Multiple choice (4 pts each) – circle the correct answers.

1. From book Mult Choic 18.21 You use a converging lens to make a focused image on a viewing screen. A piece of cardboard is lowered \textit{just in front} of the lens to cover the top half of the the lens. What happens to the image on the screen?

   (a) The upper half of the image will vanish.
   (b) The lower half of the image will vanish.
   (c) The image will become fuzzy and out of focus.
   (d) The image will become dimmer.
   (e) Nothing \textbf{2 points given for this answer}

2. From book MC 15.23 A sinusoidal wave traveling on a string with a tension of 16 N has a period of 0.25 s, a wavelength of 40 cm, and an amplitude of 8 cm. The speed of the wave is \textbf{(answer: use wavelength/period)}

   \begin{align*}
   (a) & \quad 10 \text{ cm/s} \\
   (b) & \quad 160 \text{ cm/s} \\
   (d) & \quad 32 \text{ cm/s} \\
   (e) & \quad 1 \text{ cm/s} \\
   (f) & \quad 16 \text{ cm/s}
   \end{align*}

3. From book MC 16.26 Two guitar strings made of the same type of wire have the same length. String 1 has a higher pitch than string 2. Circle \textit{all} of the correct statements.

   (a) The wave speed of string 1 is greater than that of string 2. \textbf{4 pt add}
   (b) The tension in string 2 is greater than that in string 1. \textbf{2 pt off}
   (c) The wavelength of the lowest standing-wave mode on string 2 is longer than that on string 1. \textbf{1 pt off}
   (d) The wavelength of the lowest standing-wave mode on string 1 is longer than that on string 2. \textbf{2 pt off}

4. From book Mult Choic 17.24 Yellow light of wavelength 590 nm passes through a 10-µm-wide slit and is viewed on a screen 2.0 m behind the slit. If the width of the slit is narrowed, the band of light on the screen will

   (a) become narrower, if slit is widened
   (b) become wider, if slit is narrowed
   (c) stay about the same.

5. Based on book Mult Choic 19.18 The distance between the objective and eyepiece of a telescope is 55 cm. The focal length of the eyepiece is 5 cm. What is the focal length of the objective? \textbf{answer: } L = f_o + f_e

   (a) 11 cm
   (b) 25 cm
   (c) -25 cm
   (d) 60 cm
   (e) none of the above.

6. Light from a flower goes through the lens of your eye and an image of the flower is formed on the back of your eye. The image is

   (a) upright.
   (b) flipped.
   (c) \underline{upright} or flipped depending on how close the flower is to your eye.
Problems: Show all work to receive full credit.
In all problems choose the positive x-direction to be to the right
and the positive y-direction to be up.

6 pts 1. From book Prob 19.33,19.52 The planet Neptune is $4.5 \times 10^{12}$ m from the earth. Its diameter is $4.9 \times 10^7$ m. What diameter telescope objective would be necessary to just barely see Neptune as a disk rather than as a point of light? Assume a wavelength of 550 nm. The condition for the image to be distinguishable is that the angular size be at least as big as $\theta_1 = 1.22\lambda/D$ where $D$ is the diameter of the lens. The angular size of the planet is $\tan \theta = D_p/L_p$ where $D_p$ is the planet diameter and $L_p$ is the distance to the planet.

$$\theta = \tan^{-1}\left(\frac{4.9 \times 10^7 \text{ m}}{4.5 \times 10^{12} \text{ m}}\right) = 1.09 \times 10^{-5} \text{ rad} \quad D = 1.22 \frac{550 \times 10^{-9} \text{ m}}{1.09 \times 10^{-5}} = 0.062 \text{ m} \quad (V1)$$

$$\theta = \tan^{-1}\left(\frac{2.3 \times 10^6 \text{ m}}{7.1 \times 10^{12} \text{ m}}\right) = 3.24 \times 10^{-7} \text{ rad} \quad D = 1.22 \frac{490 \times 10^{-9} \text{ m}}{3.24 \times 10^{-7}} = 1.85 \text{ m} \quad (V2)$$

$$\theta = \tan^{-1}\left(\frac{4.6 \times 10^7 \text{ m}}{2.9 \times 10^{12} \text{ m}}\right) = 1.59 \times 10^{-5} \text{ rad} \quad D = 1.22 \frac{520 \times 10^{-9} \text{ m}}{1.59 \times 10^{-5}} = 0.040 \text{ m} \quad (V3)$$

