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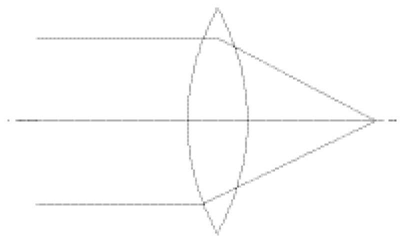
December 18th, 2014
Intermediate Experimental Physics I

Final Exam

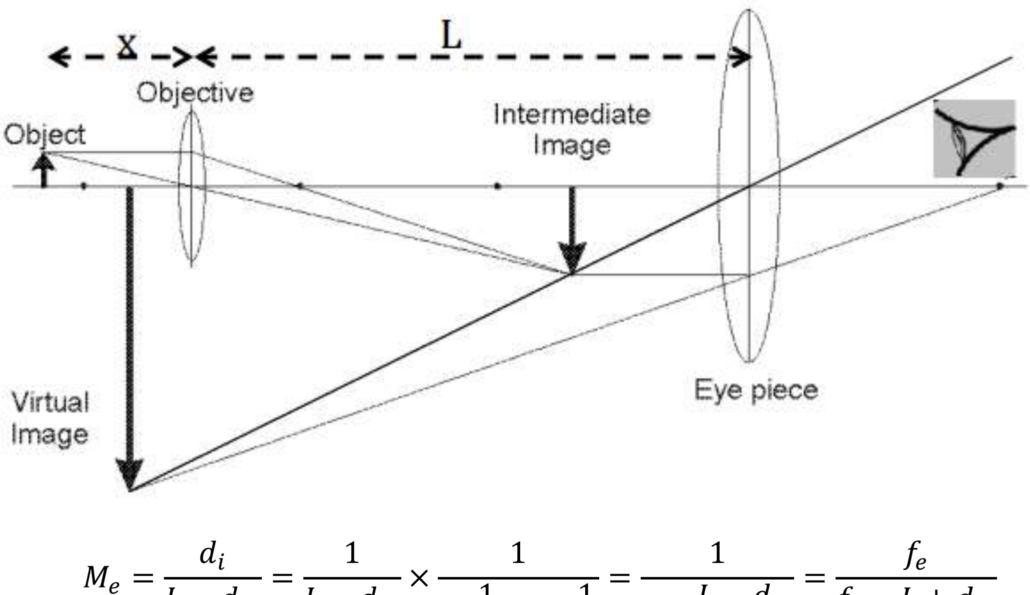
Question 1.

a) One way to find the focal length would be to allow sunlight through the light and focus the light (incident ray from an infinite distance away) on the sheet of paper. The distance between the lens and the sheet of paper could be measured to give us the focal length.
Another way this could be done is to make a slit with one sheet of paper and use it to draw the path of the light (the previous method can be used to make a rough estimate) on the other sheet of paper as it is incident at different points on the lens.



The resulting image should look like the above and will show rays converging at the focus.

b) Magnification of a compound microscope is:



$$M_e = \frac{d_i}{L - d_{io}} = \frac{1}{L - d_{io}} \times \frac{1}{\frac{1}{L - d_{io}} - \frac{1}{f_e}} = \frac{1}{1 - \frac{L - d_{io}}{f_e}} = \frac{f_e}{f_e - L + d_{io}}$$

$$= \frac{f_e}{f_e - L + \frac{x f_o}{x + f_o}} = \frac{(x + f_o) f_e}{(f_e - L)(x + f_o) + x f_o}$$

$$M_o = -\frac{d_{io}}{x} = -\frac{1}{x}\left(\frac{1}{\frac{1}{d_{io}}}\right) = -\frac{1}{x\left(\frac{1}{f_o}+\frac{1}{x}\right)} = -\frac{xf_o}{x(x+f_o)} = -\frac{f_o}{(x+f_o)}$$

$$M = M_e \times M_o = -\frac{(x+f_o)f_e}{(f_e - L)(x+f_o) + xf_o} \times \frac{f_o}{(x+f_o)} = \frac{f_e f_o}{(L-f_e)(x+f_o)+xf_o}$$

Question 3.

