2. A. The drawing to the right shows glass tubing, a rubber bulb and two bottles. Is the situation you see possible? If so, carefully describe what has taken place in order to produce the situation depicted. The situation is possible. The density of the liquid in bottle L < P₂. Initially the bulb is squeezed and released. As a result the pressure in the glass tube < P₀ and the liquids will rise up the tubes. In both cases P₂ + Pgh = P₀. Thus, P₂gh₀ = P₁gh₂ and since P₂ < P₁, h₁ > h₂.

B. Heat is added to an unknown solid at a uniform rate. The temperature-time plot is shown to the right.

1. AB Region where solid is melting.
2. CD Region where liquid vaporizes.
3. MELTING The process involving the larger latent heat.
4. VAPOR The region showing the larger specific heat capacity.
5. Tm The melting temperature of the solid.
6. Tb The boiling temperature of the liquid.

C. The picture depicts three glass vessels, each filled with a liquid. The liquids each have different densities, and Pₐ > Pₐ > P₃. In vessel B sits an unknown block halfway to the bottom.

1. C In which vessel would the block sit on the bottom?
2. A In which vessel would the block float on the top?
3. C In which vessel would the block feel the smallest buoyant force?
4. A In which vessels are buoyant forces on the block the same?
5. SINK Assume the coefficient of volume expansion for B and the block are β₃ > β_block. If the temperature of vessel B with the block is raised would block B rise to the surface, sink to the bottom, or remain where it is?
A circular tank with a 1.50 m radius is filled with two fluids, a 4.00 m layer of water and a 3.00 m layer of oil. Use $\rho_{oil} = 824 \times 10^3 \text{ kg/m}^3$ and $\rho_{water} = 1.00 \times 10^3 \text{ kg/m}^3$, and $P_{atm} = 1.01 \times 10^5 \text{ N/m}^2$.

A. What are the gauge and absolute pressures 1.00 m above the bottom of the tank?

\[
\begin{align*}
\rho_{gauge} &= \rho_{oil} g h_{oil} + \rho_{water} g h_{water} \\
&= (824 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(1 \text{ m}) + (1.00 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(3 \text{ m}) \\
&= 3.0 \times 10^5 \text{ N/m}^2
\end{align*}
\]

\[
\rho_{abs} = \rho_{gauge} + P_{atm} = 1.01 \times 10^5 \text{ N/m}^2 + 3.0 \times 10^5 \text{ N/m}^2
\]

B. A block of material in the shape of a cube ($m = 100 \text{ kg}$ and side length = 42.0 cm) is released at the top of the oil layer. Where does the block come to rest? Justify your answer. If it comes to rest between two layers, specify which layers and what portion of the block sits in each layer.

\[
\frac{m}{V} = \frac{100 \text{ kg}}{(0.42 \text{ m})^3} = 1.35 \times 10^3 \text{ kg/m}^3 > \rho_{water} > \rho_{oil}
\]

\text{Block sinks to bottom of tank}

C. A small 1.00 cm radius opening is made in the side of the tank 0.500 m up from its base. (block was removed). What volume of water drains from the tank in 10.0 s?

\[
\begin{align*}
\frac{\Delta P}{\Delta h} &= \frac{P_1 - P_2}{h_1 - h_2} \\
&= \frac{\rho_{oil} g h_{oil} + \rho_{water} g h_{water}}{h_1 - h_2} \\
&= \frac{\rho_{water} h_{water}}{h_1 - h_2} + \frac{1}{2 \rho_{water} \Delta h} \\
&= \frac{h_{water}}{1000 \text{ kg/m}^3}
\end{align*}
\]

\[v = 10.5 \text{ cm/s}
\]

\[
\frac{\Delta V}{\Delta t} = \frac{\pi r^2 h \Delta t}{3.39 \times 10^{-2} \text{ m}^3}
\]

\[\frac{\Delta V}{\Delta t} = \pi (0.01 \text{ m})^2 (10.5 \text{ cm/s}) \\
= 3.39 \times 10^{-2} \text{ m}^3
\]
A. (10 pts.) What is the gauge venous blood pressure at the position of the wrist?

\[ P_{\text{Gauge at Wrist}} = P_{\text{Gauge at Heart}} + P_{\text{Blood} \times \text{Height above Wrist over Heart}} \]

\[ = 6.16 \times 10^3 \text{ N/m}^2 + (1.06 \times 10^3 \text{ N/m}^2)(9.8 \text{ m/s}^2)(0.25 \text{ m}) \]

\[ P_{\text{Gauge at Wrist}} = 8.74 \text{ kPa} \]

B. (11 pts.) The tube coming from the wrist is connected to a bottle of whole blood the patient needs in a transfusion. See above figure (b). What is the minimum height above the level of the heart at which the bottle must be held to deliver the blood to the patient? If fluid in bottle to be delivered to patient \( P_{\text{Gauge at Wrist (or Fluid)}} > P_{\text{Gauge at Heart}} \)

Thus \( h_{\min} \) = \( \frac{P_{\text{Gauge from A}}}{{P}_{\text{Blood}}} \)

\[ h_{\min} = \frac{8.76 \times 10^3 \text{ N/m}^2}{1.06 \times 10^3 \text{ N/m}^2(9.8 \text{ m/s}^2)} \]

\[ h_{\min} = 0.843 \text{ m} \]

C. (12 pts.) Suppose the bottle of blood is held 1.00 m above the level of the heart. Assume the tube inserted in the wrist has a diameter of 2.80 mm. What is the velocity, \( v \), and flow rate of blood as it enters the wrist. You may also assume the rate at which the blood level in the bottle drops is very small.

The answer you get here is a substantial overstatement. Blood is not really a non-viscous fluid.

USB STREAMLINE from top surface of blood in bottle to a point at end of needle in arm. Also let \( P = \text{atm} \) at needle. Also, assume \( \text{surface of blood} = \text{atm} \). Then:

\[ P_{\text{atm}} + \frac{1}{2} \rho v^2 + \rho g h = P_{\text{Wrist}} + \frac{1}{2} \rho v^2 + \rho g(0) \]

\[ v = \sqrt{2 \rho g h - \rho \Delta P_{\text{Wrist}} \text{atm} + \rho \Delta P_{\text{Wrist}}} \]

\[ \text{Note: } h = 1.00 \text{ m} + 0.25 \text{ m} \]

\[ \frac{dv}{dt} = \frac{A}{V} \frac{dV}{dt} = \frac{1.7 \times 10^{-2}}{\text{m}^3} \text{ s} \]
A block is attached to a horizontal spring and oscillates back and forth on a frictionless surface with a frequency of \( f = 3.00 \text{ Hz} \). The amplitude of this motion is \( 6.00 \times 10^{-2} \text{ m} \). Assume \( t_i = 0 \) and is the instant the block is at the equilibrium position moving to the left.

**A.** (8 pts.) Write expressions \( x(t) = A \sin (\omega t + \phi) \) and \( v(t) = A \omega \cos (\omega t + \phi) \) filling in the values of \( A, \omega, \) and \( \phi \) (the initial phase).

\[
x(t) = (6.00 \times 10^{-2} \text{ m}) \sin (6\pi t + \pi)
\]

\[
v(t) = (0.36 \text{ m/s}) \cos (6\pi t + \pi)
\]

\[
x(t_i) = 0 \Rightarrow \phi = 0, \pi \]

\[
v(t_i) = -A\omega \Rightarrow \phi = \pi
\]

Since \( \omega = \sqrt{\frac{k}{m}} \)

\[
A^2 = \omega^2 m
\]

\[
x(t) = (6 \times 10^{-2} \text{ m})(6\pi \text{ m/s})^2 = 0.09 \text{ m}
\]

**B.** (5 pts.) What is the total mechanical energy \( (E_{\text{tot}}) \) of the block-spring system?

\[
E_{\text{tot}} = \frac{1}{2} m v_{\text{max}}^2 = \left( \frac{1}{2} \right)(0.36 \text{ m/s})^2 = 0.032 \text{ J}
\]

**C.** (6 pts.) Suppose the block, at the moment it reaches its maximum velocity to the left splits in half with only one of the halves remaining attached to the spring. What are the amplitude and frequency of the resulting oscillations?

WHERE THE SPLIT OCCURS \( \frac{1}{2} \) WILL BE CARRIED AWAY BY THE SEPARATED SECTION OF BLOCK

\[
A_{\text{new}} = \sqrt{\frac{0.36 \text{ m}^2}{0.35 \text{ m}}}
\]

\[
A_{\text{new}} = 4.24 \times 10^{-1} \text{ m}
\]

\[
\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{2 \times 10^3 \text{ N/m}}{0.35 \text{ kg}}} = 26.6 \text{ rad/s}
\]

\[
\frac{\omega}{2\pi} = 4.23 \text{ Hz}
\]

**D.** (6 pts.) Suppose, instead of splitting at the position of maximum velocity to the left, the block now splits when it is at the extreme position in the left. What are the amplitude and frequency of the resulting motion?

\[
A = 6.00 \times 10^{-2} \text{ m} \text{ AS BEFORE}
\]

\[
\frac{\omega}{2\pi} = 4.23 \text{ Hz} \text{ FROM C}
\]

**E.** (6 pts.) Describe in words what would happen to the period of oscillation if a second block identical to the first block were dropped on the first block at either of its extreme positions.

