1) A 15.0 N force ($F_r$) is applied to a cord wrapped around a pulley with a radius $R_o = 33.0$ cm. The pulley is observed to accelerate uniformly from rest to reach an angular speed of 30.0 rad/s in 3.00 s. The pulley rotates on an axle about its center and there is a frictional torque $\tau_f = 1.10$ N·m at the axle. What is the moment of inertia of the pulley?

\[ \sum M_0 = I_0 \omega \]
\[ F \cdot R_o - \tau_f = I_0 \left( \frac{\omega_f - \omega_0}{t} \right) \]
\[ 15.0 \text{N} \times (33 \text{cm}) = I_0 \left( \frac{30 \text{rad/s} - 0}{3 \text{sec}} \right) \]

**ANSWER:** $I_0 = 0.385 \text{kg} \cdot \text{m}^2$

2) A uniform disk (i.e., a thin solid cylinder) turns at 7.0 rev/s around a frictionless spindle. A non rotating solid rod of the same mass as the disk and length equal to the disk's diameter is dropped onto the freely spinning disk such that their centers are aligned. What is the angular velocity of the combined disk-rod system?

Conservation of Momentum about $z$ axis

\[ I_1 \omega_1 = I_2 \omega_2 \]
\[ \left( \frac{1}{2} m r^2 \right) \omega_1 = \left( \frac{1}{2} m r^2 + \frac{1}{12} m (2r)^2 \right) \omega_2 \]
\[ \frac{1}{2} \omega_1 = \left( \frac{1}{2} + \frac{1}{3} \right) \omega_2 \]
\[ \Rightarrow \omega_2 = \frac{3}{5} \omega_1 \]
\[ \omega_2 = \frac{3}{5} (7.0 \text{ rev/s}) \]

**ANSWER:** $\omega_2 = 4.2 \text{ rev/s}$
3) A 20.0 m long uniform beam weighing 605 N is supported on walls A and B as shown.
   a) Find the maximum weight a person can be to walk to the extreme end D without tipping the beam.
   b) What are the forces that walls A and B exert on the beam when the person whose weight was calculated in part a) is standing at point D?

\[ \sum F_y = N_A + N_B - W_b - W_p = 0 \]
\[ \Rightarrow N_B = W_b + W_p = 605N + 605N = 1210N \]
\[ \Rightarrow N_A = 0 \]

ANSWER: \( W_p = 605N, N_B = 1210N \), \( \frac{W_A}{N} = 0 \) 3 SF

4) A shop sign weighing 215 N is supported by a uniform 155-N beam. The guy wire is made of steel (Elastic Modulus \( E = 210 \times 10^9 \) Pa, Ultimate Strength \( U_S = 475 \times 10^6 \) Pa) and must have minimum factor of safety of 3.50. What is the minimum diameter of the guy wire?

\[ \sum \Delta = -W_b (0.85m) - W_b (1.70m) + T \sin 35^\circ (1.35m) = 0 \]
\[ \Rightarrow T = 642 N \]
\[ \sigma = \frac{T}{\frac{d^2}{4}} = \frac{W_S}{SF} \]

ANSWER: \( d = 2.45 \times 10^{-3} \) m = 2.45 mm, 3 SF
5) When a mass of 180 g is attached to a vertical spring and lowered to its equilibrium position, it is found that the spring extends 12 cm. If the mass is now displaced from its equilibrium position and released, what is the period of the resulting oscillation?

\[ F = mg = -kx \]
\[ 0.18 \text{ kg} \times 9.81 \frac{m}{s^2} = -k \times 0.12 \text{ m} \]
\[ k = 14.7 \frac{N}{m} \]
\[ \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{14.7 \text{ N/m}}{0.18 \text{ kg}}} = 9.04 \frac{1}{s} \]
\[ T = \frac{2\pi}{\omega} = \frac{2\pi}{9.04} \approx 0.70 \text{ s} \]

**ANSWER:**

\[ T \approx 0.70 \text{ s} \]

6) A simple pendulum of length 2.00 m is used to measure the acceleration of gravity at the surface of a distant planet. If the period of such a pendulum is 6.00 s, what is the local acceleration of gravity?

\[ T = 2\pi \sqrt{\frac{L}{g}} \]
\[ \frac{T^2}{4\pi^2} = \frac{L}{g} \]
\[ g = \frac{L}{\frac{T^2}{4\pi^2}} = \frac{2.0 \times 4\pi^2}{6^2} \frac{m}{s^2} \]
\[ g = 2.19 \frac{m}{s^2} \]

**ANSWER:**

\[ g \approx 2.12 \frac{m}{s^2} \]
7) Water flows at a rate of 0.25 L/s through a garden hose of inside diameter 2.0 cm. What is the speed of the water in the hose? The nozzle of the hose is a circular opening of diameter 1.0 cm. What is the speed of the water when it emerges?

