1. (1 pt) To determine the minimum force $P$ to tip over the chair, the best place to sum moments about is:
   a. A, the left side of the chair
   b. B, the middle of the chair
   c. C, the right side of the chair
   d. D, the point of application of the force

2. (1 pt) Jupiter has a semi-major axis 5.2 AU and an eccentricity of 0.05. The closest Jupiter gets to the sun is:
   a. 0.26 AU
   b. 4.94 AU
   c. 5.20 AU
   d. 5.46 AU
   e. 10.14 AU

3. (1 pt) A Canada goose floats with 25% of its body below water. What is the density of a Canada goose?
   a. $0.25 \rho_{\text{water}}$
   b. $0.75 \rho_{\text{water}}$
   c. $1.25 \rho_{\text{water}}$
   d. $4.0 \rho_{\text{water}}$

4. (1 pt) Two identical spheres are dropped into two different liquid columns. Both liquids have the same viscosity, but liquid A is denser than liquid B. In which liquid will the terminal velocity be higher?
   a. Liquid A
   b. Liquid B
   c. Both will have the same terminal velocity

5. (1 pt) Two simple pendulums have the same length, but the mass of A is twice the mass of B. The amplitude of oscillation of A is also twice that of B. What is the period of pendulum B?
   a. $T_B = 0.25T_A$
   b. $T_B = 0.5T_A$
   c. $T_B = T_A$
   d. $T_B = 2T_A$
   e. $T_B = 4T_A$

6. (1 pt) Of these properties of a wave, which one is independent of the others?
   a. wavelength
   b. speed
   c. frequency
   d. amplitude

7. (1 pt) A trombone and bassoon play notes of equal loudness with the same fundamental frequency. The two sounds differ primarily in:
   a. pitch
   b. intensity level
   c. amplitude
   d. timbre
   e. wavelength

8. (1 pt) A light ray is traveling from air into water (index of refraction of 1.33). Part of the ray will be reflected and part of the ray will be refracted. Which of the following statements is true?
   a. the refracted angle will be less than the reflected angle
   b. the refracted angle will be equal to the reflected angle
   c. the refracted angle will be greater than the reflected angle
9. (1 pt) A brass plate has a hole cut in it. As the brass plate is heated, the hole will:
   a. decrease in size
   b. stay the same size
   c. increase in size
   [ans: c]

10. (1 pt) An ideal gas has a volume of $V_0$. The temperature and pressure are each tripled during a process. The new volume is:
   a. $V_0/9$
   b. $V_0/3$
   c. $V_0$
   d. $3V_0$
   e. $9V_0$
   [ans: c]

11. (1 pt) As an ideal gas is compressed at constant temperature,
   a. heat flows out of the gas
   b. internal energy of the gas does not change
   c. the work done by the gas is zero
   d. both statement a and b
   e. both statement a and c
   f. both statement b and c
   [ans: d]

12. (1 pt) A cold bottle of Mellow Yellow is placed in a room. Which of the following is a true statement, where $\Delta S_{MY}$ is the change in entropy of the Mellow Yellow, $\Delta S_{Air}$ is the change in entropy of the air, and $\Delta S_{sys}$ is the change in entropy of the system.
   a. $\Delta S_{MY} > 0$, $\Delta S_{Air} < 0$, $\Delta S_{sys} > 0$
   b. $\Delta S_{MY} < 0$, $\Delta S_{Air} < 0$, $\Delta S_{sys} < 0$
   c. $\Delta S_{MY} < 0$, $\Delta S_{Air} > 0$, $\Delta S_{sys} > 0$
   d. $\Delta S_{MY} < 0$, $\Delta S_{Air} > 0$, $\Delta S_{sys} < 0$
   [ans: b]

13. (1 pt) The electric field at a point in space is a measure of:
   a. the total charge on an object at that point
   b. the electric force on any charged object at that point
   c. the charge-to-mass ratio of an object at that point
   d. the electric force per unit mass on a point charge at that point
   e. the electric force per unit charge on a point charge at that point
   [ans: e]

14. (1 pt) Which of these units can be used to measure electric potential?
   a. N/C
   b. J
   c. V-m
   d. V/m
   e. N·m/C
   [ans: e]

15. (1 pt) Which type of current is easier to transform to a different voltage?
   a. Alternating current
   b. Direct current
   c. Both are easily transformed
   d. Neither is easily transformed
   [ans: a]

16. (1 pt) A -2.6$\mu$C charged particle is moving with a velocity of 340i m/s through the magnetic field of 0.032$\mu$ T. The force on the particle is:
   a. 28.3i $\mu$N
   b. 28.3j $\mu$N
   c. 28.3k $\mu$N
   d. -28.3i $\mu$N
   e. -28.3j $\mu$N
   f. -28.3k $\mu$N
   [ans: b]
17. (7 pts) Determine the magnitude and direction of the reaction at the roller support. **A separate, complete FBD is required for full credit.**

\[
\begin{align*}
\Sigma M_a &= F_{by} (12 \text{ ft}) - 300 \text{ lb} (8 \text{ ft}) + 200 \text{ lb} (5 \text{ ft}) \\
F_{by} &= 117 \text{ lb}
\end{align*}
\]

