Problems 1 – 4 are worth 5 points each. For these problems, do your work in the space provided, and write your final answer in the blank. Points will be deducted for the wrong units or wrong number of significant digits. Other than that, no partial credit will be awarded for incorrect answers.

1. A “moving sidewalk” in an airport terminal building moves at 1.10 m/s and is 35.0 m long. If a woman steps on at one end and walks at 1.60 m/s relative to the moving sidewalk, how much time does she require to reach the opposite end, assuming she is walking in the same direction the sidewalk is moving?

   \[ \text{Time} = 13.0 \text{ s} \quad \text{and} \quad \nu = \frac{1.10 \text{ m}}{\text{s}} + \frac{1.60 \text{ m}}{\text{s}} = 2.70 \frac{\text{m}}{\text{s}} \]

   \[ l = \frac{35.0 \text{ m}}{2.70 \frac{\text{m}}{\text{s}}} = 13.0 \text{ s} \]

2. A soccer ball with mass 0.430 kg is initially moving with speed 2.00 m/s. A soccer player kicks the ball, exerting a constant force of magnitude 50.0 N in the same direction as the ball’s motion. Over what distance must the player’s foot be in contact with the ball to increase the ball’s speed to 6.00 m/s?

   \[ \text{Distance} = 0.138 \text{ m} \quad \text{and} \quad \mathbf{W} = \mathbf{F} \cdot \mathbf{d} = K_f - K_i \Rightarrow \]

   \[ d = \frac{1}{50.0 \text{ N}} \left[ \frac{1}{2} (0.430 \text{ kg}) \left( (6.00 \frac{\text{m}}{\text{s}})^2 - (2.00 \frac{\text{m}}{\text{s}})^2 \right) \right] = 0.138 \text{ m} \]

3. The horizontal beam in the figure is uniform and weighs 180 N. Find the tension in the diagonal cable.

   \[ \text{Tension} = 650 \text{ N} \]

   \[ \tau = 0 = (4.00 \text{ m}) T \left( \frac{3}{5} \right) - (4.00 \text{ m}) (300 \text{ N}) \]

   \[ - (2.00 \text{ m}) (180 \text{ N}) \]

   \[ \Rightarrow 2.40 T = 1560 \text{ N} \Rightarrow T = 650 \text{ N} \]

4. A 1.50 m long rope is stretched between two supports with a tension that makes the speed of transverse waves 49.0 m/s. What is the frequency of the fourth harmonic?

   \[ \text{Frequency} = 65.3 \text{ Hz} \quad \text{and} \quad \lambda = \frac{2L}{4} = \frac{3.00 \text{ m}}{4} = 0.750 \text{ m} \]

   \[ f = \frac{\nu}{\lambda} = \frac{49.0 \frac{\text{m}}{\text{s}}}{0.750 \text{ m}} = 65.3 \text{ Hz} \]
Problems 5 – 12 are worth 10 points each. Do your work in the space provided, and write your final answer in the blank. For these problems, partial credit will be awarded where appropriate, based on the work that you show.

5. An antelope moving with constant acceleration covers the distance between two points 72.0 m apart in 6.80 s. Its speed as it passes the second point is 15.0 m/s. (a) What is its speed at the first point? (b) What is its acceleration?

Speed at first point  \[ \frac{6.18 \text{ m}}{\text{s}} \]

Acceleration  \[ \frac{1.30 \text{ m}}{\text{s}^2} \]

\[
x = \frac{v_0 + v(t)}{2} \Rightarrow 72.0 \text{ m} = \frac{v_0 + 15.0 \text{ m}}{2}(6.80 \text{ s})
\]

\[
\Rightarrow 21.2 \frac{\text{m}}{\text{s}} = v_0 + 15.0 \frac{\text{m}}{\text{s}}
\]

\[
\Rightarrow v_0 = 6.18 \frac{\text{m}}{\text{s}}
\]

\[
v = v_0 + at \Rightarrow a = \frac{15.0 \frac{\text{m}}{\text{s}} - 6.18 \frac{\text{m}}{\text{s}}}{6.80 \text{ s}}
\]

\[
= 1.30 \frac{\text{m}}{\text{s}^2}
\]

6. When cars are equipped with flexible bumpers, they bounce off each other during low-speed collisions, thus causing less damage. In one such accident, a 1750 kg car traveling to the right at 1.50 m/s collided with a 1450 kg car going to the left at 1.10 m/s. Measurements show that the heavier car’s speed just after the collision was 0.250 m/s in the original direction. What was the speed of the lighter car just after the collision?

