1) Short Answer (16 [redacted] points)(Show Your Work!)

a) What is the separation (d) between 2 slits if the first minima is found at an angle of 2.1 degrees when light is incident normally on 2 slits and a diffraction pattern forms. Assume the wavelength of the light used is 632.8nm. (4 pts)

Sep. = 8.6×10^{-6} m

minima ↔ destructive

$$\delta = \frac{\lambda}{2}$$

$$d \sin\theta = (1)\frac{\lambda}{2} \qquad d = \frac{\lambda}{2\sin\theta} = \frac{632.8 \times 10^{-9}\,m}{2(\sin 2.1^\circ)}$$

$=$

b) Gordo Cooper, one of the original Mercury astronauts, claimed to be able to see objects like trains and such on the earths surface from space. Assuming Gordo was about 200 km high at the time, his pupils were open about 5.5 mm in diameter, and the fluid in his eye has n=1.33 (the wavelength will change!), about how far apart did 2 objects need to be for him to distinguish them in sunlight of 500 nm wavelength?

Sep. = 16.7 m

$$\theta_{sep} = 1.22\frac{\lambda}{D} \leftarrow \text{in his eye!}$$

$$x_{sep} = (\theta_{sep})(\text{Altitude})$$

$$= 1.22\left(\frac{(500 \times 10^{-9}\,m / 1.33)}{5.5 \times 10^{-3}\,m}\right)(200{,}000\,m) = 16.68\,m$$

1) Short Answer cont'd (Show Your Work!)

c) About how thick does the wall of a soap bubble need to be in order for you to see a bright spot if 500nm light is incident normally on the soap bubble? Assume the soap bubble is mostly water with n=1.33. (4 pts)

Minimum thickness = 94nm

2 waves

1) Reflected gets 180° inversion $n_{low} \to n_{high}$

2) wave in bubble gets phase diff from thickness (no phase from reflection)

$$\phi_1 + \phi_2 = \pi + \frac{2\pi}{\lambda/n} 2t = 2\pi \quad \text{constructive}$$

$$\frac{4t}{\lambda/n} = 1, \quad t = \frac{\lambda}{4n} = \frac{500\times10^{-9}\,m}{4(1.33)} = 93.98\,nm$$

d) An object you bombard with very high energy photons is emitting photons with a characteristic energy around 6400 eV. Assuming this characteristic photon is caused by an atomic transition from the n=2 to n=1 state, what it the object made of? (4 pts.)

Iron

n = 2 to n = 1

only one electron shielding

$$Z_{eff} = Z - 1$$

$$6400\,eV = E_{photon} = -\frac{(13.6\,eV)(Z-1)^2}{2^2} - \left(-\frac{(13.6\,eV)(Z-1)^2}{1^2}\right)$$

$$6400\,eV = (10.2\,eV)(Z-1)^2$$

$$627.45 = (Z-1)^2$$

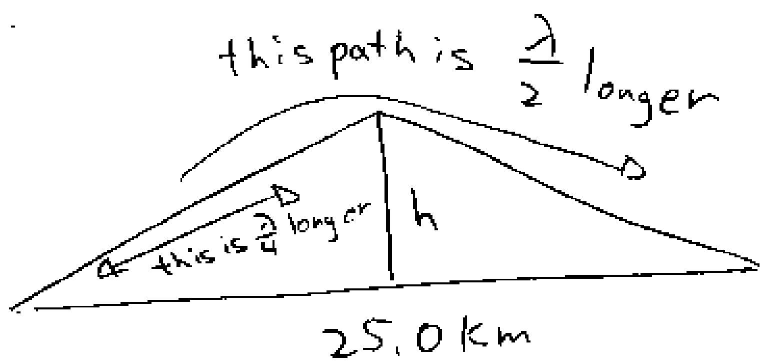
$$25 = Z - 1$$

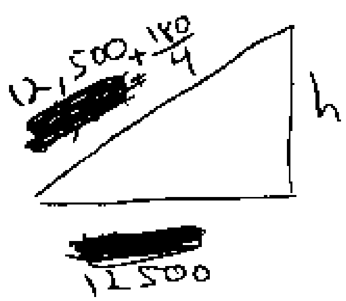
$$Z = 26$$

2) Interference (show your work)

The waves from a radio station can reach a home receiver by two paths. One is a straight-line path from transmitter to home, a distance of 25.0 km. The second path is by reflection from the ionosphere (a layer of ionized air molecules near the top of the atmosphere). Assume this reflection takes place at a point midway between receiver and transmitter. If the wavelength broadcast by the radio station is 180 m, find the minimum height of the ionospheric layer that produces destructive interference between the direct and reflected beams. (Assume no phase changes on reflection.)
Please draw a picture of the situation (2pts) and find the height (6 pts).

Height = [redacted]
= 1061.6m





$$h = \sqrt{\left(\frac{25000}{2} + \frac{180}{4}\right)^2 - \left(\frac{25000}{2}\right)^2}$$

= [redacted]
1061.6

3) Photoelectric Effect (Show your work!)

For this problem you will determine both Planks constant, h, and the work function, ϕ, of the material under test. (I.e. you can't use h from the equation sheet!) You determine that the stopping potential for light with wavelength of 300nm is 1.9V and the stopping potential for light with wavelength of 450nm is 0.50V. From your data, determine Plank's constant, h, and the work function of the material you are testing. (10 pts)

2 eq 2 unknowns

(a) $1.9\,eV = \frac{hc}{300\,nm} - \phi$

(b) $0.5\,eV = \frac{hc}{450\,nm} - \phi$

h = 6.72×10^{-34} Js
ϕ = 2.3eV

subtract (a) - (b)

$$1.4\,eV = hc\left(\frac{1}{300\,nm} - \frac{1}{450\,nm}\right) = \frac{hc}{900\,nm}$$

$$hc = 1260\,eV\,nm$$

$$h = 1260\,eV\,nm \cdot \left(1.6 \times 10^{-19} \frac{J}{eV}\right) / 3.0 \times 10^{17}\,nm/s$$

$$= 6.72 \times 10^{-34}\,Js$$

$$\phi = \frac{1260\,eV\,nm}{300\,nm} - 1.9\,eV = 2.3\,eV$$

4) Compton Effect (Show your work!)

It is observed that an electron with kinetic energy of 10.0 KeV is produced when an incoming photon of energy 105 KeV scatters off the electron (initially at rest). At what angle, relative to the initial photon direction, can you expect to find the scattered photon? (10 pts)

use cons of energy

θ = 60.8°

$$E_0 = KE_{electron} + E' \quad (E' \text{ scattered})$$

$$E' = 105\text{ keV} - 10\text{ keV} = 95\text{ keV}$$

$$\lambda' - \lambda = \frac{hc}{m_e c^2}(1 - \cos\theta)$$

$$\frac{hc}{E'} - \frac{hc}{E} = \frac{hc}{m_e c^2}(1 - \cos\theta)$$

$$\cos\theta = 1 - m_e c^2\left(\frac{1}{E'} - \frac{1}{E}\right)$$

$$\theta = \cos^{-1}\left(1 - m_e c^2\left(\frac{1}{E'} - \frac{1}{E}\right)\right)$$

$$= \cos^{-1}\left(1 - 511{,}000\left(\frac{1}{95{,}000} - \frac{1}{105{,}000}\right)\right)$$

$$= \cos^{-1}(1 - .512) = 60.8^\circ$$