18. (7 pts) A platform is supported by four brass posts that have a 0.25 in. x 0.5 in. rectangular cross-section and are 3 in. long. The strain in one post is $5 \times 10^{-4}$. Assuming each post is equally loaded, determine the force on the platform, and the factor of safety against yielding. \((E = 16 \times 10^6 \text{ psi}, \text{ yield stress} = 24000 \text{ psi})\)

**Force on platform = 4000 lb**

**Factor of safety against yielding = 3**

\[
\begin{align*}
\sigma &= E \varepsilon = 16 \times 10^6 \text{ psi} \times (5 \times 10^{-4}) = 8000 \text{ psi} \\
\sigma &= \frac{F_{\text{one}}}{A} \\
F_{\text{one}} &= E \varepsilon A = 16 \times 10^6 \text{ psi} \times (5 \times 10^{-4}) \times (0.25 \text{ in.} \times 0.05 \text{ in.}) \\
&= 1000 \text{ lb} \quad (F_{\text{one}} \times 4 \text{ posts} = 4000 \text{ lb}) \\
FS &= \frac{\sigma y}{\sigma} = \frac{24000 \text{ psi}}{8000 \text{ psi}} = 3
\end{align*}
\]
19. (7 pts) A water pump is placed at the bottom of a 20 ft deep well. The pump outlet has an area of 0.10 ft$^2$. The water comes out at the ground surface through a nozzle that has an area of 0.03 ft$^2$. The required flow rate is 240 gallons/minute. Determine the required pump pressure.

\[ V_2 = \frac{Q_2}{A_2} = \frac{240 \text{ gal/min}}{0.03 \text{ ft}^2} = 8000 \text{ ft}^3/\text{min} \]

\[ V_1 A_1 = V_2 A_2 \]

\[ V_1 (0.1 \text{ ft}^2) = 17.825 \text{ ft/s} (0.03 \text{ ft}^2) \]

\[ V_1 = \frac{53475}{53475} \text{ ft/s} \]

\[ p_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2 \]

\[ p_1 + \frac{1}{2} \left( \frac{62.4 \text{ lb/ft}^3}{32.2 \text{ ft/lb}} \right) (5.3475 \text{ ft/s})^2 = 0 \]

\[ p_1 = 1529 \text{ lb/ft}^2 \]

20. (7 pts) Dr. Bennett places his granddaughter in a baby jumper, which is a seat suspended by an elastic cord from a doorway. The unstretched length of the cord is 1.2 m and the cord stretches by 0.20 m when 6.8 kg Lydia is placed in the jumper. Dr. Bennett pulls the seat down 8 cm and releases her. Determine the period of motion and the maximum speed of Lydia.

**Period of motion** = 0.897 sec

**Maximum speed** = 0.560 m/s

\[ F = kx \]

\[ (6.8 \text{ kg})(9.81 \text{ m/s}^2) = k (0.2 \text{ m}) \]

\[ k = 333.54 \text{ N/m} \]

\[ w = \sqrt{\frac{k}{m}} = \sqrt{\frac{333.54 \text{ N/m}}{6.8 \text{ kg}}} = 7 \text{ rad/sec} \]

\[ T = \frac{2\pi}{w} = 0.897 \text{ sec} \]

\[ A = 0.08 \text{ m} \]

\[ V_{\text{max}} = Aw = 7 \text{ rad/sec} (0.08 \text{ m}) = 0.560 \text{ m/s} \]
21. (7 pts) A 0.8 m string has a mass per unit length of 1.4 g/m and a tension of 12 N. Determine the wavelength of the sound wave produced in air by this string. Assume the speed of sound is 343 m/s.

\[ \lambda = 5.93 \text{ m} \]

\[ \frac{V}{\lambda} = \frac{n}{2L} \sqrt{\frac{T}{\mu}} \]

\[ \frac{343 \text{ m/s}}{\lambda} = \frac{1}{2(0.8 \text{ m})} \sqrt{\frac{12 \text{ N}}{1.4 \text{ gram/kg}}} \]

Order of magnitude
-1

22. (7 pts) We are standing by the side of the road when Prof. McCord drives by in her Prius. The frequency of the sound of the car after her passing is 0.92 times what it was as she approached. How fast is Dr. McCord driving? Assume the speed of sound in air is 343 m/s.

\[ f_2' = f_0 \frac{V}{V-V_S} \]

\[ f_2' = f_0 \frac{V}{V+V_S} \]

\[ \frac{f_2'}{f_1} = 0.92 = \frac{V}{V-V_S} \]

\[ V - V_S = \frac{343 - V_S}{343 + V_S} \]

\[ V_S = 14.3 \text{ m/s} \]
23. (7 pts) Prof. Biegalski starts with 0.9 kg of ice at 0°C and 2.1 kg of water at 0°C. She adds 600,000 cal of heat, 80% of which actually goes into heating the ice/water mixture. Determine the mass of water that boils away.

