of 10.0°. The cliff is 274 m high. A car starts from the base of the cliff at a constant speed of 35.0 m/s. The car is on a level plane. The cannon is fired 20.0 second after the car leaves the base of the cliff. Determine the magnitude of the velocity necessary of the cannonball leaving the cannon to hit the car.

25. A uniform cylinder of mass M and radius r is released from rest at point A. Take r << R.

(a) Calculate the value of h such that the normal force on the cylinder at B (the exact top of the loop) is equal to twice the weight of the cylinder. This should be expressed as number time R.
(b) For h = 5R [not the answer to (a)], find the normal force on the cylinder at C. C is at the same height as the center of the loop. This should be expressed as a number times the weight of the cylinder.

26. A policeman (P) observes a car (A) going by. Five (5.00) seconds after car A goes by, the policeman starts off at a uniform acceleration of 3.00 m/s². The policeman catches car A 16.0 s after A passes him.

(a) How fast was the policeman going when he catches up to car A?
(b) How far is the policeman from his starting point when he catches car A?
(c) How fast was car A going? (Assume he maintains a steady speed.)

27. The system shown is released from rest. The pulley is frictionless and massless

(a) Determine which direction the system moves. The arrow shows the positive direction.
(b) Calculate the acceleration of the system.
(c) What is the speed after block 1 has fallen 1.50 m?
(d) How much time does it take for the system to move 2.25 m?

28. A bomber is flying horizontally at a speed of 275 m/s at an altitude of H = 3000 m. What distance, ℓ, from a target must a bomb be released in order to hit the target? The distance ℓ is measured by a laser scope straight from the plane to the target. The target is mall. Neglect air resistance.

29. A cone with α = 40.0° is rotating about the y axis with an angular velocity of ω = 3.00 rad/s. Calculate the range of heights (y_{min}, y_{max}) where you can place a block of mass M = 3.50 kg so that it would stay there (that is, it would not slide up or down).

μ_s = 0.41
μ_k = 0.35
30. (a) A car with wheels of diameter 28.0 inches is traveling at 60.0 mi/hr. Calculate the angular velocity of the wheels in rad/s.
   (b) Two cars are each traveling with a speed of 30.0 mi/hr. They collide head on. The cars each have a mass of 1500 kg. The collision is completely inelastic. What percentage of the initial kinetic energy is lost in this collision?
   (c) Two solid spheres of radius 5.25 cm and mass 0.560 kg, are touching. Calculate the moment of inertia for rotation about the axis that goes through the point that they touch and is tangent to the spheres at that point.
   (d) A solid sphere of mass 1.25 kg and radius 3.00 cm is rotating at 72.0 rad/s about an axis through its center of mass. It slows to a complete stop in exactly 175 revolutions. Assuming the acceleration is constant, what is the torque acting on the sphere?
   (e) For the object shown the rod is massless and the masses are small. Take a = 1.25 m. Calculate the moment of inertia for rotation about the axis shown.
   (f) A cannon is fired horizontally with a velocity of 750 m/s from a cliff on the moon. Find the distance x from the base of the cliff that the cannon ball lands. Ignore any curvature of the moon’s surface.

31. A block is at rest on an inclined plane. The external force F is applied horizontally.
   (a) Calculate the maximum value of F such that the block does not move.
   (b) Find the acceleration of the block if the external force is F = 65.0 N.

32. The car on a frictionless roller coaster starts at rest at position A. The hump at B has a radius of curvature R. B is 2R above the ground level.
   (a) Calculate the value of R (in terms of h) such that the normal force of the track on the car at B is exactly half of the weight of the car.
   (b) For the same starting location and value of R, find the maximum initial velocity needed at A such that the normal force at B is zero.
33. The block shown is launched down the incline with a speed of 5.25 m/s. Its mass is 0.850 kg. It travels 1.50 m and strikes a spring that is at its equilibrium length. The spring constant is \( k = 420 \text{ N/m} \).

