① $k = 20\frac{N}{m}$, $m = 1.5kg$

a) $\omega = \sqrt{\frac{k}{m}} = 13.3 \frac{rad}{s} = 2\pi f = \frac{2\pi}{T}$

so $T = \frac{2\pi}{\omega} = \underline{0.47s}$

b) $A = 2cm$

and $V_{max} = \omega A = 26.6 \frac{m}{s}$

$a_{max} = \omega^2 A = 353.8 \frac{m}{s^2}$

c) $x(t) = A\cos(\omega t + \phi)$

at $t=0$ $x(0) = 0$ so $0 = A\cos\phi$,

therefore $\phi = \pi/2$

and $\underline{x(t) = 2cm \cos(13.3\frac{rad}{s} t + \frac{\pi}{2} rad)}$

② $\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$, $\omega = \sqrt{\frac{k}{m}}$ or $k = m\omega^2$

$v_{max} = \omega A$

so

$\frac{1}{2}m(\frac{1}{2}\omega A)^2 + \frac{1}{2}m\omega^2 x^2 = \frac{1}{2}m\omega^2 A^2$

$\frac{1}{8}A^2 + \frac{1}{2}x^2 = \frac{1}{2}A^2$

$x^2 = A^2 - \frac{1}{4}A^2$

$x = \sqrt{\frac{3}{4}A^2} = 0.866A$, 5cm

$\underline{x = 4.33cm}$

(3) $\frac{50 \text{ vibrations}}{25 s} = f = 2 Hz$

$v = \frac{350 cm}{8 s} = 43.8 \, cm/s$

so use $v = f\lambda$

$\lambda = \frac{v}{f} = 21.9 m$

(4) $y(x,t) = (10 cm) \cos(0.5x + 40t)$

a) $A = 10 cm$

b) $\omega = \cancel{0.5}\, 40 \, \frac{rad}{s} = 2\pi f \quad f = \frac{\omega}{2\pi} = 6.4 Hz$

c) $k = \frac{2\pi}{\lambda} = 0.5 cm^{-1}$ so $\lambda = \frac{2\pi}{0.5 cm^{-1}} = 12.6 cm$

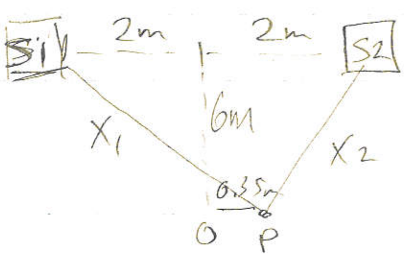
d) $v = f\lambda = 80.6 \, cm/s$

(5) $n = 6$, $\lambda = \frac{1}{3} L = \frac{1}{3}(5m) = 1.67m$

$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{20 N}{0.002 kg/m}} = 100 \, m/s$

then $f = \frac{v}{\lambda} = 59.9 Hz$

(6)



$X_1^2 = (2m + .35m)^2 + (6m)^2$

$X_1 = 6.444m$

$X_2^2 = (2m - .35m)^2 + (6m)^2$

$X_2 = 6.223m$

$\Delta X = X_2 - X_1 = 0.221m$

$\Delta x = (m + \tfrac{1}{2})\lambda$, $m = 0$, $v = 340\,\tfrac{m}{s}$ for sound

So $\lambda = 2\Delta x = 0.443\,m$

and $f = \dfrac{v}{\lambda} = \underline{\underline{767\ Hz}}$

(7)

$v = 1530\,\tfrac{m}{s}$

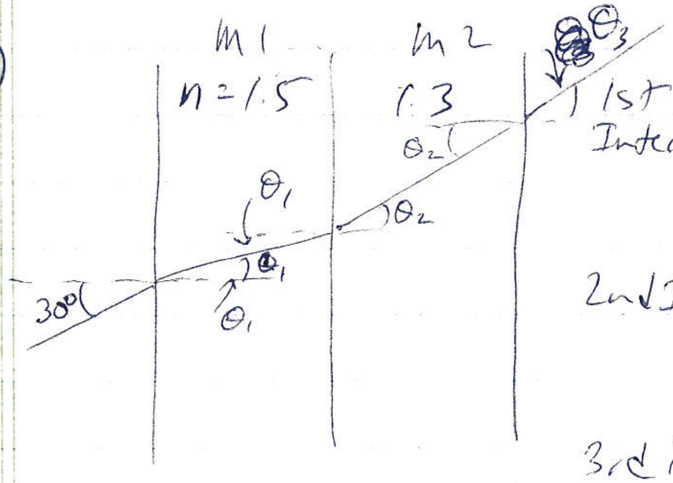
The frequency heard at S2 can be found from

$$f_{L2} = \left(\frac{v \pm v_L}{v \mp v_s}\right) f_s = \left(\frac{v + 5\,\tfrac{m}{s}}{v - 10\,\tfrac{m}{s}}\right) 1400\,Hz = 1463\,Hz$$