\[ Q = V_1A_1 = V_2A_2 \]
\[ V_2 = \frac{Q}{A_2} \]
\[ V_1 = \frac{A_2}{A_1} V_2 \]

\[ \rho \text{ is cons. of mass} \]
\[ (\rho VA)_1 = (\rho VA)_2 \]
\[ \text{Const. density} \]

\[ Q = \frac{0.25 \text{ L}}{s} \times \frac{1,000 \text{ cm}^3}{\text{L}} = \frac{320 \text{ cm}^3}{s} = 3.2 \text{ m}^3/s \]

\[ V_{\text{noz}} = \left(0.25 \frac{\text{L}}{\text{s}}\right) \times \frac{1,000 \text{ cm}^3}{\text{L}} \times \frac{\pi (0.50 \text{ cm})^2}{\text{cm}^3} = 320 \frac{\text{cm}^3}{\text{s}} = 3.2 \frac{\text{m}^3}{\text{s}} \]

\[ V_{\text{hose}} = 0.25 V_{\text{noz}} = 0.87 \frac{\text{m}^3}{\text{s}} \]

**ANSWER:**

\[ V_{\text{hose}} = 0.87 \text{ m}^3/\text{s} \]

\[ V_{\text{nozzle}} = 3.2 \text{ m}^3/\text{s} \]

8) Calculate the volume occupied by 1.0 mol of an ideal gas at 20 C and atmospheric pressure. Use this volume to calculate the mass density of air, whose molecular weight, M, is 29 g/mol.

\[ \rho V = mR \]
\[ V = \frac{mR}{\rho} \]
\[ V = \frac{(1.0)(8.3 \frac{1}{\text{mol K}})(293 \text{K})}{1.0 \times 10^5 \text{Pa}} = 0.024 \text{ m}^3 \]

\[ \frac{\rho - m}{\rho} = m^3 \]

\[ \rho_{\text{air}} = \frac{29 \text{ g}}{0.024 \text{ m}^3} = 1.2 \frac{\text{kg}}{\text{m}^3} \]

\[ V = 0.024 \text{ m}^3 \]

**ANSWER:**

\[ \rho_{\text{air}} = 1.2 \frac{\text{kg}}{\text{m}^3} \]
9) A power plant generates 800 MW of electric power. At what rate does the plant generate waste heat if its efficiency is 28%? Assuming the plant operates between 480°C and 80°C, what is the maximum efficiency possible?

\[ T_h = 480 + 273 = 753 \text{ K} \]

\[ \eta = \frac{W}{Q_h} \]

\[ \eta_{\text{max}} = 1 - \frac{T_c}{T_h} \]

First Law: \[ W = Q_h - Q_c \]

We find the rate at which heat is absorbed from the hot reservoir from

\[ \frac{dQ_h}{dt} = \frac{dW}{dt}/\eta = \frac{(800 \text{ MW})}{0.28} = 2.9 \times 10^3 \text{ MW} = 2.9 \text{ GW} \]

We find the heat flow transferred to the cold reservoir from energy conservation:

\[ dW/dt = (dQ_h/dt) - (dQ_c/dt); \]

\[ 800 \text{ MW} = 2.9 \times 10^3 \text{ MW} - (dQ_c/dt), \] which gives

\[ dQ_c/dt = 2.9 \times 10^3 \text{ MW} = 2.1 \text{ GW}. \]

The maximum efficiency is

\[ \eta_{\text{max}} = 1 - T_c/T_h = 1 - 353/753 \text{ K} = 53.1\% \]

ANSWER:

\[ Q_c = 2100 \text{ MW} = 2.1 \text{ GW} \]

\[ \eta_{\text{max}} = 53.1\% \]

10) A 9.0 mm (diameter) Xian short-barreled experimental pistol is fired, and the explosive gases push the bullet out the barrel of the gun. The pressure is carefully recorded as the bullet accelerates to the exit. Here is a sample of the data collected (the “real” data will include many more points and be a much “smoother” curve). What is the total work done on the bullet?

Position of Bullet | Pressure in the Chamber Behind the Bullet - x 10^5 N/m²
--- | ---
Down the Barrel - cm | 25 | 25 | 15 | 10 | 5.0
0.0 | 2.0 | 4.0 | 6.0 | 8.0

\[ W = \sum P dV = \text{AREA UNDER CURVE} \]

\[ = 13 \text{ SQUARES} \]

\[ W = 13 \times .645 = 8.3 \text{ J} \]

ANSWER:

\[ W = 8.3 \text{ J} \]
11) What is the Reynolds number? Describe it physically and mathematically and explain why it is so important in engineering calculations. Be concise limiting your discussion to what is really important/significant about the Reynolds number.

(See review notes)

12) Describe the Ideal gas law physically and mathematically, discuss the assumptions used in its development and from an engineering standpoint discuss the significance of the ideal gas law.

(See review notes)