(a) Find the maximum compression of the spring (in cm).
(b) If the spring is compressed 20.0 cm with the block in contact and then released, calculate how far up the incline the block will go. Measure from point A, the equilibrium position of the end of the spring.

\[ m = 0.850; \mu_s = 0.70; \mu_k = 0.55 \]

34. Block 1 is launched up the frictionless plane at an initial velocity of \( v_o = 1.25 \text{ m/s} \). Block 2 is released from rest at the same time as block 1 is launched.

(a) Find the location of the collision between blocks 1 and 2. Measure this up the plane from the initial position of block 1. Assume the blocks are small.
(b) If the collision between blocks 1 and 2 is completely inelastic, find the velocity after the collision. Take up the plane as positive. If you cannot do (a), do (b) symbolically.

\[ m_1 = 4.30 \text{ kg}; m_2 = 2.75 \text{ kg}; v_o = 1.25 \text{ m/s}; d = 6.00 \text{ m} \]

35. (c) The period of an oscillator is \( 2.00 \times 10^{-3} \text{ s} \). Find its frequency in Hertz.
(d) A pendulum clock keeps good time on Earth. It is taken to the Moon and started at 12:00 noon when the time on Earth is 12:00 MST (in Salt Lake City). When the clock on the Moon reads 1:00 p.m., what time is it in Salt Lake City?

36. (a) In a torsion oscillator, a torque of 30.4 N·m is required to twist the fiber through an angle of 15°. If the moment of inertia is 67.5 kg·m², find the angular frequency of oscillation.
(b) A pendulum clock is adjusted to keep good time at the pole \( (g = 9.82 \text{ m/s}^2) \). It taken to the equator \( (g = 9.78 \text{ m/s}^2) \) and started at 12:00 noon. What time does it read at 12:00 noon one day later?
(d) The angular frequency of an oscillator is 466 s⁻¹. Find its period.

37. A mass slides on a frictionless track. The parameters of the system are \( k = 1250 \text{ N/m} \) and \( m = 1.27 \text{ kg} \). Initially the position of the mass is at \( x = 3.25 \text{ cm} \) with a velocity of 1.40 m/s.

(a) Calculate the total energy in the system.
(b) Determine the angular frequency of oscillation of the system.
(c) Write a complete solution in the form \( x = A \sin \omega t + B \cos \omega t \) with all numerical parameters evaluated.
(d) Write a complete solution for the system in the form \( x = D \sin (\omega t + \phi) \) with all parameters evaluated.

38. An organ pipe is open at both ends. By experiment, resonances are found at 655 Hz, 1048 Hz and 2227 Hz as well as others. Take the speed of sound as 330 m/s.

(a) What is the largest value of the fundamental frequency allowed by the data? (None of the above is the fundamental.) Show clearly that all of the frequencies above are related to the fundamental you calculate in the correct manner.
(b) If there is a pressure node at each open end of the pipe, how many pressure nodes are there between the ends for the frequency 1703 Hz?
(c) How long is the pipe?
39. A violin type string is clamped between supports 27.0 cm apart. The string between the supports has a mass of 0.0150 kg, and the fundamental frequency is tuned to be 440 Hz.

(a) What is the tension needed in the string?
(b) What is the wavelength and frequency of the mode with 5 nodes between the clamps?
(c) Using the same string and the same tension, the positions of the clamps are changed. The frequency of the new first overtone (one node between the clamps) is found to be 1012 Hz. How far apart are the clamps?

40. An organ pipe is open at one end and closed at the other. By experiment, resonances are found at 635 Hz, 889 Hz, 1143 Hz and 1651 Hz, as well as others. Take the speed of sound as 330 m/s.

(a) What is the largest value of the fundamental frequency allowed by the data? (None of the above is the fundamental. The fundamental is lower than 635 Hz.)
(b) What is the length of the pipe.

41. A string is clamped between two supports 1.75 m apart. The total mass of the string free to oscillate between the supports is 0.0625 kg. The string is driven by a fixed frequency oscillator at 120 Hz.

(a) Calculate the values of the tension needed to produce the first four harmonics (the fundamental and the first three overtones) at the driving frequency.
(b) A new string is clamped in the same apparatus. It is found by experiment that the tension to produce the fundamental is 82.0% of that in (a). Find the total mass of the new string.

