\[ T = 5.60 \times 10^4 \text{ N/m} \]
\[ T = 210 \text{ N} \]

(a) We first need to draw a free-body diagram:

Since we are in equilibrium:

\[ \sum F_y = T \sin \theta + T \sin \theta - \kappa_1 x_1 = 0 \]

\[ 2T \sin \theta = \kappa_1 x_1 \]

\[ x_1 = \frac{2T \sin \theta}{\kappa_1} = \frac{2(210 \text{ N}) \sin 32.5^\circ}{5.60 \times 10^4 \text{ N/m}} \]

\[ = 4.03 \times 10^{-3} \text{ m} = 4.03 \text{ mm} \]

(b) The ropes are now replaced with springs of spring constant \( \kappa_2 \). These springs are stretched \( x = 2x_1 \) from their equilibrium positions.
The free-body diagram is

\[ \sum F_y = F \sin \theta + F \sin \theta - \ell_1 x_1 = 0 \]

\[ 2F \sin \theta = \ell_1 x_1 \]

\[ k = \frac{\ell_1 x_1}{2x \sin \theta} = \frac{\ell_1 x_1}{2(2x) \sin \theta} = \frac{\ell_1}{4 \sin \theta} = \frac{5.60 \times 10^4 \text{N/m}}{4 \sin 32.5^\circ} \]

\[ = 2.61 \times 10^4 \text{N/m} \]
$T = 16.0 \, \text{N/m}$
$A = 20.0 \, \text{cm} = 0.200 \, \text{m}$
$v_{\text{max}} = 40.0 \, \text{cm/s} = 0.400 \, \text{m/s}$

Use conservation of energy here. Take the equilibrium position, $x = 0$, as our initial position and the maximum extension as our final position. Note when $x = 0$, $v = v_{\text{max}}$; and when $x = A$, $v = 0$.

Let's assume that the change of height is small so that

$$(\text{PE}_g)_i \approx (\text{PE}_g)_f$$

$$(\text{KE} + \text{PE}_s + \text{PE}_g)_i = (\text{KE} + \text{PE}_s + \text{PE}_g)_f$$

$$(\text{KE} + \text{PE}_s)_i = (\text{KE} + \text{PE}_s)_f$$

$$\frac{1}{2} m v_i^2 + \frac{1}{2} k x_i^2 = \frac{1}{2} m v_s^2 + \frac{1}{2} k x_s^2$$

$$\frac{1}{2} m v_{\text{max}}^2 = \frac{1}{2} k A^2$$

$$m = \frac{k A^2}{v_{\text{max}}^2} = \frac{(16.0 \, \text{N/m})(0.200 \, \text{m})^2}{(0.400 \, \text{m/s})^2} = 4.00 \, \text{kg}$$

$$F_g = mg = (4.00 \, \text{kg}) (9.80 \, \text{m/s}^2) = 39.2 \, \text{N}$$
\[ L_T = 0.9927 \text{ m (Tokyo)}, \quad L_c = 0.9942 \text{ m (Cambridge)} \]

\[ T_T = 2\pi \sqrt{\frac{L_T}{g_T}} \quad \text{and} \quad T_c = 2\pi \sqrt{\frac{L_c}{g_c}} \]

Since a "seconds" pendulum travels through the equilibrium position every second, the total period is 2 times that time, or

\[ T_T = T_c = 2.00 \text{ s} \]

Let's write the period equations as a ratio:

\[ \frac{T_T}{T_c} = 1 = \frac{2\pi \sqrt{L_T/g_T}}{2\pi \sqrt{L_c/g_c}} = \frac{\sqrt{L_T/g_T}}{\sqrt{L_c/g_c}} \]

\[ \frac{L_T/g_T}{L_c/g_c} = 1, \quad \text{or} \quad \frac{L_T}{L_c} \frac{g_c}{g_T} = 1 \]

\[ \frac{g_c}{g_T} = \frac{L_c}{L_T} = \frac{0.9942}{0.9927} = 1.0015 \]

The surface gravity is 0.15% larger in Cambridge as compared to Tokyo.
a) What is $\mu$?

\[
\Sigma F_y = T - \mu \gamma = T - mg = 0
\]

\[
T = mg = (3.0 \text{ kg}) (9.80 \text{ m/s}^2) = 29 \text{ N}
\]

\[
\gamma = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{T}{\mu}}
\]

\[
\mu = \frac{T}{\gamma^2} = \frac{29 \text{ N}}{(24 \text{ m/s})^2} = 0.051 \text{ kg/m}
\]

b) When $m = 2.00 \text{ kg}$, the tension is

\[
T = mg = (2.0 \text{ kg}) (9.80 \text{ m/s}^2) = 20 \text{ N}
\]