A WOULD STAY THE SAME

\[
T_{\text{new}} = \frac{\omega}{2\pi} = \sqrt{\frac{k}{m}} = \frac{2\pi}{\omega}
\]

THEREFORE THE PERIOD \( T = \frac{1}{f} \) GETS LONGER
PROB. (SOLUTION)

\[ M_A \rightarrow M_B \]

\[ x = -A \quad x = 0 \quad x = A \]

(A) 1. AT \( x = A \)

2. AT \( x = 0 \)

3. DECREASED

4. INCREASED

5. STAYED THE SAME

6. DECREASED

7. ONE-HALF

(B) 1. \( \rho_{fl.} = \rho_{obt.} \)

2. a. DOES NOTHING

b. OBST. RISES TO SURFACE

c. OBST. RISES TO SURFACE

d. DOES NOTHING

e. DOES NOTHING
A. (15 pts.) A mass $m$ is attached to a spring and oscillating on a frictionless, horizontal surface. See figure. At the instant the mass passes the equilibrium position moving to the right, half the mass detaches from the other half. The oscillating system is now the spring and half the original mass with the detached mass moving off to the right with constant velocity. Relative to the original spring-mass system, the new spring-mass system with half the mass oscillates with...

In the spaces provided below, enter the words larger, smaller or the same that best completes the above sentence.

1. **smaller** amplitude
2. **smaller** period
3. **larger** frequency
4. **same** maximum velocity
5. **smaller** mechanical energy

B. (12 pts.) A solid cylinder is floating at the interface between water and oil with 3/4 of the cylinder in the water region and 1/4 of the cylinder in the oil region. See figure. Select the item in the parenthesis that best fits the statement.

1. **water** The item (oil, water, and/or cylinder) with the largest density.
2. **oil** The item (oil, water, and/or cylinder) with the smallest density.
3. **greater than** The weight of the cylinder (is equal to, greater than or less than) the total buoyant force it feels.
4. **less than** The density of the cylinder (is equal to, less than, or greater than) the density of water.

C. (19 pts.) Three thermometers in different settings record temperatures $T_1 = 1000^\circ$F, $T_2 = 1000^\circ$C, and $T_3 = 1000$ K. In the space below select $T_1$, $T_2$ or $T_3$ that best fits the statement.

1. **$T_2$** The thermometer in the hottest environment.
2. **$T_1$** The thermometer in the coolest environment.
3. **$T_3$** The thermometer reading a temperature $900^\circ$ above the boiling point of water.
An oil tanker in the shape of a rectangular solid is filled with oil 
\( \rho_\text{oil} = 880 \text{ kg/m}^3 \). The flat bottom of the hull is 48.0 m wide and sits 
26.0 m below the surface of the surrounding water. Inside the hull the 
oil is stored to a depth of 24.0 m. The length of the tanker, assumed 
filled with oil along the entire length, is 280 m.

**Note:** 
\( \rho_{\text{water}} = 1.015 \times 10^3 \text{ kg/m}^3 \)  
\( V_{\text{tanker}} = \text{length} \times \text{width} \times \text{height} \).

A. \( [12 \text{ pts.}] \) At the bottom of the hull, what is the water pressure 
on the outside and the oil pressure on the inside of the horizontal bottom part of the hull? Assume the \( P_\text{o} \) 
above the oil is the same as the \( P_\text{o} \) above the water and its value is \( P_\text{o} = 1.01 \times 10^5 \text{ N/m}^2 \).

\[
P_{\text{w}} = P_\text{o} + \rho_{\text{water}} g \, h_{\text{w}} = (1.01 \times 10^5 \text{ N/m}^2) + (1.015 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(26 \text{ m}) \\
= 3.60 \times 10^5 \text{ N/m}^2 \quad \text{6000} \text{ PSI}
\]

\[
P_{\text{oil}} = P_\text{o} + \rho_{\text{oil}} g \, h_{\text{oil}} = (1.01 \times 10^5 \text{ N/m}^2) + (880 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(24 \text{ m}) \\
= 3.05 \times 10^5 \text{ N/m}^2 \quad \text{6000} \text{ PSI}
\]

B. \( [4 \text{ pts.}] \) If you did part A correctly you determined that the water pressure on the horizontal bottom part of the hull is larger than the oil pressure there. Explain why this MUST be the case. 

\( P_\text{w} \) **MUST SUPPORT NOT ONLY THE WEIGHT OF THE TANKER BUT ALSO ALL THE OIL LOADED IN IT.**

C. \( [8 \text{ pts.}] \) What buoyant force does the tanker feel?

\[
B = \rho_{\text{FL}} V_{\text{disp}} g = \rho_{\text{FL}} \text{ length} \times \text{width} \times \text{height} \\
B = 3.48 \times 10^9 \text{ N} \\
\text{2 FOR CORRECT NUMBERS}
\]

D. \( [8 \text{ pts.}] \) What is the weight of the tanker, excluding the weight of the oil in the hull?

\[
W_T = B - W_{\text{oil}} \\
W_T = 3.48 \times 10^9 \text{ N} - (880 \text{ kg/m}^3)(280 \text{ m})(48 \text{ m})(280 \text{ m})(9.8 \text{ m/s}^2) \\
W_T = 6.94 \times 10^8 \text{ N} \\
\text{2 FOR CORRECT NUMBERS}
\]
A. Water is poured into a tall glass cylinder until it reaches a height of 24.0 cm above the bottom of the cylinder. Next, olive oil ($\rho_{oil} = 920 \text{ kg/m}^3$) is very carefully added until the total amount of fluid reaches 48.0 cm above the bottom of the cylinder. Olive oil and water do not mix. See figure. Take $\rho_{water} = 1.00 \times 10^3 \text{ kg/m}^3$ and $P_{atm} = 1.01 \times 10^5 \text{ N/m}^2$.

1. [4 pts.] Indicate on the drawing which layer is water and which is olive oil.

2. [5 pts.] What is the gauge pressure 10.0 cm below the top of the upper fluid layer in the cylinder.

\[
P_{gaue} = P_h - P_{atm} = \rho_{oil} gh_{oil} = (920 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(0.1 \text{ m}) = 902 \text{ N/m}^2
\]

3. [5 pts.] What is the gauge pressure on the bottom of the cylinder?

\[
P_{gaue} = P_{bot} - P_{atm} = \rho_{oil} gh_{oil} + \rho_{water} gh_{water}
\]

\[
= (920 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(1.24 \text{ m}) + (1030 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(0.24 \text{ m})
\]

\[
P_{gaue} = 4520 \text{ N/m}^2
\]

4. [5 pts.] If the cylinder is in the shape of a right circular cylinder with radius of 3.60 cm, what force is exerted on the bottom of the cylinder?

\[
F_{bot} = P_{bot} A = (1.013 \times 10^5 \text{ N/m}^2 + 4520 \text{ N/m}^2) \pi (0.036 \text{ m})^2
\]

\[
F_{bot} = 431 \text{ N}
\]

B. A 0.200 kg mass is hung from a massless spring. At equilibrium, the spring stretched 28.0 cm below its unstretched length. This mass is now replaced with a 0.500 kg mass. The 0.500 kg mass is lowered to the original equilibrium position of the 0.200 kg mass and suddenly released producing vertical SHM.

1. [5 pts.] What is the spring constant for this spring?

\[
h_2 = \frac{m g}{x_0} = \frac{0.2 \text{ kg}}{0.28 \text{ m}} = \frac{20 \text{ N}}{0.28 \text{ m}}
\]

\[
h_2 \approx 700 \text{ N/m}
\]

2. [5 pts.] What is the period of oscillation for the 0.500 kg/spring system?

\[
\omega = \frac{\sqrt{k}}{m} = \frac{\sqrt{700}}{0.5 \text{ kg}} = 20 \text{ s}^{-1}
\]

\[
T = \frac{2\pi}{\sqrt{\frac{k}{m}}} = \frac{2\pi}{\sqrt{\frac{700}{0.5 \text{ kg}}}} = 1.70 \text{ s}
\]

3. [5 pts.] What is the amplitude of this oscillation?

\[
x_e (N_{t+1}) = \frac{m_{new} \omega^2}{h_2} = \frac{(0.5 \text{ kg})(9.8 \text{ m/s}^2)}{700 \text{ N/m}} = 0.70 \text{ m}
\]

\[
A = x_{N+1} - x_{old} = 0.70 \text{ m} - 0.28 \text{ m}
\]

\[
A = 0.42 \text{ m}
\]
The drawing shows a possible design for a thermostat. It consists of an aluminum rod whose length is 5.00 cm at 20°C. The thermostat switches on the air conditioner when the end of the rod just touches the contact. The position of the contact can be changed with an adjustment screw. What is the size of the spacing such that the air conditioner turns on at 27°C? This is not a very practical device.

\[ 27.0°C \text{ Take } \alpha_{al} = 2.3 \times 10^{-5}/°C \]

\[ \Delta L = L_0 \alpha \Delta T \]

\[ = (0.05 \text{ m}) (2.3 \times 10^{-5}/°C) (7°C) \]

\[ \Delta L = 8.05 \times 10^{-6} \text{ m} \]

MUST BE QUITE AN ADJUSTMENT SCREW!
Problem 3 (cont'd.)