Speed  \[ \frac{0.409 \text{ m}}{\text{s}} \]

\[
\vec{p}_c = \vec{p}_f \Rightarrow (1750 \text{ kg})(1.50 \frac{\text{m}}{\text{s}}) - (1450 \text{ kg})(1.10 \frac{\text{m}}{\text{s}}) = (1750 \text{ kg})(0.250 \frac{\text{m}}{\text{s}}) + (1450 \text{ kg}) v_f
\]

\[
\Rightarrow 1030 \frac{\text{m}}{\text{s}} = 438 \frac{\text{m}}{\text{s}} + 1450 v_f
\]

\[
\Rightarrow v_f = 0.409 \frac{\text{m}}{\text{s}}
\]
7. An athlete whose mass is 95.0 kg is performing weight-lifting exercises. Starting from the rest position, he lifts, with constant acceleration, a barbell that weighs 510 N. He lifts the barbell a distance of 0.600 m in 1.60 s. Find the total force that his feet exert on the ground as he lifts the barbell.

Force \( \underline{1460 \text{ N}} \)

\[
y = \frac{1}{2} at^2 \Rightarrow 0.600 = \frac{1}{2} a_{\text{barbell}} (1.60^2)
\]

\[
\Rightarrow a_{\text{barbell}} = \frac{1.20}{(1.60)^2} = 0.469 \text{ m/s}^2
\]

\[
\Rightarrow F_{\text{an barbell}} = \frac{510}{9.80}\left(0.469\right) = 21.7 \text{ N}
\]

\[
\Rightarrow F_{\text{an barbell}} = 534 \text{ N}
\]

\[
\Rightarrow F_{\text{ground on a}} = 534 \text{ N}
\]

\[
+ (95.0 \text{ kg}) (9.80 \text{ m/s}^2)
\]

\[
= 1465 \text{ N}
\]
8. Adjacent antinodes of a standing wave on a string are 17.0 cm apart. A particle at an antinode oscillates in simple harmonic motion with amplitude 0.820 cm and period 0.0720 s. The string lies along the +x-axis and is fixed at \( x = 0 \). (a) Find the displacement of a point on the string as a function of position \( x \) and time \( t \). (b) Find the speed of propagation of a transverse wave along the string. (c) Find the amplitude at a point 3.00 cm to the right of an antinode.

Displacement

\[
y(x,t) = (0.820 \text{ cm}) \sin \left( \frac{18.5}{m} x \right) \sin \left( \frac{87.3}{s} t \right)
\]

Speed of wave

\[
\frac{4.72}{s}
\]

Amplitude

\[
0.697 \text{ cm}
\]

\[
y(x,t) = A_{sw} \sin \left( kx \right) \sin \left( \omega t \right)
\]

\[
A_{sw} = 0.820 \text{ cm} \quad k = \frac{2\pi}{\lambda} = \frac{2\pi}{2 \times 17.0 \text{ cm}} = \frac{100 \text{ cm}}{m}
\]

\[
= \frac{18.5}{m}
\]

\[
\omega = \frac{2\pi}{T} = \frac{2\pi}{0.0720 \text{ s}} = 87.3/s
\]

\[
u = \lambda f = \frac{\omega}{k} = \frac{87.3}{18.5} = 4.72 \frac{m}{s}
\]

First antinode is at \( x = \frac{0.170 \text{ m}}{2} = 0.0850 \text{ m} \)

\[
\Rightarrow \text{Amplitude} = (0.820 \text{ cm}) \sin \left( \frac{18.5}{m} \times 0.0850 \text{ m} \right)
\]

\[
= 0.697 \text{ cm}
\]
9. A block \( M \) with mass 3.50 kg rests on a frictionless surface and is connected to a horizontal spring of force constant \( k = 105 \text{ N/m} \). The other end of the spring is attached to a wall, as shown in the figure below. A second block \( m \) with mass 1.50 kg rests on top of the first block. The coefficient of static friction between the blocks is 0.250. Find the maximum amplitude of oscillation such that the top block will not slip on the bottom block.