6 pts 2. Based on book Prob 18.73 A slide projector creates a 90.0 cm high image of a 2.0 cm tall slide. The screen is 300 cm from the lens. (a) How far is the slide from the lens? (b) What is the focal length of the lens? You need the thin lens equation and the magnification equation to solve this problem. The magnification equation $m = h'/h = -s'/s$ lets you find $s$ from $s'$. Once you have that use the thin lens equation to find the focal length. Important that you remember that $h'/h$ is negative for a real image.

$$s = -s' \frac{h}{h'} = -300 \text{ cm} \frac{2 \text{ cm}}{-90 \text{ cm}} = 6.67 \text{ cm} \quad (V1)$$

$$\frac{1}{f} = \frac{1}{300 \text{ cm}} + \frac{1}{6.67 \text{ cm}} = 0.153 \text{ cm}^{-1} \quad f = \frac{1}{0.153 \text{ cm}^{-1}} = 6.52 \text{ cm} \quad (V1)$$

$$s = -s' \frac{h}{h'} = -250 \text{ cm} \frac{2 \text{ cm}}{-80 \text{ cm}} = 6.25 \text{ cm} \quad \left(V2\right)$$

$$\frac{1}{f} = \frac{1}{250 \text{ cm}} + \frac{1}{6.25 \text{ cm}} = 0.164 \text{ cm}^{-1} \quad f = \frac{1}{0.164 \text{ cm}^{-1}} = 6.10 \text{ cm} \quad (V2)$$

$$s = -s' \frac{h}{h'} = -210 \text{ cm} \frac{2 \text{ cm}}{-70 \text{ cm}} = 6.00 \text{ cm} \quad \left(V3\right)$$

$$\frac{1}{f} = \frac{1}{210 \text{ cm}} + \frac{1}{6.00 \text{ cm}} = 0.171 \text{ cm}^{-1} \quad f = \frac{1}{0.171 \text{ cm}^{-1}} = 5.83 \text{ cm} \quad (V3)$$
3. From book Prob 16.29 Two loudspeakers emit sound waves along the x-axis. The sound has a maximum intensity when the speakers are 24 cm apart. The sound intensity decreases as the distance between the speakers is increased, reaching zero at a separation of 30 cm. (a) What is the wavelength of the sound? (b) If the distance between the speakers continues to increase, at what separation will the intensity next again be a maximum? As the speaker is moved from the first to the second distance they go from constructive interference to destructive interference. This is $\lambda/2$. The next max is another $\lambda/2$ past the second distance.

$$\lambda = 2 \times (30 \text{ cm} - 24 \text{ cm}) = 12 \text{ cm} \quad D = 30 \text{ cm} + 6 \text{ cm} = 36 \text{ cm} \quad (V1)$$

$$\lambda = 2 \times (40 \text{ cm} - 32 \text{ cm}) = 16 \text{ cm} \quad D = 40 \text{ cm} + 8 \text{ cm} = 48 \text{ cm} \quad (V2)$$

$$\lambda = 2 \times (35 \text{ cm} - 28 \text{ cm}) = 14 \text{ cm} \quad D = 35 \text{ cm} + 7 \text{ cm} = 42 \text{ cm} \quad (V3)$$

4. Based on book Prob 15.53 Ginger (mass 60 kg) uses a 3.5-m-long rope to pull Sandra (mass 70 kg) across the floor at a constant speed of 1.3 m/s. The rope has a mass of 120 g. Sandra signals to Ginger by plucking the rope, sending a wave pulse. The pulse reaches Ginger 200 ms later. What is the tension in the rope? The speed of the wave can be found from the distance traveled divided by how long it took. The speed and the tension for a wave on a ”string” is $v = \sqrt{T/\mu}$ which can be rearranged to give $T = \mu v^2$ where $\mu = M/L$.