(a) In words describe the distinct stages in the cooling of lead.
1. Lead is cooled from \( T_P \) to its melting point (mp).
2. Lead freezes at its melting point.
3. The solid lead cools from its mp \( (327^\circ C) \) to the equilibrium temperature \( (218^\circ C) \).

(b) How many calories of heat are absorbed by the calorimeter and the water it contains to reach \( 21.8^\circ C \)?

\[
\begin{align*}
Q_{\text{gain}} &= m_W (21.8^\circ C - 10^\circ C) + m_{\text{al}} C_{al} (21.8^\circ C - 10^\circ C) \\
&= (100 \text{g})(1.00 \text{cal/g}^\circ C)(11.8^\circ C) + (100 \text{g})(0.21 \text{cal/g}^\circ C)(11.8^\circ C) \\
Q_{\text{gain}} &= 2240 \text{ cal}
\end{align*}
\]

(c) How many calories are lost by the lead in cooling from \( T_P \) to the final equilibrium temperature of \( 21.8^\circ C \)?

\[
\begin{align*}
Q_{\text{lost}} + Q_{\text{gain}} &= 0 \quad \text{ means } \quad Q_L = 2240 \text{ cal lost} \\
Q_{\text{lost}} &= -2240 \text{ cal}
\end{align*}
\]

(d) What was the original furnace temperature?

\[
\begin{align*}
Q_{\text{lost}} &= -2240 \text{ cal} = m_{\text{al}} C_{al} (327^\circ C - T_F) + m_{\text{al}} L_F + m_{\text{al}} C_{al} (327^\circ C - 218^\circ C) \\
&= (100 \text{ g})(0.21 \text{ cal/g}^\circ C)(327^\circ C - T_F) + (1100 \text{ g})(0.21 \text{ cal/g}^\circ C)(109^\circ C) \\
&= 997 \text{ cal} - 305 \text{ cal/}^\circ C T_F - 600 \text{ cal} - 961 \text{ cal} \\
&= -34 \text{ cal} = 3.15 \text{ cal/}^\circ C T_F \\
T_F &= \frac{-34 \text{ cal}}{3.15 \text{ cal/}^\circ C} = 11.0^\circ C
\end{align*}
\]

(e) If the same mass of aluminum \((C_{al} = 0.215 \text{ cal/g}^\circ C \text{ and } L_F = 21.5 \text{ cal/g})\) were used in the same furnace instead of lead, would the final equilibrium temperature be higher, less or the same as in the lead case? No calculation is needed to answer this. Please explain.

Since both \( C_{al} > C_{pb} \) and \( L_{al} (410^\circ C) > L_{pb} (60^\circ C) \) an equal amount of \( al \) can store more thermal energy than the same amount of \( pb \) at the same \( T \). Thus, the final \( T \) of the system will be higher for the multibed material than for the lead system.
PROBLEM 1 30 PTS TOTAL

The length of aluminum cable between consecutive support towers, carrying electricity to a large metropolitan area, is 180.00 m on a hot August day when the temperature is 38°C. Use α(Al) = 24 × 10⁻⁶/°C. See figure.

(a) What is the length of the same section of aluminum cable on a very cold winter day when T = -24°C?

\[
L_{\text{new}} = L_{\text{old}} + L_0 \alpha \Delta T = L_c \left(1 + \alpha \Delta T\right) = \left(180.00 \text{ m}\right) \left[1 + \left(24 \times 10^{-6}/\degree C\right)(-62\degree C)\right] = \left(179.73 \text{ m}\right)
\]

\[
L_{\text{new}} = 179.73 \text{ m}
\]

(b) If the same length of copper (α = 17 × 10⁻⁶/°C) cable (i.e., 180.00 m on the same hot August day) were used instead of aluminum, would the length of the copper cable be shorter, longer or the same as that of the aluminum on the same winter day as in (a). Please explain your conclusion. You do not have to do any calculations here.

Since α_C < α_AL, the |ΔL_C| < |ΔL_AL| for the same ΔT and L_0. The copper cable would shrink less than the Al. Hence, the copper cable would be longer than the aluminum cable on the same cold winter day.
You wish to make a cup of coffee with cream in a 0.250 kg mug (C_mug = 900 J/kg°C) and a 0.325 kg mug (C_coffee = 4.18 \times 10^3 J/kg°C) starting at 25.0°C and 10.0°C, respectively. You use a 50.0 W electric heater to bring the coffee, cream, and mug to a final temperature of 90.0°C. How long must the coffee system be heated?

\[ \frac{1}{T_0} = 90.0°C \]

\[
Q_{\text{gain, AD}} = M_{\text{mug}} C_{\text{mug}} \Delta T_{\text{mug}} + M_{\text{coffee}} C_{\text{coffee}} \Delta T_{\text{coffee}} + M_{\text{cream}} C_{\text{cream}} \Delta T_{\text{cream}}
\]

\[
= (0.250 kg) (3.5 \times 10^3 J/kg°C) (65°C) + (0.325 kg) (4.18 \times 10^3 J/kg°C) (65°C)
\]

\[
+ (0.0125 kg) (3.5 \times 10^3 J/kg°C) (80°C)
\]

\[
Q_{\text{gain, AD}} = 1.06 \times 10^5 J
\]

\[
Q_{\text{gain}} \text{ MUST be supplied by heater} = P \Delta t
\]

\[
\Delta t = \frac{Q_{\text{gain, AD}}}{P} = \frac{1.06 \times 10^5 J}{50 W} = 2120 \text{ s}
\]

\[
\Delta t = 35.3 \text{ minutes}
\]
A 75.0 kg patient is running a fever of 106°F and is given an alcohol rubdown to lower his body temperature. Take the specific heat of the human body to be \( c_{\text{body}} = 3.48 \times 10^3 \text{ J/kg°C} \), the heat of evaporation of the rubbing alcohol to be \( L_v(\text{alcohol}) = 8.51 \times 10^6 \text{ J/kg} \), and the density of the rubbing alcohol to be 793 kg/m³. You may assume that all the heat removed from the fevered body goes into evaporating the alcohol, and that while the patient's body is cooling, his metabolism adds no measurable heat.

\[ Q_{\text{removed}} = m \cdot c \cdot \Delta T = (75.0 \text{ kg}) (3.48 \times 10^3 \text{ J/kg°C}) (-7 ^\circ \text{C}) = -1.02 \times 10^6 \text{ J} \]

(a) What quantity of heat must be removed from the body to lower its temperature to 99.0°F?

\[ m = 75.0 \text{ kg} \]
\[ c = 3.48 \times 10^3 \text{ J/kg°C} \]
\[ \Delta T = -7 ^\circ \text{C} = -7 \left( \frac{5}{9} \right) \left( \frac{9}{5} \right) ^\circ \text{C} \]

(b) What volume of rubbing alcohol is required?

\[ Q_{\text{alcohol}} = m \cdot L_v = 1.02 \times 10^6 \text{ J} \]

\[ m = \frac{1.02 \times 10^6 \text{ J}}{8.51 \times 10^6 \text{ J/l}} = 1.19 \text{ l} \]

\[ V = \frac{m}{\rho} = \frac{1.19 \text{ l}}{793 \text{ l/kg}} = 1.50 \times 10^{-3} \text{ m}^3 = 1.50 \text{ l} \]

(c) This is a qualitative question. Give an answer and explanation. Suppose you were told that the alcohol applied started at room temperature (≈ 70°F) and were given the specific heat for the alcohol. Thus, you now expect some of the body heat warming the alcohol to the temperature of the fever before evaporation occurs. How would this effect the result of the calculation in part (b)?

Since some of the removed first warms the rubbing alcohol, then less of the alcohol needs to evaporate to remove the same total heat from the body. So

\[ V_{\text{heal}} < 1.50 \text{ l} \]
A 56.0 kg hypothermia victim is running a body temperature of 91.0°F. The victim is far away from any immediate medical treatment. Her friends decide to treat the hypothermia victim by placing the victim in a sleeping bag with one of her friends and use the heat from the friend to raise the victim's body temperature. Take the specific heat of the human body to be $C_{\text{body}} = 3.48 \times 10^3 \text{ J/kg}^\circ\text{C}$. Assume that the sleeping bag acts like a perfect calorimeter and also assume no heat is lost to or obtained from the sleeping bag. Finally, assume all the heat that warms the hypothermia victim comes from the basic metabolic heat produced by the body of the victim's friend in the sleeping bag with her and that metabolism is rated at $2.00 \times 10^3 \text{ cal/day}$, and that the victim's metabolism is negligible.

(a) How much heat must be added to the victim's body to get her temperature up to 98.0°F?

$$Q_{\text{added}} = M C_{\text{body}} \Delta T = (56.0 \text{ kg})(3.48 \times 10^3 \text{ J/kg}^\circ\text{C})(\frac{98.0}{91.0})^\circ\text{C} = 7.58 \times 10^5 \text{ J}$$

(b) How long must the victim remain in the sleeping bag with her friend to achieve this temperature change?