The speed of the transverse wave is

\[
\gamma = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{20 \text{ N}}{0.051 \text{ kg/m}}} = 20 \text{ m/s}
\]
5. \( f = 700 \text{ Hz} \), \( \lambda = 0.50 \text{ m} \), \( T = ? \) (Note: \( \text{Hz} = \frac{1}{s} \))

The speed of the sound wave is

\[ v = \frac{f \lambda}{(700 \text{ Hz}) (0.50 \text{ m})} = 3.5 \times 10^2 \text{ m/s} \]

Now we have \( v = \left( \frac{331 \text{ m/s}}{\sqrt{T_{273K}}} \right) \) and solve for \( T \):

\[ \sqrt{T_{273K}} = \frac{v}{331 \text{ m/s}} \]

\[ T_{273K} = \left( \frac{v}{331 \text{ m/s}} \right)^2 = (273 \text{ K}) \left( \frac{350 \text{ m/s}}{331 \text{ m/s}} \right)^2 \]

\[ T_{273K} = 305 \text{ K} \]

\[ T_c = T - 273 = 305 - 273 = \sqrt{32^\circ \text{C}} \]

6. \( \beta_{\text{orch}} = 85 \text{ dB} \), \( \beta_v = 70 \text{ dB} \), where \( \text{orch} \) = full orchestra, \( v \) = violin. Calculate \( \frac{I_{\text{orch}}}{I_v} \) (\( I \) = intensity).

Note that \( \beta = 10 \log (\frac{I}{I_0}) \), where \( I_0 = 10^{-12} \text{ W/m}^2 \).

So taking the antilog and setting up a ratio, we get \( I = I_0 10^{\beta / 10} \).

\[ \frac{I_{\text{orch}}}{I_v} = \frac{I_0 10^{\beta_{\text{orch}} / 10}}{I_0 10^{\beta_v / 10}} = 10^{(\beta_{\text{orch}} - \beta_v) / 10} = 10^5 = 32 \text{ or } [I_{\text{orch}} = 32 I_v] \]
\[ Y_{\text{exp}} = 100 \text{ m}, \text{ since the height of humans is } h < 2 \text{ m}, \]
\[ Y_{\text{exp}} \gg h, \text{ and we can assume that the sound wave is being measured at ground level.} \]

The path length that the sound travels to each observer is

\[ r_A = \Delta y = Y_{\text{exp}} = 100 \text{ m} \]
\[ r_B = \sqrt{\Delta x_{AB}^2 + \Delta y^2} = \sqrt{(100 \text{ m})^2 + (100 \text{ m})^2} = 141 \text{ m} \]
\[ r_C = \sqrt{\left(\Delta x_{AB} + \Delta x_{BC}\right)^2 + \Delta y^2} = \sqrt{(100 \text{ m} + 100 \text{ m})^2 + (100 \text{ m})^2} = 224 \text{ m} \]

The intensity at distance \( r \) from the source is

\[ I = \frac{P}{4\pi r^2} = \frac{(P/4\pi)}{r^2}, \text{ where } P = \text{ power of the explosion which is constant for all 3 observers.} \]
a) \[ \frac{I_A}{I_B} = \frac{(\Omega/4\pi)/r_A^2}{(\Omega/4\pi)/r_B^2} = \left( \frac{r_B}{r_A} \right)^2 \]
\[ = \left( \frac{141\text{ m}}{100\text{ m}} \right)^2 = 2.0 \]

b) \[ \frac{I_A}{I_C} = \frac{(\Omega/4\pi)/r_A^2}{(\Omega/4\pi)/r_C^2} = \left( \frac{r_C}{r_A} \right)^2 \]
\[ = \left( \frac{224\text{ m}}{100\text{ m}} \right)^2 = 5.0 \]

8.

Since the observer hears a reduced frequency, the source and the observer are getting farther apart. Hence, the bicyclist is behind the car.

With the bicyclist (observer) behind the car (source) and both moving in the same direction, the observer moves towards the source \((v_o > 0)\) while the source moves away from the observer \((v_s < 0)\). Thus \(f'_o = 415\text{ Hz}\), \(v'_o = +\frac{v_{\text{car}}}{3}\) and \(v'_s = -v_{\text{car}}\). Hence, \(f'_s = \frac{440\text{ Hz}}{3}\).