\[ 200.7 \text{ g} \]

\[ Q_{\text{remaining}} = 480,000 \text{ cal} - 71,640 \text{ cal} = 408,360 \text{ cal} \]

\[ \frac{m_{\text{boil}}}{540 \text{ cal/g}} = 1083.6 \text{ g} \]

\[ m_{\text{boil}} = 200.7 \text{ g} \]

24. (7 pts) Determine the work done in one cycle of the heat engine.

\[ 83.4 \text{ kJ} \]

\[ W_{\text{isothermal}} = nRT \ln \frac{V_2}{V_1} \]

\[ pV = nRT \Rightarrow T = \frac{pV}{nR} \]

\[ W = nR \left( \frac{pV}{nR} \right) \ln \frac{V_2}{V_1} = pV \ln \frac{V_2}{V_1} = 100 \text{ kPa} \left( \frac{0.24 m^3}{0.02 m^3} \right) \ln \left( \frac{0.24 m^3}{0.02 m^3} \right) = -59.6 \text{ kJ} \]

\[ W_{B\rightarrow A} = 100 \text{ kPa}(0.24 m^3 - 0.02 m^3) + \frac{1}{2} (1200 \text{ kPa} - 100 \text{ kPa})(0.24 m^3 - 0.02 m^3) = 22 \text{ kJ} + 121 \text{ kJ} = 143 \text{ kJ} \]

\[ W_{\text{TOTAL}} = 143 \text{ kJ} - 59.6 \text{ kJ} = 83.4 \text{ kJ} \]
25. (7 pts) The compressor of a refrigerator follows the cycle shown. The coefficient of performance of the refrigerator is 2.5. Determine the amount of heat extracted from the refrigerator in each cycle.

\[ K = \frac{|Q_c|}{|W|} \]

\[ 2.5 = \frac{|Q_c|}{12 \text{ kJ}} \]

\[ Q_c = 30 \text{ kJ} \]

\[ W_{\text{done}} = (500 - 200) \text{ kPa} \left( 0.06 - 0.02 \right) \text{ m}^3 = 12 \text{ kJ} \]

-2 \Rightarrow \text{ changing } K \text{ to EER}
-2 \Rightarrow \text{ solving for } Q_c \text{ instead of } W
-1 \Rightarrow W = 22 \text{ kJ}

26. (7 pts) Determine the magnitude and direction of the force on \( q_3 \) from the other two point charges, \( q_1 \) and \( q_2 \).

\[ 0.00466 \text{ N at } 68^\circ \text{ CCW from } X \]

\[ |F_{q_{13}}| = k \frac{q_1 q_3}{(r_{13})^2} = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \frac{(1.4 \text{ nC})(0.2 \text{ nC})}{(1.7 \text{ m})^2} = 0.00175 \hat{i} \text{ N} \]

\[ |F_{q_{23}}| = k \frac{q_2 q_3}{(r_{23})^2} = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \frac{(0.6 \text{ nC})(0.2 \text{ nC})}{(0.5 \text{ m})^2} = 0.00432 \hat{j} \text{ N} \]

\[ |F| = \sqrt{0.00175^2 + 0.00432^2} = 0.00466 \text{ N} \]

\[ \tan^{-1} \left( \frac{0.00432}{0.00175} \right) = 68^\circ \]
27. (7 pts) Two circuits are constructed using identical batteries (3 V) and 
identical light bulbs (resistance = 8 Ω). Find the power that is dissipated 
in each light bulb for each circuit.

Circuit 1: Power dissipated = 0.281 W

Circuit 2: Power dissipated = 1.125 W

Circuit 1:
\[ V = 3 \text{ Volts}, \quad I = (16 \Omega) = 0 \]
\[ I_1 = \frac{3}{16} \text{ amps} \]
\[ P = \frac{V^2}{R} = \frac{1.5^2}{8} = 0.281 \text{ Watts} \]

Circuit 2:
\[ V = 3 \text{ Volts}, \quad I = (R_{eq}) = 0 \]
\[ R_{eq} = 4 \Omega, \quad I_{eq} = \frac{3}{4 \Omega} = 0.75 \text{ Amps} \]
\[ I_1 + I_2 = 0.75 \text{ Amps} \]
\[ I_1 = 0.375 \text{ Amps}, \quad I_2 = (0.375 \text{ A})^2 (8 \Omega) = 1.125 \text{ W} \]

28. (7 pts) A defibrillator consists of a 15 μF capacitor that is charged to 9.0 kV. The capacitor is discharged in 
2.0 ms. Determine how much charge is passed through the body tissues and the average power delivered to 
the tissues.

Charge = 0.135 C

Power = 304 kW

\[ C = \frac{Q}{V} \]
\[ 15 \times 10^{-6} \text{ F} = \frac{Q}{9 \times 10^3 \text{ V}} \]
\[ Q = 0.135 \text{ C} \]

\[ U = \frac{1}{2} CV^2 = \frac{1}{2} (15 \times 10^{-6} \text{ F})(9000 \text{ V})^2 \]
\[ = 607.5 \text{ J} \]

\[ \frac{U}{t} = \frac{607.5 \text{ J}}{2 \times 10^{-3} \text{ sec}} = 304 \text{ kW} \]