$$v = \frac{3.5 \text{ m}}{0.2 \text{ s}} = 17.5 \frac{\text{m}}{\text{s}} \quad \mu = \frac{0.12 \text{ kg}}{3.5 \text{ m}} = 0.0343 \frac{\text{kg}}{\text{m}}$$

$$T = 0.0343 \frac{\text{kg}}{\text{m}} \times (17.5 \frac{\text{m}}{\text{s}})^2 = 10.5 \text{ N} \quad (V1)$$

$$v = \frac{3.0 \text{ m}}{0.2 \text{ s}} = 15.0 \frac{\text{m}}{\text{s}} \quad \mu = \frac{0.21 \text{ kg}}{3.0 \text{ m}} = 0.070 \frac{\text{kg}}{\text{m}}$$

$$T = 0.070 \frac{\text{kg}}{\text{m}} \times (15.0 \frac{\text{m}}{\text{s}})^2 = 15.8 \text{ N} \quad (V2)$$

$$v = \frac{4.0 \text{ m}}{0.2 \text{ s}} = 20.0 \frac{\text{m}}{\text{s}} \quad \mu = \frac{0.14 \text{ kg}}{4.0 \text{ m}} = 0.0350 \frac{\text{kg}}{\text{m}}$$

$$T = 0.0350 \frac{\text{kg}}{\text{m}} \times (20.0 \frac{\text{m}}{\text{s}})^2 = 14.0 \text{ N} \quad (V3)$$
The angular positions of the bright spots are given by $d \sin \theta_m = m\lambda$ where $m = -2, -1, 0, 1, 2$ are the bright spots shown in the figure. You can use geometry to find the angles: $y_m = L \tan \theta_m$ where $L$ is the distance to the screen. For (a), solve for $\theta_1$ using geometry and then find $d$ using the physics relation. For (b), use the $d$ you found in (a) to predict where the $m = 2$ bright spot should be.

\[
\theta_1 = \tan^{-1} \left( \frac{41.1 \text{ cm}}{110 \text{ cm}} \right) = 20.5^\circ \quad d = \frac{1 \times 600 \times 10^{-9}}{\sin 20.5^\circ} = 1.714 \times 10^{-6} \text{ m}
\]

Number of lines = \frac{1 \times 10^{-3} m}{1.714 \times 10^{-6} m} = 583 \text{ lines/mm}

\[
\theta_2 = \sin^{-1} \left( \frac{2 \times 600 \times 10^{-9}}{1.714 \times 10^{-6}} \right) = 44.4^\circ \quad y = 110 \text{ cm} \times \tan(44.4^\circ) = 107.8 \text{ cm}
\]

y = L_a + L_b = 41.1 \text{ cm} + 66.7 \text{ cm} = 107.8 \text{ cm} \quad \text{OK} \quad (V1)

\[
\theta_1 = \tan^{-1} \left( \frac{49.3 \text{ cm}}{120 \text{ cm}} \right) = 22.3^\circ \quad d = \frac{1 \times 600 \times 10^{-9}}{\sin 22.3^\circ} = 1.579 \times 10^{-6} \text{ m}
\]

Number of lines = \frac{1 \times 10^{-3} m}{1.579 \times 10^{-6} m} = 633 \text{ lines/mm}

\[
\theta_2 = \sin^{-1} \left( \frac{2 \times 600 \times 10^{-9}}{1.579 \times 10^{-6}} \right) = 49.5^\circ \quad y = 120 \text{ cm} \times \tan(49.5^\circ) = 140.3 \text{ cm}
\]

y = L_a + L_b = 49.3 \text{ cm} + 91.0 \text{ cm} = 140.3 \text{ cm} \quad \text{OK} \quad (V2)

\[
\theta_1 = \tan^{-1} \left( \frac{48.0 \text{ cm}}{110 \text{ cm}} \right) = 23.6^\circ \quad d = \frac{1 \times 600 \times 10^{-9}}{\sin 23.6^\circ} = 1.500 \times 10^{-6} \text{ m}
\]

