PHYS 201 WINTER 2010

HOMEWORK 4

Solutions

1. Half-Baked

Wien's displacement law says that the peak wavelength emitted by a blackbody at temperature T (in kelvins) is given by this empirical formula:

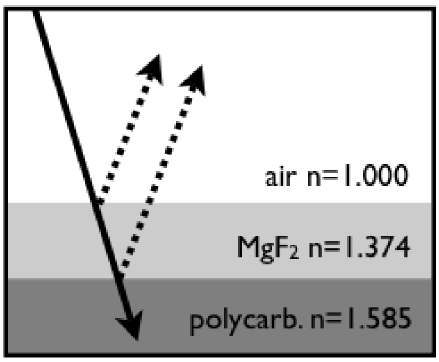
$$\lambda_{peak} = \frac{2.898 \times 10^{-3}\ K \cdot m}{T}$$

If $\lambda_{peak} = 630 \times 10^{-9}\ m$, then $T = 4600\ K = 4327\ ^\circ C$.
If $\lambda_{peak} = 740 \times 10^{-9}\ m$, then $T = 3916\ K = 3643\ ^\circ C$.

2. Sunglasses At Night

2.1. When light reflects off a medium with larger n than the medium in which it is traveling, it undergoes a phase shift. Since MgF_2 has a larger n than air and polycarbonate has a larger n than MgF_2, both reflections produce a phase shift.

2.2. For small angles of incidence, the path difference is 2τ, where τ is the thickness of the MgF_2 coating. (See the picture below.) Both paths include a 180° phase shift, so the phase shifts cancel out. For destructive interference, path difference $\times$ index of refraction should be one half wavelength: $(2\tau)n = \frac{\lambda}{2}$.



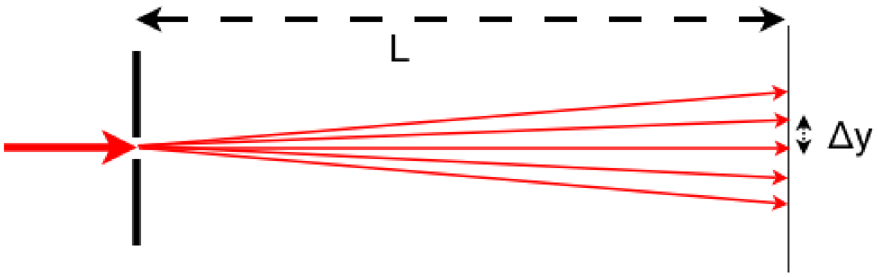
Since $\lambda = 525 \times 10^{-9}\ m$ and $n = 1.374$, $\tau = 9.55 \times 10^{-8}\ m = 95.5\ nm$.

(Technically $(2\tau)n = m\frac{\lambda}{2}$, where m can be any odd integer, so the coating could also be $287\ nm, 478\ nm, 669\ nm$, etc.)

Dotted lines indicate phase-shifted paths.

3. The Bends

3.1. Here's a picture:



In this case, $L = 5.00\ m$ and $\Delta y = 4.20 \times 10^{-3}\ m$. The angle between the central bright spot and first dark spot is given by $(\sin\theta_{min}) = \lambda/a$. From the picture, this angle is also given by $(\tan\theta_{min}) = \Delta y/L$. Using $\sin\theta \approx \tan\theta$, we can write:

$$\frac{\lambda}{a} = \frac{\Delta y}{L}$$

Since $\lambda = 680 \times 10^{-9}\ m$, we can find $a = 8.10 \times 10^{-4}\ m = 810\ \mu m$.

3.2. Bright spots appear at $d(\sin\theta_{max}) = \pm\lambda$ and $d(\sin\theta_{max}) = \pm 2\lambda$. In this case, $d \approx 1.5\ \mu m$ and the angles given were $\pm 26.4° \approx \pm 0.4608\ rad$ and $\pm 62.5° \approx \pm 1.091\ rad$. Plugging these in for θ_{max} in the formulas above gives

$$\lambda = 6.67 \times 10^{-7}\ m \qquad \lambda = 6.65 \times 10^{-7}\ m$$

so the actual wavelength is somewhere between 665 and 667 nanometers.

4. Bonus Problem

The energy needed is $E \geq 13.6$ eV. Einstein's assumption $E = hf$ then says:

$$f \geq \frac{E}{h} \approx \frac{13.6}{4.136 \times 10^{-15}} \approx 3.29 \times 10^{15}$$

The value of h used here is in units of eV·seconds. The answer is then in s^{-1}: $3.29 \times 10^{15}\ s^{-1}$ = **3.29 petahertz**. (If you looked up a value of h in joule·seconds, that's OK, but don't forget to convert between eV and joules!)

3.29 petahertz is in the extreme ultraviolet range of the electromagnetic spectrum, so **no**, visible light cannot ionize a hydrogen atom. For most practical purposes, visible light is incapable of ionizing atoms. UV light, X-rays, and gamma rays *can* ionize many organic compounds, which is why they are potentially dangerous.