Heat from friend:

$$\text{Heat from friend} = \frac{4.19 \times 10^3 \text{ J}}{\text{cal}} \times \frac{1}{2.00 \times 10^6 \text{ cal}} = 3.49 \times 10^{-5} \text{ J/ln} = \frac{\Delta Q}{\Delta t}$$

Heat gained from friend:

$$\text{Heat gained from friend} = \left(\frac{\Delta Q}{\Delta t}\right) \Delta t = 7.58 \times 10^5 \text{ J}$$

$$\frac{7.58 \times 10^5 \text{ J}}{3.49 \times 10^{-5} \text{ J/ln}} = 2.17 \text{ ln}$$

07 2 HOURS 10 MIN (AND LESS)

(c) This is a qualitative question. If the thermal properties of the sleeping bag are now taken into account, but still assuming no heat leaves or enters the sleeping bag, how will the answer to question (b) above be different?

Since some of the heat derived from metabolic processes from the friend goes to heating the sleeping bag itself, then the friend must remain in the bag longer to warm not only the victim, but also the bag.
A few years back a lawsuit was filed by a woman against McDonald's because she scalded herself with a Styrofoam cup filled with coffee which she spilled on herself while driving. This question was spawned by that incredible legal action and represents a possible action taken by McDonald's to insure cooler coffee. Suppose a typical cup of coffee sold by McDonald's is basically 400 ml of hot water and when poured into the Styrofoam cup its temperature is 96.0°C. Take 1.00 ml to have a mass of 1.00 gm and \( c_{H_2O} = 4.19 \times 10^{-3} \text{kJ/kg°C} \). Neglect any heat lost to the cup and assume no heat is lost by the coffee to the environment.

A. How much heat is lost by the coffee to bring its temperature to a drinkable 68.0°C?

\[
\text{Q}_{\text{lost}} = m \cdot c_{H_2O} \cdot (T_f - T_i) = (1.00 \text{gm}) \cdot (4.19 \times 10^{-3} \text{kJ/kg°C}) \cdot (68.0°C - 96.0°C) \\
= 4.69 \times 10^{-3} \text{kJ} \quad \text{(This is heat lost)}
\]

B. McDonald's possible approach to lowering the temperature of the 96.0°C coffee to 68.0°C is to add a cube of ice initially at 0.0°C. (Take \( L_f = 334 \text{kJ/kg} \).) What mass of ice has to be added to the coffee to reduce its initial temperature to the desired 68.0°C?

\[
\text{Q}_{\text{gain}} = 4.69 \times 10^{-3} \text{kJ} = m \cdot L_f + m \cdot c_{H_2O} \cdot (T_f - T_i) \\
\Rightarrow m = \frac{4.69 \times 10^{-3} \text{kJ}}{3.34 \times 10^{-3} \text{kJ/kg} + (4.19 \times 10^{-3} \text{kJ/kg°C})(68°C)}
\]

\[
m = 0.0758 \text{ kg} = 75.8 \text{ g}
\]
A. \[ 3000 \text{ Cal} = (3 \times 10^3 \text{ Cal}) \left( 4.19 \times 10^3 \text{ J/Cal} \right) = 1.26 \times 10^7 \text{ J} \]

Assume none of the water boils away. You might wonder how you would know some does.

\[ 1.26 \times 10^7 \text{ J} = Mn_{H_2O} \cdot C_{H_2O} \cdot (T_f - 37.0^\circ C) \]

\[ T_f = \frac{1.26 \times 10^7 \text{ J}}{18 \text{ J/g}} \cdot (9.19 \times 10^3 \text{ J/g}^\circ C) + 37.0^\circ C \]

\[ T_f = 83.2^\circ C \]

B. \[ \text{Heaters} = \frac{1 \text{ heater}}{10 \text{ ft}^2} \cdot \frac{1.61 \text{ ft}^2}{100 \text{ ft}^2} \cdot 3000 \text{ Cal} \]

\[ = 4.83 \rightarrow 5 \text{ heaters} \]

C. \[ 5000 \text{ Cal} = 5 \times 10^3 \text{ Cal} \times 4.19 \times 10^3 \text{ J/Cal} = 2.095 \times 10^7 \text{ J} \]

Let's see if water reaches BP at 100°C.

\[ \text{Q (required)} = m_{H_2O} \cdot C_{H_2O} \cdot (100^\circ C - 37^\circ C) \]

\[ = (18 \text{ g}) \times (4.19 \times 10^3 \text{ J/g}^\circ C) \times (63^\circ C) = 1.116 \times 10^7 \text{ J} \]

Water does get to BP and there is Q left over to boil some of it away.

\[ \text{Q (left)} = (2.095 - 1.116) \times 10^7 \text{ J} = 3.779 \times 10^6 \text{ J} \]

\[ 3.793 \times 10^6 \text{ J} = m_{H_2O} \cdot C_{H_2O} \cdot (410^\circ C) \]

\[ m_{H_2O} = \frac{3.793 \times 10^6 \text{ J}}{3.35 \times 10^3 \text{ J/g}^\circ C} = 1.13 \text{ g} \]

\[ T_f = 100^\circ C \]
B. (12 pts.) Below is the position vs. time graph for the simple harmonic of a spring oscillation on a frictionless horizontal surface. Motion to the right is positive.

1. __ The earliest instant of time, including \( t = 0 \) at which the PE is maximum.
2. __ The earliest instant of time at which the KE of the mass is a maximum and the mass is moving to the right.
3. __ The earliest instant of time at which the acceleration of the mass is maximum and positive.
4. __ The earliest instant of time at which the speed of the mass is zero.
A spring is attached to a post at the top of a 15.0° frictionless ramp. A 2.00 kg mass is attached to the spring and the mass is slowly allowed to stretch the spring to the equilibrium position of the mass-spring system, the spring stretches by 0.400 m. See figure. The mass is now pulled an additional 10.0 cm and released. The mass-spring system executes simple harmonic motion.

1. (8 pts.) What is the spring constant, k, of the spring?
$$k = \frac{mg \sin 15.0°}{x_e} \approx \frac{20 \times 0.259}{0.10} \approx 49.3 \text{ N/m}$$

B. A solid, uniform cylinder is floating at the interface between water ($\rho_{\text{water}} = 1.00 \times 10^3 \text{ kg/m}^3$) and oil ($\rho_{\text{oil}} = 8.24 \times 10^2 \text{ kg/m}^3$) with 3/4 of the cylinder in the water region and 1/4 of the cylinder in the oil region. Assume the axis of the cylinder is perfectly vertical. See figure.

1. (8 pts.) What is the density of the material out of which the cylinder is made?
$$\rho_{\text{cyl}} = \frac{\rho_{\text{oil}} \frac{3}{4} + \rho_{\text{water}} \frac{1}{4}}{\frac{3}{4} + \frac{1}{4}} = \frac{8.24 \times 10^2 + 1 \times 10^3}{2} \approx 9.56 \times 10^2 \text{ kg/m}^3$$

2. (8 pts.) Assume the upper surface of the oil region is open to the atmosphere ($\rho_{\text{atm}} = 1.01 \times 10^5 \text{ N/m}^2$) and the oil-water interface is 0.300 m below the upper surface of the oil. Also assume the height of the cylinder is 10.0 cm. What is the gauge pressure on the bottom surface of the cylinder? Recall: $P = \rho g h$
$$P_{\text{gauge}} = \rho_{\text{atm}} g h = 4 \times 10^5 \times 0.3 \text{ N/m}^2 = 1.2 \times 10^5 \text{ N/m}^2$$
A. (14 pts.) A mass m is attached to a spring and is oscillating on a frictionless horizontal surface (see figure). At the instant the mass is at an amplitude position a second identical mass is carefully placed on top of the original mass. The oscillating system is now the spring and the two identical masses. Relative to the original spring-single mass system, the new spring-2-mass system oscillates with a ...

In the spaces provided below, enter (I) for increased, (D) for decreased, or (R) remains unchanged, that best completes the above last sentence.

1. R amplitude.
2. I period.
3. D frequency.
4. D spring constant.
5. R maximum speed.
6. D mechanical energy.
7. D maximum acceleration.

B. (14 pts.) Suppose you are asked about the absolute pressure at some depth h below the surface of a liquid. The top surface is exposed to the atmosphere on a sunny day in Salt Lake City. For each statement below in the spaces provided, enter I for increase, D for decrease, or R for remains the same, when accounting for what happens to the absolute pressure at the point you are observing.

1. D More liquid is added so now the observation point is farther below the surface.
2. I The fluid is now exchanged for a less dense fluid. The observation point is at same h.
3. D The experiment is moved to New York City, which is at sea level, on a sunny day.
4. D The fluid is now seen to be moving with some speed v past the observation point.
5. D The observation point is moved closer to the surface of the liquid.
6. D The air above the fluid is removed by a vacuum system.
7. I The apparatus is moved to a laboratory on the surface of the moon.
A 3.00 kg mass is attached to a spring (k = 52.0 N/m) that is hanging vertically from a fixed support. The mass is moved to a position 0.800 m lower than the unstretched position of the end of the spring. The spring is then released and the mass-spring system executes SHM. Take the 0.800 m of the mass as the reference location for its gravitational PE.

