Remember:
Show all your work for full credit. Minimum of 4 steps:

- Draw a diagram !!
- What equation are you plugging into?
- What numbers are you substituting?
- What is your final answer?

Ask if anything seems unclear.

Vectors have magnitude and direction or two components!

Formulae and Constants:
Note: **bold** means vector!

\[ g = 9.80 \text{ m/s}^2 = 980 \text{ cm/s}^2 \]
\[ G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2 \]
\[ f_k = \mu_k F_N \]
\[ f_s \leq \mu_s F_N \]
\[ a_c = a_{\text{radial}} = v^2 / r \]
\[ F = GM_1 m_2 / r^2 \]
\[ W = \oint \vec{F} \cdot d\vec{r} = - U \]
\[ F_x = -dU/dx \]
\[ K = \frac{1}{2} mv^2 \]
\[ \vec{p} = m\vec{v} \]
\[ F = d\vec{p}/dt \]
\[ \text{Impulse} = \int \vec{F} \, dt = \Delta \vec{p} \]
\[ \vec{r} = \vec{r} \times \vec{F} = F \cos \theta \]
\[ \tau = F \sin \theta \]

\[ i = \vec{r} \times \vec{p} \]
\[ I = \sum m \, r^2 = \int r^2 \, dm \]
\[ I_c = \text{I}_{cm} + M h^2 \]
\[ \text{stress} = F/A \]
\[ \text{strain} = \Delta L/L \]
\[ \text{stress} = (\text{modulus})(\text{strain}) \]
\[ \omega_{\text{spring}} = \sqrt{k/m} \]
\[ \omega_{\text{pend}} = \sqrt{g/L} \]
\[ U_{\text{spr}} = \frac{1}{2} kx^2 \]
\[ F_{\text{spring}} = -kx \]
\[ x = x_m \cos (\omega \cdot t + \phi_0) \]
\[ \beta_1 - \beta_0 = 10 \log (I_1/I_0) \]
\[ I_0 = 1 \times 10^{-12} \text{ W/m}^2 \]
\[ v = \lambda f = \omega / k \]
\[ v_{\text{sound}} = 343 \text{ m/s in air} \]
\[ v_{\text{light}} = 3 \times 10^8 \text{ m/s} \]
\[ v_{\text{string}} = \sqrt{F_T / \mu} \]
\[ v_{\text{sound}} = \sqrt{B / \rho} \]

\[ f' = f \left( v \pm v_D \right) / \left( v \pm v_S \right) \]

\[ P = \frac{1}{2} \mu v^2 \gamma_m^2 = \text{constant} \times \gamma_m^2 \]
\[ I = \frac{1}{2} \rho v^2 s_m^2 = \text{constant} \times s_m^2 \]

\[ n = c/v \]
\[ \lambda_n = \lambda / n \]
\[ d \sin \theta_m = m \lambda \quad (m = 0, 1, 2, ...) \]
\[ a \sin \theta_m = m \lambda \quad (m = 1, 2, ...) \]
1. (9 pts) You have 2 waves given as follows:
\[ y_1 = (7.00 \text{ mm}) \sin [4.0 \times x + 5.0 \times t] \]
\[ y_2 = (10.0 \text{ mm}) \sin [4.0 \times x + 5.0 \times t + 2\pi/3] \]
where \( x \) is in m and \( t \) is in seconds.
(a) What are the units of the constant “4.00”?
(b) Sketch the phasors associated with these two waves and their sum in the space to the right.
(c) Calculate the amplitude and phase of the sum of the 2 waves, \( y_1 + y_2 \).

2. (6 pts) A police car (with siren frequency 500 Hz) is traveling east at 35.0 m/s on his way to the scene of an accident. At the same time, an ambulance is heading west towards the same accident at 25.0 m/s.

Write an equation (with all numbers substituted) for the frequency that the ambulance driver hears for the police siren. Don’t calculate.

3. (15 pts) An organ pipe, open at both ends, has length \( L = 1.44 \text{ m} \).
(a) Draw a sketch on the first axis below showing the displacement wave of the fundamental frequency, then draw one showing the second allowed wave, and repeat showing the third allowed wave.
(b) On your second diagram, indicate the positions of the nodes by labeling them with the letter N and the positions of the antinodes using the letter A.
(c) What is the speed of the fundamental wave?
(d) What is the wavelength of the fundamental wave?
(e) What is the frequency of the fundamental wave?
4. (5 pts) The volume on your stereo system is turned from 40 dB to 75 dB. What is the ratio of the final intensity to the original intensity?

5. (8 points) Assume that we lived somewhere on Earth where the Sun can be directly overhead. On a day when the Sun is directly overhead, you stand outside and look directly east.

(a) We see the blue sky because the sunlight scatters off the molecules in the atmosphere. **Draw** a light ray that comes from the Sun that can be seen by the observer looking east.

(b) Circle the polarization(s) in the diagram to the right that **could** be present in the **sunlight** as it enters the atmosphere from above.

(c) Circle the polarization(s) in the diagram to the right that reflect toward the **observer**.

6. **thin films question omitted**
7. (5 pts) I have two waves in a string. One of them is given below,

\[ y_1 = (7.00 \text{ mm}) \sin [4.0 \times - 5.0 \text{ t}] \]

where \( x \) is in m and \( t \) is in seconds.

Write the function for a wave that produces beats when added to the first wave.

8. (25 pts) The pattern of bright and dark spots shown below is due to a green laser shining on two slits. I have made it darker on the page where the light is brighter on the screen.

(a) Sketch a graph of intensity as a function of position for the pattern shown above. Match the horizontal scales.

(b) Assume the diagram above is to scale. Determine the spacing between adjacent fringes by making the most appropriate measurement(s) on the diagram above. Mark the distance that you measure on the diagram.

Distance measured: ______________________

Spacing between adjacent fringes: ________________

(c) Calculate the separation of the slits if they are located a distance \( L = 2.40 \text{ m} \) from the screen and if the light had wavelength 546 nm.

(d) Label the center bright spot with a zero, it is the zeroth order maximum.

(e) What is the path difference for this maximum? ____________

(f) Number the rest of your maxima with the appropriate value of \( m \) (the integer number of wavelengths of path difference).
9. (10 pts) **Real double slits** You are given the following plots of intensity as a function of position. All are to the same horizontal scale, but the vertical scales are adjusted to have the same maximum values.

(a) Order these by slit separation $d$ from largest to smallest. Use $=$ if two are the same.

(b) Order these by slit width $a$ from largest to smallest. Use $=$ if two are the same.

(c) For Pattern A, determine the ratio of the slit separation $d$ to the slit width $a$. 