Number of lines = \frac{1 \times 10^{-3} m}{1.500 \times 10^{-6} m} = 667 \text{ lines/mm}

\[
\theta_2 = \sin^{-1} \left( \frac{2 \times 600 \times 10^{-9}}{1.500 \times 10^{-6}} \right) = 53.1^\circ \quad y = 110 \text{ cm} \times \tan(53.1^\circ) = 146.6 \text{ cm}
\]

y = L_a + L_b = 48.0 \text{ cm} + 98.7 \text{ cm} = 146.7 \text{ cm} \quad \text{OK} \quad (V3)
Basic Mathematic Formulas

\[ \sin \theta = \frac{O}{H} \quad \cos \theta = \frac{A}{H} \quad \tan \theta = \frac{O}{A} \quad H^2 = O^2 + A^2 \quad A_{\text{circ}} = \pi r^2 \]

\[ C_{\text{circ}} = 2\pi r \quad V_{\text{sph}} = \frac{4\pi}{3} r^3 \quad A_{\text{surf of sph}} = 4\pi r^2 \quad x = -\frac{b \pm \sqrt{b^2 - 4ac}}{2a} \]

\[ F_{\text{net}} = F_1 + F_2 + \ldots = m\ddot{a} \quad \tau = rF_\perp = rF \sin \phi \quad F = \frac{mv^2}{r} \]

\[ m_p = 1.67 \times 10^{-27} \text{ kg} \quad m_e = 9.11 \times 10^{-31} \text{ kg} \quad u = 1.66 \times 10^{-27} \text{ kg} \quad m_o = 4u \]

Index of refraction: Water (1.33), Ethyl Alc. (1.36), Glass (1.50), Diamond (2.42)

Chapter 15

\[ y(x, t) = A \cos \left( 2\pi \left[ x \lambda + \frac{t}{T} \right] \right) \]

\[ T = \frac{1}{f} \quad v = f\lambda \quad v_{\text{str}} = \sqrt{T_s/\mu} \quad v_{\text{snd}} = 343 \text{ m/s} \]

\[ c = 3.00 \times 10^8 \text{ m/s} \quad I = P/A \quad I = P_{\text{src}}/(4\pi r^2) \quad f_\pm = f_0/(1 [\pm|v_s/v|]) \quad f_{\pm} = (1 [\pm|v_o/v|])f_0 \]

Chapter 16

\[ \lambda_m = 2L/m \quad f_m = m(v/[2L]) \quad m = 1, 2, 3... \]

Chapter 17

\[ w = 2\lambda L/a \quad a \sin \theta_p = p\lambda \quad y_p = L \tan \theta_p \quad p = 1, 2, 3... \]

\[ d \sin \theta_m = m\lambda \quad d \sin \theta_m = (m + 1/2)\lambda \quad y_m = L \tan \theta_m \quad m = 0, 1, 2... \]

Chapter 18

\[ \theta_r = \theta_i \quad n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad \theta_e = \sin^{-1}(n_2/n_1) \quad v = \frac{c}{n} \quad \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad m = -\frac{s'}{s} \]

Chapter 19

\[ d_{\text{min}} = 0.61\lambda/NA \quad \theta_1 = 1.22\lambda/D \quad P = 1/f \quad M = \theta/\theta_0 = 25 \text{ cm}/f \]

\[ M = -f_o/f_e \quad M = -L \times 25 \text{ cm}/(f_o f_e) \]

Chapter 20

\[ F_{1,\text{on}2} = K|q_1||q_2|/r^2 \quad K = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \quad e = 1.60 \times 10^{-19} \text{ C} \quad \vec{E} = \vec{F}_{\text{on}}/|q| \]

\[ \vec{E}_{\text{tot}} = \vec{E}_1 + \vec{E}_2 + \ldots \quad E = K|q|/r^2 \quad E = Q/(\varepsilon_0 A) \quad \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2) \]