A. [6 pts.] What is the equilibrium position of the mass-spring system?
\[ x_{eq} = \frac{m_0 g}{k} = \frac{3.00 \times 9.8}{52} = 0.565 \text{ m} \]

B. [6 pts.] What is the amplitude of the SHM the mass-spring system executes?
\[ A = 0.800 - 0.565 = 0.235 \text{ m} \]

C. [6 pts.] What is the period of the oscillation of this system?
\[ T = 2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{3.00}{52}} = 1.51s \]

D. [6 pts.] What is the total mechanical energy of the mass-spring system at the moment the mass is released?
\[ E = \frac{1}{2} m_0 x_{eq}^2 = (3.00)(0.565)^2 = 16.65 \text{ J} \]

E. [12 pts.] What are (i) the KE of the mass and (ii) the speed of the mass when the spring is at its equilibrium position?
\[ v_{max} = \omega A = \sqrt{\frac{52}{3.00}} \times 0.235 = 0.97 \text{ m/s} \]
\[ KE_{max} = \frac{1}{2} m v_{max}^2 = (3.00)(0.97)^2 = 1.44 \text{ J} \]
A 38.0 block is moving back and forth on a frictionless horizontal surface between two springs. The spring on the right has a force constant $k_R = 2.50 \times 10^3$ N/m. When the block is between the two springs its speed $v$ is 1.82 m/s. See figure.

**A. [12 pts.]** If the block compresses the left spring to 5.62 cm beyond its uncompressed length, determine the value of $k_L$.

$$k_R = \frac{1}{2} m v^2 = (1.5)(1.82 \text{ m/s})^2 = 62.9 \text{ J}$$

$$k_R = \frac{1}{2} f_k l^2 = 62.9 \text{ J}$$

$$f_k = \frac{(2)(62.9 \text{ J})}{0.0562 \text{ m}^2} = 3.99 \times 10^4 \text{ N/m}$$

**B. [12 pts.]** What is the maximum compression of the right spring when the mass interacts with it?

$$k_R = \frac{1}{2} m a^2 = 62.3 \text{ J}$$

$$a = \sqrt{\frac{(2)(62.3 \text{ J})}{2.50 \times 10^3 \text{ N/m}}} = 0.224 \text{ m}$$

**C. [10 pts.]** What is the total time the spring on the right is compressed during a single event?

Time requested is $T/2$.

$$T/2 = \pi \sqrt{\frac{m}{f_k}} = \pi \sqrt{\frac{38 \text{ kg}}{2.5 \times 10^3 \text{ N/m}}} = (T/2) = 0.38 \text{ s}$$
Two identical containers are connected at the bottom via a tube of negligible volume and a valve which is closed. Both containers are filled initially to the same height of 1.00 m, one with chloroform ($\rho_c = 1530 \text{ kg/m}^3$) in the left chamber and the other with mercury in the right chamber ($\rho_{Hg} = 1.36 \times 10^4 \text{ kg/m}^3$). Sitting on top of each identical circular container is a massless plate that can slide up or down without friction and without allowing any fluid to leak past. The radius of the circular plate is 12.0 cm. The valve is now opened.

**A.** (20 pts.) What volume of mercury drains into the chloroform container? (Note: $V_c = \pi r^2 h$)

First find $h_{Hg}$, the height of $Hg$ in left chamber.

$$P_{atm} + \rho_c g h_{c0} = P_{atm} + \rho_{Hg} g (1.00m - h_{Hg})$$

$$\rho_c g h_{c0} + \rho_{Hg} g h_{Hg} = \rho_{Hg} g (1.00m)$$

$$h_{Hg} = \frac{\rho_c g h_{c0}}{\rho_{Hg} g - \rho_c g} = \frac{(9.8 \text{ m/s}^2)(1 \text{ m})(1.36 \times 10^4 \text{ kg/m}^3 - 1.53 \times 10^4 \text{ kg/m}^3)}{9.8 \text{ m/s}^2 \times 2.52 \times 10^4 \text{ kg/m}^3}$$

$$h_{Hg} = 0.449 \text{ m}$$

$$V_{Hg} = \pi r^2 h_{Hg} = \pi (0.12 \text{ m})^2 (0.449 \text{ m})$$

$$V_{Hg} = 2.01 \times 10^{-2} \text{ m}^3$$

**B.** (14 pts.) What mass must be placed on the plate on the chloroform side to force all the mercury, but none of the chloroform, back to the mercury chamber? Pressure supplied by mass is $P_{atm} + \frac{m g}{A_{plate}} = P_{atm} + \rho_{Hg} g h_{Hg}$

$$m = \frac{\pi r^2 g (\rho_{Hg} - \rho_c)}{\rho_{Hg} g - \rho_c g} = \pi r^2 (\rho_{Hg} - \rho_c)(1.00m)$$

$$m = \pi (0.12 \text{ m})^2 (1.36 \times 10^4 \text{ kg/m}^3 - 1.53 \times 10^4 \text{ kg/m}^3)(10 \text{ m})$$

$$m = 546 \text{ kg}$$
A 12.0 kg mass M is attached to a cord that is wrapped around a wheel in the shape of a uniform disk of radius \( r = 12.0 \) cm and mass \( m = 10.0 \) kg. The block starts from rest and accelerates down the frictionless incline with constant acceleration. See figure. Assume the disk axle is frictionless. Note: \( L_{ax} = 1/2 \ m^{2} \).

A. Use energy methods to find the velocity of the block after it has moved 2.00 m down the incline.

\[
\frac{1}{2} M \omega^2 = \frac{1}{2} \left( \frac{1}{2} m R^2 \right) \left( \frac{v}{R} \right)^2 = \frac{m v^2}{4}.
\]

\[
M g h = \frac{1}{2} m v^2 \left( \frac{R}{2} \right) \left( \frac{v}{R} \right)^2 = \frac{m v^2}{4}.
\]

\[
\omega = \sqrt{\frac{\frac{M g h}{\frac{1}{2} m + \frac{m}{4}}}} = \sqrt{\frac{120 \cdot 9.8 \cdot 0.12}{6.0 \cdot 9.8 + 2.5 \cdot 9.8}} = 4.07 \text{ m/s}
\]

B. What is the constant acceleration of the block and the angular acceleration of the wheel?

\[
v^2 = u_o^2 + 2ax
\]

\[
a = \frac{v^2}{2a} = \frac{(4.07 \text{ m/s})^2}{4 \cdot 0.3 \text{ m}} = 4.15 \text{ m/s}^2
\]

\[
\omega = \frac{a}{r} = \frac{4.15 \text{ m/s}^2}{0.12 \text{ m}} = 34.6 \text{ rad/s}^2
\]

C. How many revolutions does the wheel turn for the distance the block travels in (A)?

\[
\Delta \theta = \frac{v^2 - u_o^2}{2a} = \frac{4.07 \text{ m/s}^2}{12 \text{ m}} \cdot 0 = 0
\]

\[
\Delta \theta = \frac{(16.6 \text{ rad}) \cdot (1 \text{ rev})}{2 \pi \text{ rad}} = 2.65 \text{ rev}
\]

D. If the uniform disk were replaced by a uniform sphere with the same \( r \) and \( m \) of the disk, would the acceleration of the block attached to the sphere be larger, smaller, or the same as that for the block attached to the disk? Note: \( L_{ax} = 2/5 \ m^{2} \).

\[
\text{FOR SPHERE } v_{so} = \sqrt{\frac{M g h}{\left( \frac{r^2}{2} + \frac{m g}{5} \right)}} > v_{disk}
\]

**ACC. OR BLOCK WOULD BE LARGER**
A pulley is in the shape of a uniform disk of mass \( m = 5.00 \text{ kg} \) and radius \( r = 6.40 \text{ cm} \). The pulley can rotate without friction about an axis through the center of mass. A massless cord is wrapped around the pulley and connected to a 1.80 kg mass. The 1.80 kg mass is released from rest and falls 1.50 m. See figure. Note: \( I_{\text{Disk}} = \frac{1}{2} m r^2 \).

A. Use energy methods to determine the speed of the block after falling 1.50 m.

\[
M \frac{M g h}{2} = \frac{1}{2} M v^2 + \frac{1}{2} I \omega^2
\]

\[
\frac{1}{2} I \omega^2 = \frac{1}{2} \left( \frac{1}{2} m \pi^2 \right) \left( \frac{v}{r} \right)^2 = \frac{m v^2}{4}
\]

\[
M \frac{M g h}{2} = M v^2 \left( \frac{m}{2} + \frac{M}{2} \right)
\]

\[
\omega = \sqrt{\frac{M \frac{M g h}{2}}{\left( \frac{m}{2} + \frac{M}{2} \right)}} = \sqrt{\frac{(1.8 \text{ kg})(9.8 \text{ m/s}^2)(1.50 \text{ m})}{0.9 \text{ kg} + 1.25 \text{ kg}}} = 2.35 \text{ rad/s}
\]

\[
v = 3.51 \text{ m/s}
\]

B. What is the constant acceleration of the block and the angular acceleration of the wheel?

\[
v^2 = v_0^2 + 2ax
\]

\[
a = \frac{v^2}{2x} = \frac{(3.51 \text{ m/s})^2}{3.0 \text{ m}} = 4.10 \text{ m/s}^2
\]

\[
\alpha = \frac{a}{r} = \frac{4.10 \text{ m/s}^2}{0.064 \text{ m}} = 64.1 \text{ rad/s}^2
\]

C. How many revolutions does the pulley disk turn for the distance the block travels in (A)?

\[
\Delta \theta = \frac{\omega^2 - \omega_0^2}{2} = \frac{(3.51 \text{ rad/s})^2 - 0}{18.2 \text{ rad/s}^2} = 23.5 \text{ rad}
\]

\[
\Delta \theta = (23.5 \text{ rad}) \left( \frac{1 \text{ rev}}{2 \pi \text{ rad}} \right) = 3.73 \text{ rev}
\]

D. Suppose the disk were replaced by a uniform sphere with the same \( r \) and \( m \) of the disk. Would the acceleration of the block attached to the sphere be larger, smaller, or the same as that for the block attached to the disk? Note: \( I_{\text{Sphere}} = 2\frac{1}{2} m r^2 \).

\[

\text{Acc. of Block WOULD BE LARGER}
\]
An 700.0 N fisherman is walking toward the edge of a 200 N plank as shown. He has placed a can of worms weighing 75.0 N on the left side of the plank as indicated in the drawing. The plank is the horizontal section in the drawing.