This now acts as the source frequency for the reflected wave and the frequency heard by S1 will now be given by

$$f_{L1} = \left(\frac{v + 10\,\tfrac{m}{s}}{v - 5\,\tfrac{m}{s}}\right)(1463\,Hz) = 1{,}529\ Hz$$

(8)



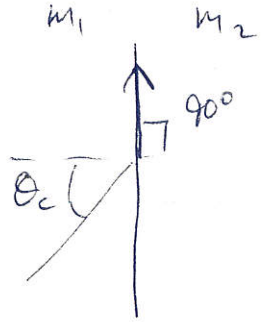
1st Interface $\left\{ \begin{array}{l} 1 \sin 30° = 1.5 \sin\theta_1 \\ \theta_1 = 19.5° \end{array} \right.$

2nd Interface $\left\{ \begin{array}{l} 1.5 \sin 19.5° = 1.3 \sin\theta_2 \\ \theta_2 = 22.7° \end{array} \right.$

3rd interface $\left\{ \begin{array}{l} 1.3 \sin 22.7° = 1 \sin\theta_3 \\ \theta_3 = 30° \end{array} \right.$

The ray comes out parallel to the incident ray

The critical angle occurs when the refracted angle is 90°



$1.5 \sin \theta_c = 1.3 \sin 90°$

$\underline{\theta_c = 60.1°}$

(9) a) $s = 20\text{ cm}$, $f = -10\text{cm}$

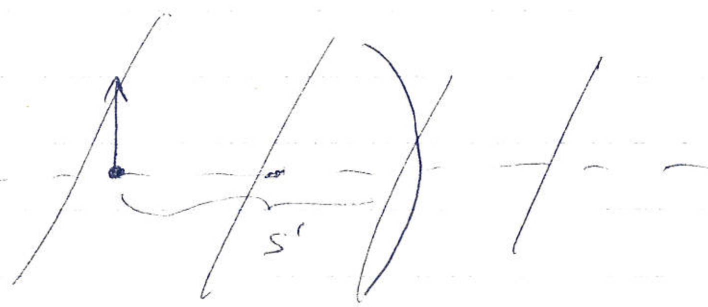
$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{20\text{cm}} + \frac{1}{s'} = \frac{1}{-10\text{cm}}$$

$$\frac{1}{s'} = \frac{-3}{20\text{cm}}, \quad s' = -6.67\text{cm}$$

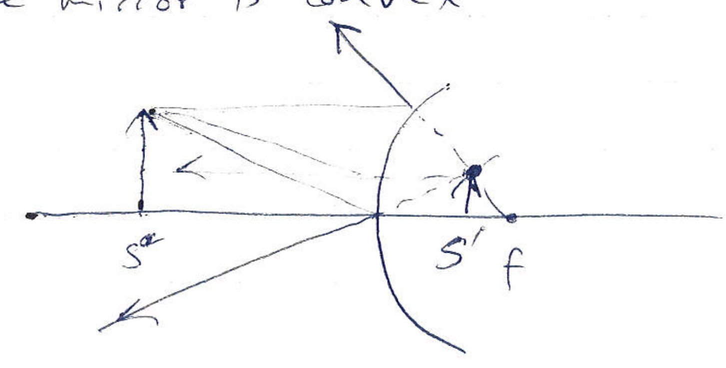
this is a <u>virtual</u> image

b) $m = -\frac{s'}{s} = \frac{-(-6.67\text{cm})}{20\text{ cm}} = 0.33$ or $\frac{1}{3}$, upright