Obs. freq: \(f'_o = f_s \left( \frac{v + v_o}{v - v_s} \right) = f_s \left[ \frac{v + v_{\text{car}}/3}{v - (-v_{\text{car}})} \right] \)
\[ = f_s \left( \frac{v + v_{\text{car}}/3}{v + v_{\text{car}}} \right), \text{ where } v = \text{speed of sound} \]
Solving for $v_{\text{car}}$ gives

$$s'_{0}(v + v_{\text{car}}) = s_{5}(v + \frac{v_{\text{car}}}{3})$$

$$s'_{0}v_{\text{car}} - \frac{1}{3} s_{5}v_{\text{car}} = s_{5}v - s'_{0}v$$

$$v_{\text{car}}(\frac{s_{5} - s'_{0}}{\frac{1}{3}s_{5}}) = (s_{5} - s'_{0})v$$

$$v_{\text{car}} = \frac{s_{5} - s'_{0}}{\frac{1}{3}s_{5}}v$$

$v$ here is the velocity of sound, since they did not give us a temperature of the air, we will use room temperature of 293 K and use $v = 343$ m/s (see page 429 of the textbook), so

$$v_{\text{car}} = \frac{440 \text{ Hz} - 415 \text{ Hz}}{415 \text{ Hz} - \frac{1}{3} \cdot 440 \text{ Hz}}(343 \text{ m/s})$$

$$= \frac{25 \text{ Hz}}{268.3 \text{ Hz}}(343 \text{ m/s}) = 0.093(343 \text{ m/s})$$

$$= 32 \text{ m/s}$$

(Note that a statement was made at the beginning of the Problems in this chapter to use $v = 343$ m/s if the speed of sound is not given. However, for this and other problems from this chapter, I will use $T_{\text{room}} = 293K + 20^\circ \text{C}$ with $v = 343$ m/s for the sound speed.)
\[ f = 500 \text{ Hz} \]

Assume \( v = 343 \text{ m/s} \) for \( T = 293 \text{ K} \)

\[ \lambda = \frac{v}{f} = \frac{343 \text{ m/s}}{500 \text{ Hz}} = 0.686 \text{ m} \]

a) To produce destructive interference, the speaker should be moved back a distance

\[ d = \frac{\lambda}{2} = \frac{0.686 \text{ m}}{2} = 0.343 \text{ m} \]

b) If top speaker is moved back 2d in distance, the speakers will be separated by a full wavelength and constructive interference will occur.

\[ F = T = 600 \text{ N} \]

\[ m_w = 0.300 \text{ g} = 3.00 \times 10^{-4} \text{ kg} \]

\[ L = 70.0 \text{ cm} = 0.700 \text{ m} \]

Mass/length: \( \mu = \frac{m_w}{L} = \frac{3.00 \times 10^{-4} \text{ kg}}{0.700 \text{ m}} = 4.29 \times 10^{-4} \text{ kg/m} \)

Wave vel: \( \nu = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{600 \text{ N}}{4.29 \times 10^{-4} \text{ kg/m}}} = 1.18 \times 10^3 \text{ m/s} \)

Fundamental: \( \lambda_1 = 2L = 1.40 \text{ m}, f_1 = \frac{\nu}{\lambda_1} = \frac{1.18 \times 10^3 \text{ m/s}}{1.40 \text{ m}} = 845 \text{ Hz} \)

2nd harmonic: \( f_2 = 2f_1 = 1690 \text{ Hz} \), 3rd: \( f_3 = 3f_1 = 2540 \text{ Hz} \)
11. \[ L = 2.8 \text{ m} = 2.8 \times 10^{-2} \text{ m}, \quad \sigma = 340 \text{ m/s} \]

Hearing would be best at the fundamental resonance, so \( \lambda = 4L = 4(2.8 \times 10^{-2} \text{ m}) = 0.112 \text{ m} \)

\[
f = \frac{c}{\lambda} = \frac{340 \text{ m/s}}{0.112 \text{ m}} = 3000 \text{ Hz} = \boxed{3.0 \text{ kHz}}
\]

12. \( B_{\text{MAX}} = 1.5 \times 10^{-7} \text{ T}, \quad \sigma = c = 3.0 \times 10^8 \text{ m/s} \)

\( \text{a) } \quad \frac{E_{\text{MAX}}}{B_{\text{MAX}}} = c, \quad E_{\text{MAX}} = c B_{\text{MAX}} = (3.0 \times 10^8 \text{ m/s}) \times (1.5 \times 10^{-7} \text{ T}) = \boxed{45 \text{ V/m}} \)