A. Identify all the forces the plank feels before it begins to tip. Draw a free body diagram.

B. As the fisherman nears the point on the plank where it begins to tip, how do the upward forces the supports exert on the plank change?

-CROBASZ WHILE FN increases until FN = 0 AT MOMENT OF TIPPING-

C. How far a distance, as measured from the center of the right support, can he walk before the plank begins to tip? Call this distance \( n \). At tipping location \( FN = W_m + 200N + 75N = 975N \) SEE PIVOT POINT AT RIGHT SUPPORT.

\[
\begin{align*}
S_{net} &= 0 = W_m \Delta W + W_p \Delta p - W_m \Delta p \\
\Delta p &= \frac{(75N)(25m) + (200N)(10m)}{975N} \\
\Delta p &= 5.54 m
\end{align*}
\]
A 75.0 kg sign hangs from a 4.80 m uniform horizontal rod whose mass is 120 kg. The rod is supported by a cable that makes an angle of 53° with the rod. See figure. The sign hangs 3.60 m out along the rod.

A. What is the tension in the cable?

\[ \tau = \psi = P_\psi + T \sin 53^\circ = 1350 - 1170 = 0 \]  

\[ \tau = P_\psi + T \tan 53^\circ = 1350 - 1170 = 0 \]

\[ -W_s (3.40 m) + T (2.40 m \sin 53^\circ) - W_b (3.60 m) = 0 \]

\[ T = \frac{(1170 N)(3.40 m) + (1350 N)(3.60 m)}{2.40 m \tan 53^\circ} \]

\[ T = 2850 N \]

B. What are the forces \( P_v \) and \( P_h \) exerted by the wall on the left end of the rod?

From (1) above:

\[ P_h = T \cos 53^\circ = (2850 N)(.6) \]

\[ P_h = 1710 N \]

From (2) above:

\[ P_v = 735 N + 1170 N - T \tan 53^\circ \]

\[ P_v = 494 N - 2880 N \]

\[ P_v = 389 N \]

Note: \( P_v \) points down

11 PTS
A 1.00 x 10^4 N great white shark is hanging by a cable attached to a 4.00 m massless rod that can pivot at its base. See figure.

A. (12pts)

Determine the tension in the cable supporting the upper end of the rod.

\[ \sum F_x = 0 \quad \Rightarrow \quad F_x - T \cos 20^\circ = 0 \]
\[ \sum F_y = 0 \quad \Rightarrow \quad F_y + T \sin 20^\circ - W = 0 \]
\[ \sum T = 0 \quad \Rightarrow \quad \sum T = -N_{\text{rot}} W = 0 \]

\[ (R_{\text{rod}} \sin 80^\circ) T - (R_{\text{rod}} \sin 30^\circ) W = 0 \]

\[ T = \frac{W \sin 30^\circ}{\sin 80^\circ} = \frac{10^4 \text{ N}}{0.948 = 5080 \text{ N}} \]

CALL \( F_x = x \) comp
OR FORCE ON BASE
OR ROD
\( F_y = y \) comp.

SELECT BASE AS AXIS

B. (20pts)

Determine the force exerted on the base of the rod. Suggestion: Find this force by first evaluating the separate components of the force.

\[ F_x = T \cos 20^\circ = (5080 \text{ N}) \cos 20^\circ \]
\[ F_x = 4770 \text{ N} \] (6 pts)

\[ F_y = W - T \sin 20^\circ \]
\[ F_y = 10^4 \text{ N} - (5080 \text{ N}) \sin 20^\circ \]
\[ F_y = 8260 \text{ N} \] (10 pts)

\[ F = F_x \hat{i} + F_y \hat{j} = (4770 \text{ N}) \hat{i} + (8260 \text{ N}) \hat{j} \] (6 pts)
A 6.00 m uniform beam extends horizontally from a hinge fixed on a wall on the left. A cable is attached to the right end of the beam. The cable makes an angle of 30.0° with respect to the horizontal and the right end of the cable is fixed to a wall on the right. At the right end of the cable hangs a 140.0 kg mass. The mass of the beam is 240.0 kg. See figure.

A. [15 pts.] Find the tension in the cable. **This is an equilibrium problem and requires no torque.**

\[
\sum F_y = 0 = T_x + T_y + T_{wall} + T_{hoist} - T_{load} = 0
\]

\[
T = 5100 \text{ N}
\]

B. [20 pts.] Find the vertical and horizontal forces the hinge exerts on the left end of the beam.

\[
\sum F_x = 0 = T_c \cos 30° - F_H
\]

\[
F_H = T_c \cos 30° = 4410 \text{ N} \quad \text{(Correct)}
\]

\[
\sum F_y = 0 = F_V + T \sin 30° - W_B - W_L
\]

\[
F_V = (380 \text{ kg})(9.8 \text{ m/s}^2) - (5100 \text{ N}) \cdot (0.5) = 1180 \text{ N}
\]
A. The blades of a "Cuisinart" blender when run at the "mix" level, start from rest and reach 2.00 × 10^5 rpm (revolutions per minute) in 1.60 s. The edges of the blades are 3.10 cm from the center of the circle about which they rotate.

\[ \omega = 2 \times 10^5 \text{ rpm} = 2 \times 10^5 \times \frac{2 \pi}{60} \text{ rad/s} \]

\[ \alpha = \frac{2 \times 10^5 \times 2 \pi}{1.60} \times \frac{1}{60^2} = \frac{181 \text{ rad/s}^2}{1.60} \]

1. [5 pts.] What is the angular acceleration of the blades in rad/s² while they are accelerating?

2. [5 pts.] Through how many rotations did the blades travel in that 1.60 s?

\[ \theta = \frac{2 \times 10^5 \times 1.60}{2} = \frac{120 \pi}{1.6} = \frac{26.3 \pi}{1.6} \]

3. [5 pts.] If the blades have a moment of inertia of 5.00 × 10⁻⁴ kg m², what net torque did the blades feel while accelerating?

\[ \tau = \sum \tau = 5 \alpha = 5 \times (5 \times 10^{-4} \text{ kg m}^2 \cdot \text{rad/s}^2) \left( \frac{181 \text{ rad/s}^2}{1.60} \right) \]

\[ \tau = 6.55 \times 10^{-3} \text{ Nm} \]

B. A 7.50 × 10⁴ N shipping crate is hanging by a cable attached to a uniform 1.20 × 10⁻³ N steel beam that can pivot at its base. A second cable supports the beam and is attached to a wall. See figure.

1. [10 pts.] Determine the tension T in the upper cable.

\[ \sum F_x = 0 = F_{\text{lower}} - T \cos 35° \]

\[ T = \frac{6.00 \times 10^{-3} \text{ kg} \cdot \text{m/s}^2}{\cos 35°} = 8.39 \times 10^{-4} \text{ N} \]

2. [20 pts.] Determine the magnitude of the force exerted on the beam at its base.

\[ \sum F_x = 0 = F_{\text{lower}} - T \cos 35° \]

\[ F_{\text{lower}} = 4.89 \times 10^{-4} \text{ N} \]

\[ \sum F_y = 0 = F_{\text{vert}} + T \sin 35° - 1.20 \times 10^{-3} \text{ N} \]

\[ F_{\text{vert}} = 6.92 \times 10^{-4} \text{ N} \]

\[ F_{\text{total}} = \sqrt{F_x^2 + F_y^2} = \sqrt{(4.89 \times 10^{-4} \text{ N})^2 + (6.92 \times 10^{-4} \text{ N})^2} \]

\[ F_{\text{total}} = 8.07 \times 10^{-4} \text{ N} \]
The diagram shows a uniform ladder of length $L$ and weight 220 N. The ladder is sitting at an angle of 30° above the horizontal resting on the corner of a concrete wall at a point that is one-fourth the way from the end of the ladder. A 640 N construction worker is standing on the ladder one-third of the way up from the end of the ladder which is resting on the ground. Assume the corner of the wall on which the ladder rests exerts only a normal force on the ladder at the point where there is contact.