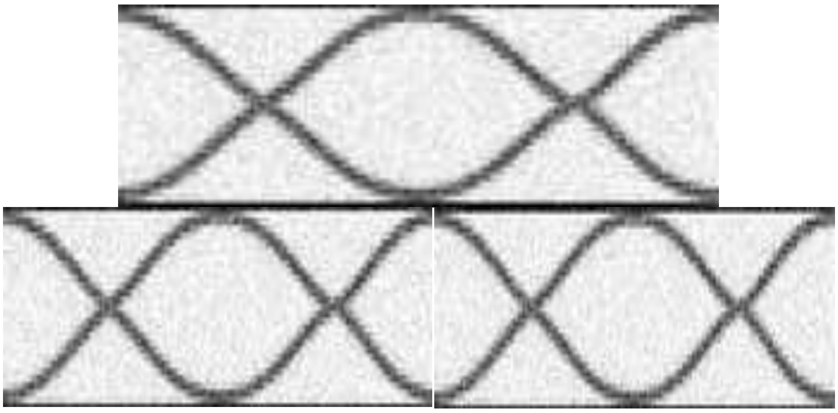
a) The torus is analogous to an open tube of

$$2\pi R = \frac{m\lambda}{2} \; so \; f = \frac{mv}{4\pi R} \qquad where \; m = 1, 2, 3 \ldots$$

But since the two ends of the tube are at the same point odd values of m undergo destructive interference and is no longer a resonance frequency. So we use only even values of m giving us:

$$f = \frac{mv}{2\pi R} \quad where \; m = 1,2,.$$

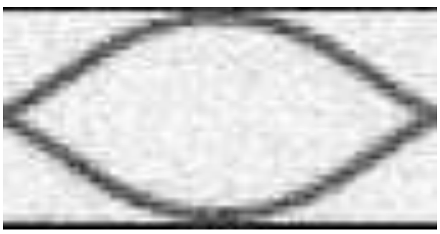
$$f_1 = \frac{v}{2\pi R} \qquad and \; f_2 = \frac{v}{\pi R}$$

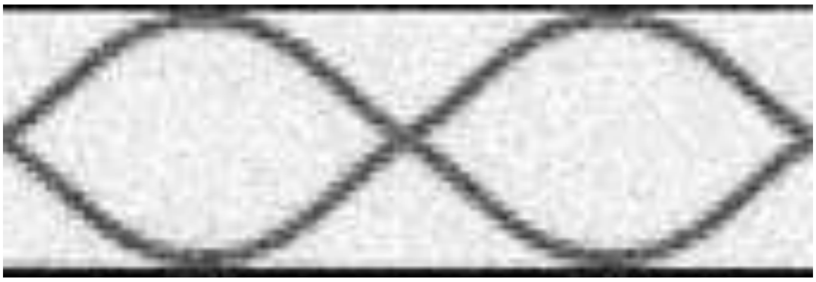


b) If there is a wall inserted into the torus, it will be analogous to a closed tube of length 2π

$$2\pi R = \frac{m\lambda}{2} \; so \; f = \frac{mv}{4\pi R} \qquad where \; m = 1, 2, 3 \ldots$$

$$f_1 = \frac{v}{4\pi R} \qquad and \; f_2 = \frac{v}{2\pi R}$$





c) The microphone has a ribbon that moves with sound and generates an imaging voltage between the ends of the ribbon which is proportional to the velocity of the ribbon.
The speaker works on the same principal but converts the imaging voltage to sound.

Question 4.

a)

$$d \sin \theta = \left(m + \frac{1}{2}\right) \lambda$$

Given that the field is far away, we can reasonably assume:

$$\theta \cong \sin \theta = \left(m + \frac{1}{2}\right) \frac{\lambda}{d} = \left(m + \frac{1}{2}\right) \left(\frac{500 \times 10^{-9}}{5 \times 10^{-4}}\right) = \left(m + \frac{1}{2}\right) 10^{-3}$$

So:

$$\theta_0 = 0.5 \times 10^{-3}$$
$$\theta_1 = 1.5 \times 10^{-3}$$
$$\theta_2 = 2.5 \times 10^{-3}$$
$$\theta_3 = 3.5 \times 10^{-3}$$
$$\theta_4 = 4.5 \times 10^{-3}$$

b)