Maximum amplitude \( 0.117 \text{ m} \)

**Small Block:**

Max a when \( F_f = \mu_s mg \Rightarrow \mu_s Mg = M a_{\text{max}} \)

\[ a_{\text{max}} = \mu_s g \]

**Large Block:**

\[ F_s = kA \]

\[ N_{\text{max}} = mg \]

\[ F_f = \mu_s mg \]

\[ kA - \mu_s mg = Ma_{\text{max}} = \mu_s Mg \]

\[ kA = \mu_s (m+M)g \Rightarrow A = \frac{\mu_s (m+M)g}{k} \]

\[ = 0.250 \times 5.00 \text{ kg} \times 9.80 \text{ m/s}^2 \div \left( \frac{105 \text{ N/m}}{m} \right) = 0.117 \text{ m} \]

Alternative second part:

For SHM, \( a_{\text{max}} = A\omega^2 \) with \( \omega = \sqrt{\frac{k}{m+M}} \) in this case

\[ \mu_s g = A \frac{k}{m+M} \Rightarrow A = \frac{\mu_s g (m+M)}{k} \]. Same eqn!
10. On the ride “Spindletop” at the amusement park Six Flags Over Texas, people stood against the inner wall of a hollow vertical cylinder with radius 2.6 m. The cylinder started to rotate, and when it reached a constant rotation rate of 0.60 rev/s, the floor on which people were standing dropped about 0.5 m. The people remained pinned against the wall. What minimum coefficient of static friction is required if the person on the ride is not to slide downward to the new position of the floor?

\[
\mu_s = \frac{0.27}{0.28}
\]

Need \( F_f = mg \Rightarrow mg \leq \mu_s N \)

with \( N = \frac{mu^2}{R} \Rightarrow mg \leq \mu_s \frac{mu^2}{R} \)

\[
\Rightarrow \frac{gR}{u^2} \leq \mu_s
\]

\[
\Rightarrow \frac{(9.80 \text{ m/s}^2)(2.6 \text{ m})}{\left[ \frac{2\pi(2.6 \text{ m})}{0.60 \text{ rev/s}} \right]^2} = 0.265
\]
11. A string is wrapped several times around the rim of a small hoop with radius 8.00 cm and mass 0.190 kg. The free end of the string is held in place and the hoop is released from rest. The hoop falls, as illustrated in the figure below. After the hoop has descended 80.0 cm, calculate (a) the angular speed of the rotating hoop, and (b) the speed of its center.

Angular speed \[ \frac{35.0}{s} \] 

Speed of center \[ \frac{2.80}{s} \]

\[ K_f + U_f = K_i + U_i \Rightarrow \]

\[ \frac{1}{2} M v_{cm}^2 + \frac{1}{2} I_{cm} \omega_{cm}^2 = M g H_i \]

\[ I_{cm} = MR^2 \text{ and } \omega_{cm} = \frac{v_{cm}}{R} \]

\[ \Rightarrow \frac{1}{2} M v_{cm}^2 + \frac{1}{2} MR^2 \left( \frac{v_{cm}}{R} \right)^2 = M v_{cm}^2 = M g H_i \]

\[ \Rightarrow v_{cm} = \sqrt{g H_i} = \sqrt{(9.80 \text{ m/s}^2)(0.800 \text{ m})} \]

\[ = 2.80 \text{ m/s} \]

\[ \Rightarrow \omega = \frac{v_{cm}}{R} = \frac{2.80 \text{ m/s}}{0.0800 \text{ m}} = \frac{35.0}{s} \]
12. Your starship, the *Aimless Wanderer*, lands on the mysterious planet Mongo. As chief scientist-engineer, you make the following measurements: A 2.50 kg stone thrown upward from the ground at 12.0 m/s returns to the ground in 8.00 s; the circumference of Mongo at the equator is $2.00 \times 10^7$ km; and there is no appreciable atmosphere on Mongo. The starship commander, Captain Confusion, asks you what the period will be if he places *Aimless Wanderer* in a circular orbit around Mongo 30,000 km above the surface. What do you tell him?

Orbital period $5.54 \times 10^4$ s

$$g(t) = (12.0 \m/s) t - \frac{1}{2} g_m t^2 = 0 \Rightarrow 12.0 \m/s = \frac{1}{2} g_m (8.00 \, s)$$

$$g_m = 3.00 \m/s^2.$$  

$$g_m = \frac{GM_M}{R_m^2}, \quad R_m = \frac{2.00 \times 10^8 \, m}{2\pi} = 3.18 \times 10^7 \, m$$

$$M_m = \frac{(3.00 \m/s^2) (3.18 \times 10^7 \, m)^2}{6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}} = 4.56 \times 10^{25} \, \text{kg}$$

$$T = \frac{2\pi a^3}{\sqrt{GM}} = \frac{2\pi (6.18 \times 10^7 \, m)^{3/2}}{ \sqrt{(6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}) (4.56 \times 10^{25} \, \text{kg})}}$$

$$= 5.54 \times 10^4 \, \text{s}$$