Chapter 21

\[ U_{\text{elec}} = qV \quad K_f + qV_f = K_i + qV_i \quad V = Kq/r \quad \Delta V_C = Q/C \quad C = \kappa \varepsilon_0 A/d \]

\[ U_C = \frac{1}{2} C(\Delta V)^2 \quad u_E = \frac{1}{2} \kappa \varepsilon_0 E^2 \quad V = \frac{x}{d} \Delta V \quad E = \frac{\Delta V_C}{d} \quad 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \]
Chapter 22

\[ I = \frac{\Delta q}{\Delta t} \quad R = \rho L / A \quad I = \frac{\Delta V}{R} \quad P_{\text{emf}} = I \mathcal{E} \quad P_R = I^2 R = \frac{(\Delta V_R)^2}{R} \]

Chapter 23

\[ \sum_i \Delta V_i = 0 \quad \sum I_{\text{in}} = \sum I_{\text{out}} \quad R_{eq} = R_1 + R_2 + \ldots \quad (1/C_{eq}) = (1/C_1) + (1/C_2) + \ldots \]

\[ (1/R_{eq}) = (1/R_1) + (1/R_2) + \ldots \quad C_{eq} = C_1 + C_2 + \ldots \]

Chapter 24

\[ F = qvB \sin \alpha \quad F = ILB \quad \tau = (IA)B \sin \theta \quad r = mv/|q|B \]

\[ B = \mu_0 I/(2\pi r) \quad B = \mu_0 I/(2R) \quad B = \mu_0 I N/L \quad \mu_0 = 1.26 \times 10^{-6} \text{T} \cdot \text{m/A} \]

Chapter 25

\[ \Phi = AB \cos \theta \quad \mathcal{E} = |\Delta \phi/\Delta t| \quad E_0 = cB_0 \quad E = hf \quad I = I_0 \cos^2 \theta \quad \lambda_{\text{peak}} = 2.9 \times 10^6 \text{nm} \cdot \text{K}/T \]

Chapter 26

\[ \beta = v/c \quad \Delta t = \Delta \tau / \sqrt{1 - \beta^2} \quad L = \sqrt{1 - \beta^2 \ell} \quad p = \gamma mu \quad \gamma = 1 / \sqrt{1 - u^2 / c^2} \]

\[ E = \gamma mc^2 = mc^2 + (\gamma - 1)mc^2 \quad u' = (u-v)/(1-uv/c^2) \quad u = (u'+v)/(1+u'v/c^2) \]

Chapter 27

\[ h = 6.626 \times 10^{-34} \text{J} \cdot \text{s} \quad \lambda = h/(mv) \quad \Delta x \Delta p_x \geq h/(2\pi) \quad V_{\text{stop}} = K_{\text{max}}/e = (hf - E_0)/e \]

\[ 2d \cos \theta = m\lambda \quad m = 1, 2, 3, \ldots \]

Chapter 28

\[ E_{\text{phot}} = \Delta E_{\text{atom}} = |E_f - E_i| \quad 2\pi r = n\lambda \quad E_n = -13.6 \text{eV/n}^2 \quad r_n = n^2 a_B \quad a_B = 0.053 \text{nm} \]

\[ \lambda_{n \rightarrow m} = 91.1 \text{nm} / (1/m^2 - 1/n^2) \quad m = 1, 2, 3 \ldots \quad n = m + 1, m + 2, m + 3 \ldots \]

\[ h = h/(2\pi) \quad L = \sqrt{\ell(\ell + 1)h} \quad \ell = 0, 1, 2, \ldots \quad m = -\ell, -\ell + 1, \ldots, 0, \ell - 1, \ell \quad m_s = \pm 1/2 \]

Chapter 29

\[ A = Z + N \quad B = (Zm_H + Nm_n - m_{\text{atom}}) \quad 931.49 \text{MeV/u} \quad A^4 X \rightarrow A^4 Y + \alpha + E \]

\[ A^4 X \rightarrow A^4 Y + \beta + E \quad N = N_0 e^{-t/\tau} \quad N = N_0 (1/2)^{t/\tau} \quad t_{1/2} = \tau \ln 2 \quad R = N/\tau \]

\[ \text{dose equiv (Sv)} = \text{dose(Gy)} \times \text{RBE} \]