42. Given a wire 2.500 m long, whose mass is 0.150 kg. This wire is stretched between supports 2.500 m apart. Tension is supplied until the third harmonic standing wave occurs (2 nodes between the supports).

(a) Find the tension necessary to produce this result if the frequency of excitation is 125 Hz.
(b) Find the frequency of the fourth harmonic (3 nodes between supports) if all the conditions remain the same.

43. While singing in the shower, we notice that the system is resonant at certain frequencies. Consider only the end walls that are 8.00 ft apart (i.e., ignore effects due to side walls, ceiling and floor.)

(a) Calculate the first four frequencies at which resonant standing waves would occur between these walls. Assume the air is at 20.0°. \( V_{\text{sound}} = 1128.6 \text{ ft/s} \)
(b) If turning on the shower and increasing the humidity lowers the density of the air by 2.5%, leaving all other quantities unchanged, find the new fundamental resonance frequency. (A numerical value for the density of air is not needed.)

44. A tuning fork placed over an open vertical tube partly filled with water causes strong resonances when the water surface is 8 cm and 28 cm from the top of the tube and for no other positions. The speed of sound in the air in the room is 330 m/s. What is the frequency of the tuning fork?

45. An organ pipe is open at one end and closed at the other. It is adjusted so that the first overtone (the first resonant frequency higher than the fundamental) occurs when the tube is 2.25 m long. Take the velocity of sound to be 330 m/s. Report numerical answers to three significant figures.

(a) Find the wavelength of the first overtone.
(b) Find the frequency of the first overtone.
(c) Find the frequency of the fundamental.
(d) If the velocity of sound is increased by 1.00%, find the new frequency of the first overtone.

46. A string of 1.34 m in length and clamped at both ends, is excited at 250 Hz. The mass density of the string is .015 kg/m. Three nodes appear between the supports.

(a) Calculate the fundamental frequency.
(b) Calculate the tension in the string.
(c) Now the tension is increased until there are only two nodes between the supports for the same frequency of excitation. Find the new fundamental frequency and the new tension.
47. A violin string 0.700 m long is clamped at both ends. The mass of the string is 12.0 grams.

(a) Find the tension necessary so that the fundamental mode will be at a frequency of 440 Hz.
(b) Set the origin of your coordinate system \(x = 0\) at the midpoint of the string as shown. Write, as completely as possible, the function describing the waves on this string for the fundamental and the first two overtones. (Hint: Draw pictures of the waves for the three situations, and use these pictures to determine the appropriate functions.)

48. A violin string is given a tension of 200 N. The string has a mass density of 0.004 kg/m.

(a) Find the velocity of waves in this string.
(b) Find the wavelength of a 440 Hz wave in this string.
(c) If the string is attached between the supports 0.5 m apart, find a general formula for the allowed wavelengths in the system.
(d) For the three longest wavelengths you obtain in (c), find the frequency in Hz.

49. A violin string is tuned so that the fourth harmonic (three nodes between the supports) has a frequency of 1900 Hz. The tension in the string is 900 N. The supports are 0.30 m apart.

(a) Calculate the mass density of the string.
(b) If the tension is increased by 1.00%, calculate the frequency of the fundamental.
(c) Write a complete expression for the displacement \(y\), as function of time and position, for the fourth harmonic described above. Choose \(x = 0\) at the mid-point of the string.

50. A violin string is clamped between supports 0.45 m apart.

(a) If the string is tuned to a fundamental of 440 Hz with a tension of \(2.75 \times 10^3\) N, calculate the mass density of the string.
(b) If the tension is increased to \(2.85 \times 10^3\) N, calculate the new fundamental frequency.
(c) If it is desired to have the mode with two nodes between the supports be at a frequency of 1285 Hz, what tension is needed?

51. A tube is 1.45 m long and open at both ends. Resonances are found at 234 Hz, 585 Hz, 936 Hz, and 1404 Hz among others.

