Physics 256 Assignment 3 Fall 2012
Submit online or Place in Phys 256 box, Phys 2nd floor Wednesday October 3rd, 2012 by 4pm TATAL MARKS 43

1 Follow up question from Hecht Problem 3.14

b) What is the photon flux from the light bulb in 3.14 assuming negligible heat loss and a wavelength of 600 nm? Remember, you calculated iiradiance as 1.59W/m^2 in the last problem set.

1. b)5marks photon flux

$$\Phi = \frac{power}{h\nu} = \frac{power * \lambda}{h * c} = \frac{(20\ Js^{-1})(6 \text{ X } 10^{-7}\ m)}{(6.6 \text{ X } 10^{-34}\ Js)(3 \text{ X } 10^{8}\ ms^{-1})} \approx 6.06 \text{ X } 10^{19}$$

photon/s

Wrong answer:

$$Mean\ photon flux\ density = \frac{\Phi}{A} = \frac{I}{h\nu_0} = \frac{1.6W/m^2}{6.626X10^{-34}\ Js\left(\frac{2.998X10^8\ m/s}{5X10^{-7}\ m}\right)} = 4.03X10^{18}$$

photons/m^2/sec. *This is flux density and then flux is:*

$Mean\ photon flux = flux\ densityXarea = 4.03X10^{18}\ \ photons/m^2/\sec X 4\pi\ m^2 =$ 5.06X10^{19} photons/sec which is consistent

2 a) For the blue wavelength in slide 11, show whether the wavelengths and energies given are consistent.

a)5 marks

$$E = h\nu = \frac{hc}{\lambda} = \frac{(6.6 \text{ X } 10^{-34}\ Js)(3 \text{ X } 10^{8}\ ms^{-1})}{(4 \text{ X } 10^{-7}\ m)(1.602 \text{ X } 10^{-19}\ JeV^{-1})} \approx 3.1\ eV$$

yes, the wavelength and energy given are consistent.

b) For the red light, no electron is freed from the surface. Why is this?

2 marks The photon energy is smaller than the energy needed to liberate a single electron from its highest orbital.

c) What is the momentum of a green photon in slide 11?

5 marks

$$p = \frac{h\nu}{c} = \frac{h}{\lambda} = \frac{6.6 \text{ X } 10^{-34}\ Js}{5.5 \text{ X } 10^{-7}\ m} \approx 1.2 \text{ X } 10^{-27}\ Jsm^{-1} (\ m\ kgs^{-1})$$

d) Do Hecht Problem 3.58

5 marks

$$\nu = \frac{E}{h} = \frac{(11\ eV)(1.602 \times 10^{-19}\ J/eV)}{(6.62 \times 10^{-34}\ Js)} \approx 2.67 \times 10^{15}\ Hz$$

3 a) A 200 mW laser is focused in an optical trap to create "laser tweezers". What is the force of the laser on a particle which reflects all of the light?

5 marks $F = \frac{2power}{c} = \frac{2*200\ mW}{3 \times 10^{8}\ ms^{-1}} = 1.33 \times 10^{-9}\ N$ reflected

b) What is the photon flux if the wavelength is 500 nm?

$$\Phi = \frac{power}{h\nu} = \frac{power * \lambda}{hc} = \frac{200\ mW * 500nm}{6.62*10^{-34} Js * 3*10^{8} m/s} = 5.04*10^{17} \text{ photon/sec}$$

c) If the laser beam is focused so that its cross section is 9 μm² what is the average radiation pressure of the beam incident perpendicular to a cell which absorbs all the light?

5 marks

$F = \frac{power}{c} = \frac{*200\ mW}{3 \times 10^{8}\ ms^{-1}} = 6.67 \times 10^{-10}\ N$ absorbed

$P = \frac{F}{A} = \frac{6.67 * 10^{-10}\ N}{9 \times (10^{-6})^{2} m^{2}} \approx 7.4*10\ Nm^{-2}$ absorb

d) What is the photon flux density of the beam? 3 marks

Photon flux density = $\frac{\Phi}{A} = \frac{5.04*10^{17} \text{ photon/sec}}{9*10^{-12}\ m^{2}} = 5.6*10^{28} \text{ photon/s}\cdot\text{m}^2$

4) A satellite has a "photon sail" of size 50 m by 50 m. What is the force exerted on it by sunlight if it strikes the mirror at an angle of 45° from the normal? The irradiance of sunlight is 1400 W/m² measured with a detector whose surface is perpendicular to the sun's rays. Hint: *You might find it helpful to calculate the power and irradiance incident on the mirror first. Remember that force is a vector.*

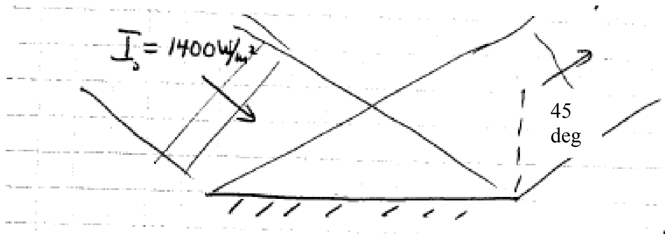
5 marks The irradiance perpendicular to the beam is 1400W/m². The area of the photon sail over which this irradiance falls is 1m/cos(theta) where theta is the angle to the normal of the ray (45deg).

Thus $I_{on\ the\ sail} = 1400\cos(45)\ W/m^2 = 989.9 W/m^2$

$F_{normal\ to\ the\ beam} = PA = \frac{2IA}{c} = \frac{2*(1400\ Wm^{-2})\cos(45)(2500\ m^{2})}{3 \times 10^{8}\ ms^{-1}} \approx 1.65*10^{-2}\ N$

reflect

2marks $F_{exerted} = (F_{normal})(\cos(45°)) = 1.65*10^{-2}*0.707 \approx 0.012\ N$ *See below, this is because the momentum change is in the vertical*



change in momentum, hence causes the force.