\( \text{b) } \quad \text{Av. power per unit area} = \text{Intensity} \)

\[
I = \frac{E_{\text{MAX}} B_{\text{MAX}}}{2 \mu_0} = \frac{(45 \text{ V/m}) (1.5 \times 10^{-7} \text{ T})}{2 (4\pi \times 10^{-7} \text{ Tm/A})} = \boxed{2.7 \text{ W/m}^2}
\]
13. AM (540 - 1600 Hz): Since $\nu \propto \frac{1}{\lambda}$, 
$\nu_{\text{MIN}} \rightarrow \lambda_{\text{MAX}}$ and $\nu_{\text{MAX}} \rightarrow \lambda_{\text{MIN}}$

($\omega \equiv \text{Greek } \text{nu} \equiv \text{frequency of } E/H \text{ wave}$) [Hz = \frac{1}{4}]

$\lambda_{\text{MIN}} = \frac{C}{\nu_{\text{MAX}}} = \frac{3.00 \times 10^8 \text{ m/s}}{1600 \times 10^3 \text{ Hz}} = \boxed{188 \text{ m}}$

$\lambda_{\text{MAX}} = \frac{C}{\nu_{\text{MIN}}} = \frac{3.00 \times 10^8 \text{ m/s}}{540 \times 10^3 \text{ Hz}} = \boxed{556 \text{ m}}$

b) FM (88 - 108 MHz):

$\lambda_{\text{MIN}} = \frac{C}{\nu_{\text{MAX}}} = \frac{3.00 \times 10^8 \text{ m/s}}{108 \times 10^6 \text{ Hz}} = \boxed{2.78 \text{ m}}$

$\lambda_{\text{MAX}} = \frac{C}{\nu_{\text{MIN}}} = \frac{3.00 \times 10^8 \text{ m/s}}{88 \times 10^6 \text{ Hz}} = \boxed{3.4 \text{ m}}$

14. a) From Coulomb's law: $F_e = \frac{q_1 q_2}{r^2}$, $q_1 = q_2 = +e$

$F_e = \frac{(8.99 \times 10^9 \text{ N m}^2/\text{C}^2) (1.60 \times 10^{-19} \text{ C})^2}{(1.0 \times 10^{-15} \text{ m})^2} = \boxed{2.3 \times 10^2 \text{ N}}$

b) The electrical potential energy: $P_E = \frac{q_1 q_2}{r}$

$P_E = \frac{(8.99 \times 10^9 \text{ N m}^2/\text{C}^2) (1.60 \times 10^{-19} \text{ C})^2}{1.8 \times 10^{-15} \text{ m}} = 2.3 \times 10^{-3} \frac{1 \text{ MeV}}{1.6 \times 10^{-13}} = \boxed{1.4 \text{ MeV}}$
a) \[ r_n = n^2 a_0, \quad r_2 = 4(0.0529 \text{ nm}) = 0.212 \text{ mm} \]
(Note that 1 nm = 10^{-9} m)

b) With electrical force supplying the centripetal acceleration, \( F_e = F_c \), \( q = e \), so
\[ \frac{m_e v_n^2}{r_n} = \frac{k_e e^2}{r_n^2} \]
\[ v_n = \sqrt{\frac{k_e e^2}{m_e r_n}} \]
and \( p_n = m_e v_n = \sqrt{m_e k_e e^2} \) = linear momentum

So, \( p_2 = \sqrt{\frac{m_e k_e e^2}{r_2}} \)
\[ = \sqrt{\frac{(9.11 \times 10^{-31} \text{ kg})(8.99 \times 10^9 \text{ Nm}^2/\text{C}^2)(1.60 \times 10^{-19} \text{ C})^2}{0.212 \times 10^{-9} \text{ m}}} \]
\[ = 9.95 \times 10^{-25} \text{ kg m/s} \]

c) Angular momentum: \( L_m = n \left( \frac{h}{2\pi} \right) \)
\[ L_2 = 2 \left( \frac{6.63 \times 10^{-34} \text{ J s}}{2\pi} \right) = 2.11 \times 10^{-34} \text{ J s} \]

d) \( K E_n = \frac{1}{2} m_e v_n^2 = \frac{p_n^2}{2m_e} \)
\[ K E_2 = \frac{p_2^2}{2m_e} = \frac{(9.95 \times 10^{-25} \text{ kg m/s})^2}{2(9.11 \times 10^{-31} \text{ kg})} \]
\[ = 5.43 \times 10^{-19} \text{ J} \left( \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}} \right) = 3.40 \text{ eV} \]
e) \( PE_m = \frac{q_1 q_2}{r} \), though here, we need to pay attention to the sign of the charges:

\[ q_1 = -e \text{ (electron)}, \quad q_2 = e \text{ (proton)} \]

\[ PE_2 = \frac{q_1 e (-e)}{r_2} = -\left( \frac{8.99 \times 10^9 \text{ Nm}^2/\text{C}^2 \times 1.60 \times 10^{-19} \text{ C}^2}{0.212 \times 10^{-9} \text{ m}} \right) \]

\[ = -1.09 \times 10^{-18} \text{ J} \left( \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}} \right) = -6.80 \text{ eV} \]