(a) Find the largest value of the fundamental allowed by these data.
(b) How many nodes for pressure are there for 1404 Hz—not counting the ends.
(c) Calculate the velocity of sound for this system.

52. A traveling wave is described by the function

\[ y = (1.78 \text{ mm}) \sin \left( 27.0x + 5720t + \frac{\pi}{6} \right) \]

Except where shown, all distance are in meters. Other quantities are in the usual and appropriate units.

(a) Calculate the magnitude of the velocity of the wave.
(b) Specify in words, the direction of the wave.
(c) Calculate the wavelength.
(d) Calculate the frequency in Hertz.
(e) At \(t = 0\), calculate the first positive value of \(x\) for which \(y = 0\).
53. An open tube is arranged with one end in a beaker of water. When a tuning fork (1024 Hz) is held nearby, resonances are observed for \( d = 3.00 \text{ in}, 9.45 \text{ in}, 15.90 \text{ in} \) and 22.35 in. Take the speed of sound as 1100 ft/s.

(a) For \( d = 15.90 \text{ in} \), calculate the frequency of the fundamental. Include the "end correction" calculated from the information given.

(b) If helium is added to the tube so that its density is reduced from 1.29 g/l to 1.17 g/l, calculate the new value of the fundamental in (a). Consider only the change in density of the gas in the tube.

54. A wave on a string is described by the solution: \( y = (6.25 \times 10^{-3}) \sin (575x + 425t + 0.87) \). Distances are in meters, time in seconds, and other quantities have the usual and appropriate SI units.

(a) Calculate the velocity of the wave (including direction).

(b) Calculate the maximum value of the transverse velocity.

(c) At \( t = 0 \), calculate the smallest positive value of \( x \) for which the displacement is \( +3.00 \times 10^{-3} \text{ m} \).

(d) Calculate the maximum value of the displacement.

(e) Calculate the frequency, \( f \) (the number of peaks per second passing a given point).

55. A wave on a string is described by the solution: \( y = (3.25 \times 10^{-3}) \cos (42.7x + 57.5t + 0.25) \). All distances are in meters, time in seconds, and all other quantities the usual and appropriate SI units.

(a) Calculate the velocity of the wave, including direction.

(b) Calculate the frequency, \( f \), in Hz.

(c) Calculate the maximum value of the transverse velocity.

(d) Calculate the wavelength.

(e) Calculate the maximum value of the displacement.

56. A wave on a string is described by the function \( y = (4.75 \times 10^{-3}) \sin (7.50x + 32.0t - 0.35) \). Distances are in meters, time in seconds, and other quantities have the usual and appropriate SI units.

(a) Calculate the velocity of the wave (including direction).

(b) Calculate the maximum value of the transverse velocity.

(c) Calculate the maximum value of the displacement.

(d) Calculate the frequency \( f \) (the number of peaks per second past a given point).

(e) At \( x = 0 \), calculate the smallest positive value of \( t \) (\( t > 0 \)) for which the displacement is \( 2.00 \times 10^{-3} \text{ m} \).

57. A wave on a string can be described by the solution
\[
y = (1.30 \times 10^{-3}) \sin (65.0x + 2400t)
\]
All quantities have the usual and appropriate SI units.

(a) Calculate the velocity of the wave (including direction).

(b) Calculate the frequency in Hertz.

(c) Calculate the wavelength.

(d) If the tension in the string is 45 N, calculate the mass density of the string.

(e) Calculate the first positive value of \( t \) (\( t > 0 \)) for which the displacement has its maximum negative value at \( x = 0 \).

58. The function below describes a wave traveling on a stretched string. (\( x \) is in meters and \( t \) in seconds.)
\[
y = (1.50 \text{ mm}) \sin(9.90x + 125t - \frac{\pi}{3})
\]

(a) Calculate the wavelength of the wave.

(b) Calculate the velocity of the wave, including its direction.

(c) Calculate the transverse velocity, giving its correct units and direction, for \( x = +2.00 \text{ m} \) and \( t = +3.00 \text{ s} \).

(d) Calculate the period \( T \) for the wave.