A. \[12 \text{ pts.}\] What is the magnitude of the normal force the wall exerts on the ladder?

This is an equilibrium problem. Select contact point of ladder with ground as axis.

\[
\sum F_{\text{ext}} = 0 = T_{\text{up}} + T_{\text{down}} + T_{\text{wall}} + T_{\text{ground}} = 0 + 0 - W_{\text{P}} - W_{\text{L}} + F_{\text{w}}
\]

\[
F_{\text{w}} = \frac{(640 \text{ N})(\frac{L}{3} \cos 30°) + (220 \text{ N})(\frac{L}{2} \cos 30°)}{\frac{L}{4}}
\]

\[
= \frac{1850 + 950}{3}
\]

\[
F_{\text{w}} = 374 \text{ N}
\]

B. \[24 \text{ pts.}\] Find the magnitude of both the normal force the ground exerts on the left end of the ladder and the static frictional force the ground exerts on the left end of the ladder.

\[
\sum F_x = 0 = F_{\text{w}} \cos 60° - F_{\text{fr}}
\]

\[
F_{\text{fr}} = (374 \text{ N}) \cos 60°
\]

\[
F_{\text{fr}} = 187 \text{ N}
\]

\[
\sum F_y = 0 = F_{\text{w}} - W_{\text{P}} - W_{\text{L}} + F_{\text{fr}} \sin 60°
\]

\[
F_{\text{fr}} = 640 \text{ N} + 220 \text{ N} - (374 \text{ N}) \sin 60°
\]

\[
F_{\text{fr}} = 536 \text{ N}
\]
A. A solid, right circular cylinder (radius $r = 0.150$ m, height $h = 0.120$ m) has a mass $m$. The cylinder is floating in a tank in the interface between two liquids that do not mix: water on the bottom and oil above. One-third of the cylinder is in the oil layer ($\rho_{\text{oil}} = 725$ kg/m$^3$) and two-thirds in the water layer ($\rho_{\text{water}} = 1.00 \times 10^3$ kg/m$^3$). See drawing.

Note: $V(\text{circular cylinder}) = \pi r^2 h$.

1. [10 pts.] Find the mass of the cylinder.

$$m = m_{\text{oil}} \left( \frac{2}{3} \pi r^2 h \right) + m_{\text{water}} \left( \frac{1}{3} \pi r^2 h \right) = \pi (0.15 \text{ m}) (0.12 \text{ m}) \left( \frac{2}{3} \cdot 725 \text{ kg/m}^3 \right) + \frac{1}{3} \cdot 1 \text{ kg/m}^3 \cdot \pi (0.15 \text{ m})^2 (0.12 \text{ m})$$

$$m = 7.71 \text{ kg}$$

2. [10 pts.] With the cylinder present, take the thickness of the oil layer to be 0.200 m and the thickness of the water layer to be 0.300 m. What is the gauge pressure at the bottom of the tank? Assume the top of the oil layer is exposed to the atmosphere.

$$P_{\text{gauge}} = P_{\text{abs}} - P_{\text{atm}} = P_{\text{oil}} + P_{\text{water}} = \rho_{\text{oil}} g h_{\text{oil}} + \rho_{\text{water}} g h_{\text{water}} = (725 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(0.2 \text{ m}) + (1 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(0.3 \text{ m})$$

$$P_{\text{gauge}} = 436 \text{ N/m}^2$$

B. A block rests on a frictionless horizontal surface and is attached to a spring. When set into simple harmonic motion, the block oscillates back and forth with an angular frequency of $\omega = 7.52$ rad/s. The drawing indicates the position of the block when the spring is unstretched. That position is labeled “$x = 0$ m” in the drawing. The drawing also shows a small bottle whose left edge is located at $X_b = 0.0900$ m. The block is now pulled to the right, stretching the spring by $x_s = 0.0343$ m, and is then thrown to the left, i.e., given an initial push to the left. In order for the block to knock over the bottle when it is moving to the right, it must be “thrown” with an initial speed to the left $v_0$. Ignoring the width of the block, what is the minimum value of $v_0$?

$$\text{USING ENERGY CONSERVATION}$$

$$\frac{1}{2} m v_0^2 + \frac{1}{2} k x_s^2 = \frac{1}{2} k x_b^2$$

$$v_0^2 = \frac{1}{m} \left( x_b^2 - x_s^2 \right) = \omega^2 \left( x_b^2 - x_s^2 \right)$$

$$v_0 = \left( 2 \pi \text{ rad/s} \right) \sqrt{(0.09 \text{ m})^2 + (0.034 \text{ m})^2}$$

$$v_0 = 0.626 \text{ m/s}$$
B. \(12\text{ pts.}\) Three objects, a disk \((I_{cm} = \frac{1}{2} MR^2)\), a hoop \((I_{cm} = MR^2)\), and a hollow ball \((I_{cm} = \frac{3}{5} MR^2)\) all have the same mass and radius. Each is subject to a uniform tangential force that causes the object, starting from rest, to rotate with increasing angular speed about an axis through the center of mass for each object. In the case of the hollow ball the tangential force has a moment arm equal to the radius of the ball. In the space below, enter D for disk, H for hoop, and/or B for hollow ball, or same to best answer the question.

1. **Hoop** The object with the largest moment of inertia about the axis through the CM.
2. **Same** The object experiencing the greatest net torque.
3. **Disk** The object with the greatest angular acceleration during the period the force is acting.
4. **Hoop** The object rotating with the smallest angular speed assuming the force has been acting for the same length of time on each object.

C. \(5\text{ pts.}\) Explain how an airbag protects the passengers of a car from serious injury in an accident from the perspective of the physics you learned in chapter 7 of the text.

WHEN AN ACCIDENT OCCURS AND THE AIRBAG DEPLOYS, THE IMPACT TIME DURING WHICH THE PASSENGER IS STRIKING THE AIRBAG TO BRING HER/HIM TO REST IS EXTENDED GREATLY RELATIVE TO NO AIRBAG PRESENT. AS A RESULT THE IMPACT FORCE BRINGING THE PASSENGER TO REST IS REDUCED. (LOOK FOR \(d\) LENGTHENED AND IMP REDUCED)
A. [14 pts.] A uniform disk (D), hoop (H), and sphere (S), all with the same mass and radius, can freely rotate about an axis through the center of mass (CM) of each. A massless string is wrapped around each item. The string is used to apply a constant and equal tangential force to each object. See figure. For the statements below, enter D, H, S, none or the same. Assume all objects start from rest at the same instant.

\[
\begin{align*}
\text{Disk} & : I_{\text{CM}} = 0.5 MR^2 \\
\text{Hoop} & : I_{\text{CM}} = MR^2 \\
\text{Sphere} & : I_{\text{CM}} = 0.4 MR^2
\end{align*}
\]

1. S The one with the smallest moment of inertia about the shown axis.
2. same The object experiencing the largest net torque.
3. H The object undergoing the smallest angular acceleration.
4. S The object with the largest angular speed after an elapsed time of 5.0 s.
5. S The object for which the largest amount of string has unraveled in 5.0 s.
6. H The object with the smallest KE_{rot} after 5.0 s.
7. S The object that undergoes the most rotations in 5.0 s.

B. [14 pts.] A spherical object is completely immersed in a liquid of density \(\rho_{\text{inl}}\) some distance above the bottom of the vessel. See figure. The upper surface is initially open to the earth’s atmosphere at sea level. Assume the liquid and object are both incompressible. For the items below, indicate whether the object sinks to the bottom (B), rises to the surface (T), or does nothing (N).

1. N The vessel is brought to Salt Lake City.
2. T Salt is dissolved in the liquid in the same way fresh water is turned into salt water.
3. N The top 50 cm\(^3\) of the liquid is removed from the vessel.
4. T The entire apparatus is transported to the surface of the moon.
5. T The volume of the spherical object is increased by heating it without heating the liquid.
6. N The spherical object is moved 10 cm farther down in the vessel and released.
7. N A mass is placed on the top surface of the liquid in the vessel increasing the pressure at the surface. No fluid leaks.
A 2.20 \times 10^3 \text{ N} uniform beam is attached to an overhead beam as shown in the drawing. A 3.60 \times 10^3 \text{ N} trunk hangs from an attachment to the beam two-thirds of the way down from the upper connection of the beam to the overhead support. A cable is tied to the lower end of the beam and is also attached to the wall on the right.

A. \[5 \text{ pts.}\] What is the tension in the cable connecting the lower end of the beam to the wall? \text{ \textit{USE ROT. EQUIL.}}

\[ \sum T = 0 = T_{\text{total}} \]
\[ = T_{\text{FV}} + T_{\text{FH}} + T_{\text{WB}} + T_{\text{WL}} + T_{\text{T}} \]
\[ = 0 + 0 - W_{\text{B}} l_{\text{B}} - W_{\text{L}} l_{\text{L}} + T_{\text{T}} \]
\[ 0 = - (2.2 \times 10^3 \text{ N})(\frac{2}{3} \text{ L} \sin 37^\circ) - (3.6 \times 10^3 \text{ N})(\frac{2}{3} \text{ L} \sin 37^\circ) + T_{\text{T}} \]
\[ 0 = (2.2 \times 10^3 \text{ N})(0.3) + (3.6 \times 10^3 \text{ N})(0.4) + T_{\text{T}} \]
\[ T_{\text{T}} = \frac{(2.2 \times 10^3 \text{ N})(0.3) + (3.6 \times 10^3 \text{ N})(0.4)}{1} \]
\[ T_{\text{T}} = 2100 \text{ N} \]

B. \[5 \text{ pts.}\] What are the vertical and horizontal components of the force the overhead beam exerts on the upper end of the beam at P? \text{ \textit{USE TRANSLATIONAL EQUILIBRIUM}}

\[ \sum F_x = 0 = T_{\text{total}} \cos 37^\circ - F_{\text{FH}} \]
\[ F_{\text{FH}} = (2100 \text{ N}) \cos 37^\circ \]
\[ F_{\text{FH}} = 1680 \text{ N} \]

\[ \sum F_y = 0 = F_{\text{V}} + T_{\text{total}} \sin 37^\circ - W_{\text{B}} - W_{\text{L}} \]
\[ F_{\text{V}} = 2.2 \times 10^3 \text{ N} + 3.6 \times 10^3 \text{ N} - (2100 \text{ N}) \sin 37^\circ \]
\[ F_{\text{V}} = 4540 \text{ N} \]
A. A 12.0 kg block moves back and forth on a frictionless horizontal surface between two springs. The spring on the right has a force constant $k = 825 \text{ N/m}$. When the block arrives at the spring on the right, it compresses that spring 0.180 m from its unstretched position.