5) Total energy: \( E_m = KE_m + PE_m \)

\[ E_2 = KE_2 + PE_2 = 3.40 \text{ eV} - 6.80 \text{ eV} = -3.40 \text{ eV} \]

Since the energy is negative, the electron is bound to the proton as it orbits it.

When the centripetal acceleration is supplied by the gravitational force, we have:

\[ \frac{mv^2}{r} = \frac{GMm}{r^2} \quad \text{or} \quad v^2 = \frac{GM}{r} \]

where here, \( M \equiv \text{mass of Sun}, \quad m \equiv \text{mass of Earth}, \quad r \equiv \text{separation of Sun-Earth}. \)
a) With \( PE = -\frac{GMm}{r} \), the total energy is
\[
E = KE + PE = \frac{1}{2}mv^2 - \frac{GMm}{r} = \frac{m}{2} \left( \frac{GM}{r} \right) - \frac{GMm}{r}
\]
\[
E = -\frac{GMm}{2r}
\]

b) Using the Bohr quantization rule,
\[
L_m = mv_m r_m = m\hbar, \quad \omega = \frac{m\hbar}{mv_m}, \quad \hbar = \frac{h}{2\pi}
\]
and \( v^2 = \frac{GM}{r} \) becomes \( \left( \frac{m\hbar}{mv_m} \right)^2 = \frac{GM}{r_m} \), or
\[
\frac{v_m}{r_m} = \frac{\hbar^2}{GMm^2} = \frac{m^2}{r_0}
\]
with \( r_0 = \frac{\hbar^2}{GMm^2} = \frac{(6.63 \times 10^{-34} \text{ J s})^2}{4\pi^2} \]
\[
= \frac{(6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}) (1.99 \times 10^{30} \text{ kg}) (5.98 \times 10^{24} \text{ kg})}{2.32 \times 10^{-13} \text{ m}}
\]
\[
r_0 = 2.32 \times 10^{-13} \text{ m}
\]

c) The energy in the \( n \)th orbit is
\[
E_n = -\frac{GMm}{2r_n} = -\frac{GMm}{2} \left( \frac{GMm^2}{m^2\hbar^2} \right) = \left( -\frac{E_0}{m^2} \right)
\]
where
\[
E_0 = \frac{GM^2m^3}{2\hbar^2} = \frac{(6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}) (1.99 \times 10^{30} \text{ kg})^2 (5.98 \times 10^{24} \text{ kg})^3}{2(6.63 \times 10^{-34} \text{ J s})^2/4\pi^2}
\]
\[
= 1.71 \times 10^{18} \text{ J}
\]
17. \( r_m = n^2 r_0 \), so setting \( r_m = 1 \text{AU} \), we get

\[
m^2 = \frac{r_m}{r_0} = \frac{1.49 \times 10^{11} \text{m}}{2.32 \times 10^{-13} \text{m}} = 6.42 \times 10^{14} \]

or \( m = 2.53 \times 10^{74} \)

2) No, since the quantum numbers are so large in this region, the allowed energies of orbits are essentially continuous.

\[
r_m = \frac{n^2}{Z} \left( \frac{\alpha^2}{m_e^2 e^2} \right) = \frac{n^2 a_0}{Z}, \quad \text{so} \quad r_1 = \frac{a_0}{Z} = \frac{0.0529 \text{nm}}{Z}
\]

a) For He\(^+ = \text{He}^{\text{II}} \), \( Z = 2 \), \( r = \frac{0.0529 \text{nm}}{2} = 0.0265 \text{nm} \)

b) For Li\(^{2+} = \text{Li}^{\text{III}} \), \( Z = 3 \), \( r = \frac{0.0529 \text{nm}}{3} \)

\[
> \frac{0.0176 \text{nm}}{}
\]

c) For Be\(^{3+} = \text{Be}^{\text{IV}} \), \( Z = 4 \), \( r = \frac{0.0529 \text{nm}}{4} \)

\[
= 0.0132 \text{nm}
\]