(e) If the string has a linear mass density of 0.020 kg/m, calculate the tension in the string.
59. A violin string with 30.0 cm between supports is tuned to a fundamental frequency of 440 Hz. The seventh harmonic is generated (six nodes between the supports not including those of the supports, i.e., 7 antinodes).

(a) Calculate the speed of the waves on the string.
(b) Find the frequency \textbf{AND} wavelength of the seventh harmonic.
(c) Determine the tension needed if the 30.0 cm of string has a mass of 17.0 gms.

60. Resonances are observed for an organ pipe open at one end and closed at the other for the following frequencies (none of these is the fundamental): 291 Hz; 679 Hz; 1067 Hz; 1649 Hz.

(a) Calculate the largest value of the fundamental frequency (in Hz) permitted by this data.
(b) If the speed of sound is taken to be 330 m/s, calculate the effective length of this organ pipe.
(c) If helium is mixed with air to reduce its density by 10.0%, determine the new value of the 291 Hz resonance considering \textit{only} the density change.

61. A traveling wave is described by the function

\[ y = (2.45 \text{ mm}) \cos \left( 62.5x + 7520t - \frac{\pi}{3} \right) \]

Except where shown, lengths are in meters. Other quantities are in the usual appropriate units.

(a) Calculate the magnitude of the velocity of the wave.
(b) Calculate the transverse velocity at \( t = 10.0 \text{ s} \) and \( x = 0 \).
(c) Calculate the wavelength.
(d) Calculate the frequency in Hertz.
(e) Calculate the first value of the time, \( t \), for \( t > 0 \) such that a positive peak of the wave is at \( x = 0 \).

62. A pipe is open at one end and closed at the other. The length of the pipe is 2.74 meters.

(a) The frequency of the fundamental is found to be 30.70 Hz. Calculate the speed of sound.
(b) Ignoring end effects, calculate the position of the displacement anti-node nearest to \( x = 0 \) for \( f = 153.5 \text{ Hz} \).
(c) If the density of the air in the pipe is reduced by 3.00% by adding helium (new density 97% of old density), calculate to four significant figures the new value of the fundamental, ignoring all other effects.

63. A string is clamped at both ends. The ends are 1.80 m apart. When the tension is 3.25 N, and the string is excited at 45.0 Hz, five nodes are observed between the support (not counting the ends).

(a) Calculate the mass density of the string.
(b) Calculate the value of the tension needed to produce 3 nodes between the clamps.
(c) For case (a), calculate the frequency, in Hz, of the fundamental.

64. For a pipe open at one end and closed at the other, several resonances are observed. Take the speed of sound as 340 m/s. Resonances are observed at 468.5 Hz, 736.2 Hz and 1137.8 Hz, among others. Ignore end effects.

(a) What is the largest value of the fundamental allowed by the data?
(b) What is the length of the pipe?
65. (a) A disc of mass $M$ and radius $R$ rotates on an axle through its center. Around the edge are three smaller discs of radius $\frac{1}{3}R$ and mass $\frac{1}{9}M$. Their centers are at the exact edge of the main disc. Calculate the moment of inertia of this system for rotation about the center of the main disc (shown by $A$).

(b) The planet Jupiter has a mass of approximately $1.80 \times 10^{27}$ kg. Its moon, Io, has an orbit about the planet with a period of 42.0 hours. Find the distance from Io to the center of Jupiter from this data assuming the orbit of Io is circular.

(c) Calculate the gravitational force between two spherical objects whose centers are 5.00 cm apart. One has a mass of 1.00 kg and the other a mass of 0.100 kg.

(d) A traveling wave is described by the function $y = [3.25 \times 10^{-3} \text{ m}] \cos (12.0 \times - (1.50 \times 10^3)t)$. Determine the speed of this wave.

(e) Calculate the period, on the moon, of a simple pendulum 3.00 m long.

(f) If the mass of the earth were doubled and the radius of the earth were doubled, what would be the new value of "$g$"?

66. The two blocks shown are on an inclined plane. The force $F$ is parallel to the plane. All surfaces have the same coefficients of friction.