1. [9 pts.] What is the total mechanical energy of the block and two spring system?

$$M_E(\text{SYSTEM}) = \frac{1}{2} k \Delta x^2 = (15)(825 \text{ N/m})(0.18 \text{ m})^2$$

$$M_E(\text{SYSTEM}) = 13.45 \text{ J}$$

2. [9 pts.] With what speed does the block travel between the two springs while not in contact with either spring? $M_E (\text{SYS.}) = \frac{1}{2} m v_{max}^2$  

$$v_{max} = \sqrt{\frac{2(M_E)}{m}}$$

$$v_{max} = \sqrt{\frac{2(13.45 \text{ J})}{12.0 \text{ kg}}} = 1.49 \text{ m/s}$$

3. [9 pts.] Suppose the block, after arriving at the left spring, remains in contact with that spring for a total time of 0.650 s, before separating on its way to the right spring? Using the connection between this 0.650 s and the period of oscillation between the block and the left spring, determine the spring constant of the left spring.

$$T = 1.305 \text{ s} = 2\pi \sqrt{\frac{m}{k_L}}$$

$$k_L = \left(\frac{2\pi}{1.305}\right)^2 m = \left(\frac{2\pi}{1.305}\right)^2 (12.0 \text{ kg})$$

$$k_L = 280 \text{ N/m}^2$$

B. [10 pts.] A turkey baster (see figure) consists of a squeeze bulb attached to a plastic tube. When the bulb is squeezed and released, with the open end of the tube under the surface of the turkey gravy, the gravy rises in the tube to a distance $h$, as shown in the drawing. It can then be squirted over the turkey. Using $P_{\text{atm}} = 1.013 \times 10^5 \text{ N/m}^2$ for atmospheric pressure and $1.10 \times 10^3 \text{ kg/m}^3$ for the density of the gravy, determine the absolute pressure of the air in the bulb with the distance $h = 0.160 \text{ m}$. Give answer to three significant digits.

At the level of the gravy at the bottom of the tube, $P = P_{\text{atm}}$. Thus,

$$P_{\text{atm}} = P_{\text{air}} + P_{\text{gravy}}$$

$$P_{\text{air}} = P_{\text{atm}} - P_{\text{gravy}} = 1.013 \times 10^5 \text{ N/m}^2 - (1.1 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(0.16 \text{ m})$$

$$P_{\text{air}} = 9.96 \times 10^4 \text{ N/m}^2$$
EXAM 4

A. [9 pts.] The pictures below depict three glass vessels, each filled with a liquid. The liquids each have different densities, and \( \rho_A > \rho_B > \rho_C \). In vessel C an unknown block is neutrally buoyant halfway to the bottom and completely submerged.

![Image of three vessels labeled A, B, and C]

A, B, and/or C, or none are all possible answers.

1. \( \text{NON answer} \) In which vessel(s) would the block sink all the way to the bottom?
2. \( A \) In which vessel(s) would the largest volume of the block be exposed above the surface of the liquid?
3. \( A, B, C \) In which vessel(s) would the buoyant forces on the block be the same?

B. [15 pts.] A swinging pendulum (A) and a mass-spring system (B) are built to have identical periods. For the statements below enter either A, B, U (unchanged) to best fit which oscillating system would have the larger period as a result of the change.

1. \( B \) The mass of the mass-spring system is increased.
2. \( U \) The mass of the swinging pendulum is increased without altering the location of its center of mass.
3. \( A \) The spring constant of the mass-spring system is increased.
4. \( A \) The length of the swinging pendulum system is increased.
5. \( A \) Both systems are taken to the moon and set oscillating.

C. [9 pts.] A block of mass \( m \) moves back and forth on a frictionless surface between two springs. See drawing. Assume \( k_L > k_R \). For the statements below enter L for the left spring, R for the right spring, or same as the case may be.

![Diagram of two springs with block]

1. \( R \) The spring that has the maximum compression when \( m \) is momentarily at rest.
2. \( \text{SAME answer} \) The spring that stores the larger elastic potential energy when maximally compressed.
3. \( L \) The spring that momentarily stops the block in the least time once the block arrives at the spring.
A uniform beam extending at right angles from a wall is used to display an advertising sign for an eatery. The beam is 2.50 m long and weighs 80.0 N. The sign, whose dimensions are 1.00 m by 0.800 m, is uniform, and weighs 200. N, hangs from the beam as shown in the drawing. A cable, attached to the wall of the eatery at a point on the beam where the inside end of the sign is attached to the beam and making an angle of 60.0° with the beam, supports this advertising structure.

A. \(60 \text{ pts.}\) What is the magnitude of the tension in the cable supporting the beam? \(\Sigma F_i = 0\)

\[ \Sigma F_i = \Sigma F_T + \Sigma F_R + \Sigma F_v + \Sigma F_{W_R} + \Sigma F_{W_S} = 0 \]

\[ T \cdot l_T + 0 + 0 - W_R \cdot l_R - W_S \cdot l_S = 0 \]

\[ T = \frac{W_R \cdot l_R + W_S \cdot l_S}{l_T} = \frac{(80 \text{ N})(1.25 \text{ m}) + (200 \text{ N})(2.00 \text{ m})}{1.30 \text{ m}} \]

\[ T = 385 \text{ N} \]

B. \(40 \text{ pts.}\) What are the magnitudes of the horizontal and vertical forces the wall exerts on the left end of the beam? \(\Sigma F_x = 0\) AND \(\Sigma F_y = 0\)

\[ \Sigma F_x = 0 = F_H - T \cos 60^\circ \]

\[ F_H = (385 \text{ N})(0.5) = 192 \text{ N} \]

\[ F_H = 192 \text{ N} \]

\[ \Sigma F_y = 0 = T \sin 60^\circ - F_v - W_R - W_S \]

\[ F_v = -(80 \text{ N} + 200 \text{ N}) + (385 \text{ N})(\sin 60^\circ) \]

\[ F_v = 53.4 \text{ N} \]
A. [20 pts.] Examine the picture shown to the right. Initially, before the pump is turned on, the two masses \(m_1 = 1.00\ \text{kg}, \ m_2 = 2.75\ \text{kg}\) are held in place. The pressures above and below \(m_1\) are \(P_{\text{atm}} = 1.01 \times 10^5 \text{N/m}^2\) and the spring is in its unstretched position. The pump is turned on and the masses are allowed to move. The mass \(m_1\) moves without friction inside a cylindrical piston of radius \(r = 3.85\ \text{cm}\). Once equilibrium is established, by what distance has the spring stretched? Take \(k = 2.00 \times 10^3 \text{N/m}\) for the spring constant.

\[
\frac{m_1}{T - m_1 g} - P_{\text{atm}} A = 0
\]

\[
\frac{m_2}{T - m_2 g} + 2kx = 0
\]

\[
x = \frac{P_{\text{atm}} A - (m_2 - m_1) g}{2k}
\]

\[x = 0.227\ \text{m}\]

B. [16 pts.] A solid cylinder (radius 0.125 m and height 0.150 m) has a mass of 6.50 kg. The cylinder is floating in water. Oil \((\rho_{\text{oil}} = 725 \text{ kg/m}^3)\) is poured on top of the water until the situation shown in the drawing results. How much of the height (in meters) of the cylinder remains in the water layer?

\[
m_{\text{cyl}} = \rho_{\text{oil}} \cdot \text{Vol}_{\text{oil}} + \rho_{\text{H}_2\text{O}} \cdot \text{Vol}_{\text{H}_2\text{O}}
\]

\[
6.50\ \text{kg} = (725\ \text{kg/m}^3)(1.15\ \text{m})^2 x + (103\ \text{kg/m}^3)(1.15\ \text{m})^2 (1.5 \text{m})
\]

\[
\frac{6.50\ \text{kg}}{103\ \text{kg/m}^3} = 525\ \text{kg/m}^3 x - 103\ \text{kg/m}^3 x + (103\ \text{kg/m}^3)(1.15\ \text{m})
\]

\[
x = \frac{(160 - 132) \text{kg/m}^3}{225 - \text{kg/m}^3}
\]

\[x = 0.0639\ \text{m}\]

This is amount in oil layer

\[= 0.150\ \text{m} - 0.0639\ \text{m} = 0.086\ \text{m}\]