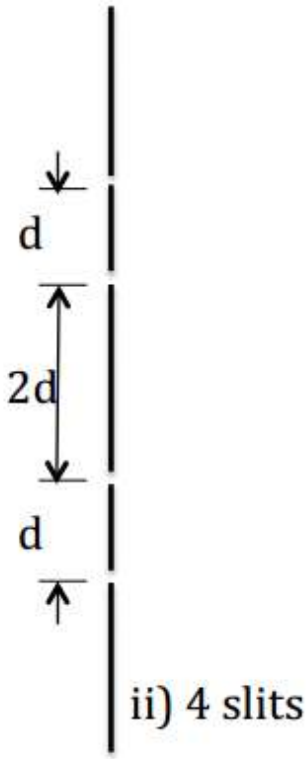
if we position the 0 of our y-axis halfway between the middle two slits we can say that (with θ being the angle from the horizontal):

$$r_1 = r - 2d \sin \theta$$
$$r_2 = r - d \sin \theta$$
$$r_3 = r + d \sin \theta$$
$$r_4 = r + 2d \sin \theta$$

Then we can see that:

$$E = E_o e^{i(kr - \omega t)} [e^{idksin\theta} + e^{-idksin\theta} + e^{i2dksin\theta} + e^{-idksin\theta}]$$

Which means: if I_o is I at $\theta = (kr - \omega t)$



$$I = I_o\left[e^{idksin\theta} + e^{-idksin\theta} + e^{i2dksin\theta} + e^{-i2dksin\theta}\right]^2$$
$$= I_o(2\,cos(kd\sin\theta) + 2\cos(2kd\sin\theta))^2$$
$$= \; I_o\left(4\,cos\left(\frac{3kd}{2}\sin\theta\right)\cos\left(-\frac{kd}{2}\sin\theta\right)\right)^2$$
$$= I_o\left(4\,cos\left(\frac{3kd}{2}\sin\theta\right)\cos\left(\frac{kd}{2}\sin\theta\right)\right)^2$$

For points of zero intensity, we need:

$$cos\left(\frac{3kd}{2}\sin\theta\right) = 0 \quad or \quad \cos\left(\frac{kd}{2}\sin\theta\right) = 0$$

Which means:

$$\frac{3\pi d}{\lambda}\sin\theta = (2n+1)\frac{\pi}{2} \quad or \quad \frac{\pi d}{\lambda}\sin\theta = (2n+1)\frac{\pi}{2}$$

Or:

$$\theta \cong \sin\theta = \frac{\lambda}{6\,d}(2n+1) \quad or \quad \theta \cong \frac{\lambda}{2d}(2n+1)$$

Question 5.

a) i) We can approximate the solar spectrum to that of a black body, in which case we can fit it to a blackbody spectrum to derive the temperature of the sun.
ii) We can apply Planck's law and Stefan-Boltzmann law to Jupiter's spectrum. The total energy over the wave band can then be used to derive the temperature since we know that:

$$P = A\epsilon\sigma T^4$$

b) The absorption lines are the black lines on the given spectrum. Their energies correspond approximately to the wavelengths (in nm): 410, 430, 440, 485, 530, 589, 590, 660
We know that:

$$E = h\nu = \frac{hc}{\lambda}$$

So, the energies corresponding to these wavelengths should be (in eV): 3.02, 2.88, 2.82, 2.56, 2.34, 2.10, 2.11, 1.87

c) The 590nm wavelength corresponds to the Sodium electron jump from np 3 to ns 3 (with energy 2.11 eV)
The 485nm wavelength corresponds to the Hydrogen electron jump from n2 to n4 (with energy 2.56eV)
The 589nm wavelength corresponds to the Helium electron jump from 2p to 3s (with energy 2.10eV) for ortho or parahelium

d) Elements like Hydrogen with fewer energy levels and lower ionization energies are able to emit all of their spectral lines but for larger atoms, the energy of the light is absorbed by the outermost electron orbitals and the rest is reflected as a wave of lower frequency (energy).