(a) Draw careful, clear, free body and force diagrams for object 1 and object 2. Label them clearly.

(b) Calculate the maximum value of $F$ such that object 2 does NOT slide with respect to object 1.

$m_1 = 3.25 \text{ kg}; m_2 = 2.65 \text{ kg}; \mu_s = 0.60; \mu_k = 0.40; \theta = 27.0^\circ$

67. A small sphere (r $<<$ R), of mass $m$, rolls without sliding on the loop-the-loop shown. It starts with zero velocity at point A, a distance 9R above the bottom of the loop. The loop is circular.

(a) What is the speed of the center-of-mass of the sphere at point B? B is at the same level as the center of the loop.

(b) Find the normal force on the sphere at B.

(c) Find the normal force on the sphere at point C, the exact top.

68. Block 1 is at rest on the spring after all motion has ceased. Block 2 is dropped from a height $h$ above block 1 and they collide in a completely inelastic collision. The spring is long enough that its length is not an issue.

(a) Calculate the speed of blocks 1 and 2 the instant after the collision.

(b) Using $y = 0$ as shown in the diagram, find the value of $y$ (for the bottom of block 1) when the spring is at its maximum compression.

(c) What is the angular frequency of the oscillation of this system after the collision?

(d) Find the value of $y$ (the bottom of block 1) when the system comes to rest after all oscillations have died out.

$m_1 = 4.75 \text{ kg}; m_2 = 2.50 \text{ kg}; h = 1.75 \text{ m}; k = 1100 \text{ N/m}$
69. Block 2 slides on a frictionless table. The pulley is a cylinder whose radius is 3.00 cm and its mass is 2.20 kg. It turns on a frictionless axle. The rope does NOT slip on the cylinder.

(a) Using energy methods, calculate the speed of block 2 after it has moved 0.65 m from rest.
(b) Find the acceleration of block 2.

\[ m_1 = 3.40 \text{ kg}; m_2 = 7.95 \text{ kg} \]

70. Initially block 2 is at rest and the spring is at its equilibrium length. The two masses are on a frictionless table. Mass 1 is launched with an initial velocity \( v_0 \), and collides in a completely inelastic collision with Mass 2.

(a) Find the frequency \( f \), and the angular frequency \( \omega \), for the resulting oscillations.
(b) Write a complete expression describing the oscillations in the form \( x = A \cos(\omega t - \phi) \), and evaluate \( A \), \( \omega \) and \( \phi \) numerically, including the sign in front of \( \phi \).

\[ m_1 = 4.35 \text{ kg}; m_2 = 6.75 \text{ kg}; k = 750 \text{ N/m}; V_0 = 4.00 \text{ m/s} \]

71. The wave velocity on a violin string is given by

\[ v_{\text{wave}} = \sqrt{\frac{T}{\mu}} \]

where \( T \) is the tension in Newtons, and \( \mu \) the linear mass density in kg/m. A violin string is tuned so that the 2\(^{nd} \) overtone (two nodes between the supports, as shown) has a frequency of 1400 Hz.

(a) Calculate the frequency of the fundamental.
(b) Find the frequency of the 4\(^{th} \) overtone (4 nodes between supports).
(c) The tension is increased by 5.00%. Nothing else is changed. What is the new frequency of the 2\(^{nd} \) overtone (the one pictured above)?
Data: Use these constants (where it states for example, 1 ft, the 1 is exact for significant figure purposes).

1 ft = 12 in (exact)
1 m = 3.28 ft
1 mile = 5280 ft (exact)
1 hour = 3600 sec = 60 min (exact)
1 day = 24 hr (exact)

\[ g_{\text{earth}} = 9.80 \text{ m/s}^2 \]
\[ = 32.2 \text{ ft/s}^2 \]

\[ g_{\text{moon}} = 1.67 \text{ m/s}^2 \]
\[ = 5.48 \text{ ft/s}^2 \]

1 year = 365.25 days
1 kg = 0.0685 slug
1 N = 0.225 pound
1 horsepower = 550 ft·pounds/s (exact)