~~c)~~



c) the mirror is convex



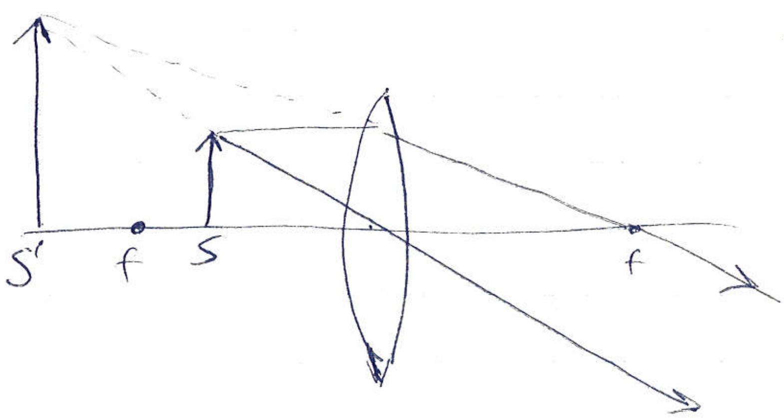
(10) $s = 10\text{cm}$, $f = +15\text{ cm}$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{10\text{cm}}\,\tfrac{3}{30} + \frac{1}{s'} = \frac{1}{15\text{cm}}\,\tfrac{2}{30}$$

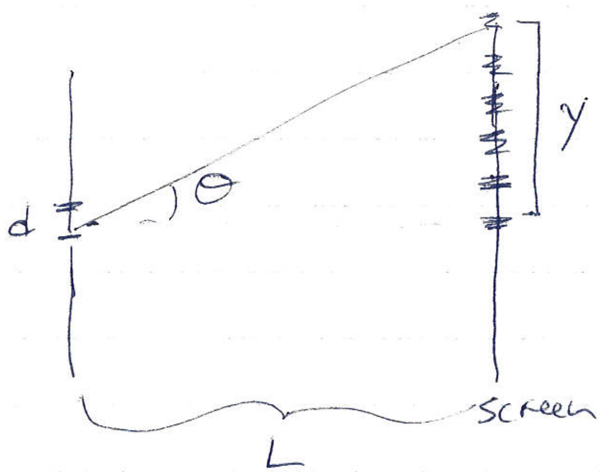
$$\frac{1}{s'} = -\frac{1}{30\text{cm}} \quad , \quad \underline{s' = -30\text{cm}} \text{ , virtual}$$

b) $m = -\frac{s'}{s} = \frac{-(-30\text{cm})}{10\text{cm}} = +3$, upright

c)



(11)



$\lambda = 550\text{nm}$
$d = 0.35\text{mm}$
$L = 50\text{cm}$

$m = 5$ and $d\sin\theta = m\lambda$

so $\theta = \sin^{-1}\left(\frac{5(550\text{nm})}{0.35\text{mm}}\right) = 0.45°$

then $y = L\tan\theta = 0.39\text{cm}$ or

(13) $P = 1.2\times10^{-3}\,W = \frac{E_{total}}{t}$

$t = 1s$ and $E = hf = \frac{hc}{\lambda}$

$$E = \frac{(6.63\times10^{-34}\,J\cdot s)(3\times10^{8}\,m/s)}{632.8\times10^{-9}\,m} = 3.14\times10^{-19}\,J$$

so $\#\,photons/s = \frac{P}{E} = \frac{1.2\times10^{-3}\,W}{3.14\times10^{-19}\,J} = 3.8\times10^{15}\,\frac{photons}{s}$

(14) $K_{max} = hf - \phi = \frac{hc}{\lambda} - \phi$

for max. ~~frequency~~ wavelength $K_{max} = 0$ so

$$\frac{hc}{\lambda} = \phi$$

so $$\phi = \frac{(6.63\times10^{-34}\,J\cdot s)(3\times10^{8}\,m/s)}{264\times10^{-9}\,m} = 7.53\times10^{-19}\,J$$

Convert to eV

$$\phi = 7.53\times10^{-19}\,J\left(\frac{1\,eV}{1.6\times10^{-19}\,J}\right) = \underline{\underline{4.7\,eV}}$$

(15) $E_n = \frac{-13.6\,eV}{n^2}$, $E_5 = \frac{-13.6\,eV}{5^2} = -0.544\,eV$, $E_3 = -1.51\,eV$

$|E_5 - E_3| = 0.966\,eV = 1.55\times10^{-19}\,J$

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34}\,J\cdot s)(3\times10^{8}\,m/s)}{1.55\times10^{-19}\,J}$$

$\lambda = 1.283\times10^{-6}\,m = 1283\,nm$, Infrared.