Reference for Homework 5

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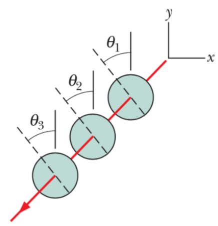
Please read the preface before reading this document!!!

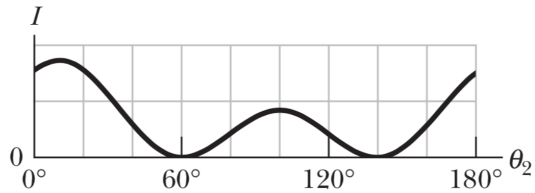
1

At a beach the light is generally partially polarized due to reflections off sand and water. At a particular beach on a particular day near sundown, the horizontal component of the electric field vector is 2.3 times the vertical component. A standing sunbather puts on polarizing sunglasses; the glasses eliminate the horizontal field component.
(a) What fraction of the light intensity received before the glasses were put on now reaches the sunbather's eyes?
(b) THe sunbather, still wearing the glasses, lies on his side. What fraction of the light intensity received before the glasses were put on now reaches his eyes?
Reference:
(a) the fraction is $\frac{E_\perp^2}{E_\parallel^2+E_\perp^2} = 0.16$
(b) the fraction is $\frac{E_\parallel^2}{E_\parallel^2+E_\perp^2} = 0.84$

2

In the left figure, unpolarized light is sent into a system of three polarizing sheets. The angles θ_1, θ_2 and θ_3 of the polarizing directions are measured counterclockwire from the positive direction of the y axis (they are not drawn to scale). Angles θ_1 and θ_3 are fixed, but angle θ_2 can be varied. The right figure gives the intensity of the light emerging from sheet 3 as a function of θ_2. (The scale of the intensity axis is not indicated.) What percentage of the light's initial intensity is transmitted by the three'sheet system when $\theta_2 = 90°$?
No reference yet.





3

A beam of partially polarized light can be considerd to be a mixture of polarized and unpolarized light. Suppose we send such a beam through a polarizing filter and then rotate the filter through 360° while keeping it perpendicular to the beam. If the transmitted intensity varies by a factor of 5.0 during the rotation, what fraction of the intensity of the original beam is associated with th beam's polarized light?
Reference:
suppose that the fraction of the intensity of the original beam is associated with the beam's polarized light is $f \Rightarrow \frac{fI_0+\frac{1}{2}I_0(1-f)}{\frac{1}{2}I_0(1-f)} = 5 \Rightarrow f = \frac{2}{3}$

4

A special kind of lightbulb emits monochromatic light of wavelength 630 nm. Electrical energy is supplied to it at the rate of 60 W, and the bulb is 93% efficient at converting that energy to light energy. How many photons are emtited by the bulb during its lifetime of 730 h?
Reference:
$\Rightarrow Pt\eta = nhv$ and $v = \frac{c}{\lambda} \Rightarrow n = \frac{Pt\eta\lambda}{ch} = 4.65 \times 10^{26}$

5

In a photoelectric experiment using a sodium surface, you find a stopping potential of 1.85 V for a wavelength of 300 nm and a stopping potential of 0.820 V for a wavelength of 400 nm. From these data find (a) a value for the Planck constant, (b) the work function Φ for sodium, and (c) the cutoff wavelength λ_0 for sodium.
Reference:
(a) we have $eV + \Phi = h\frac{c}{\lambda} \Rightarrow h = \frac{eV_1-eV_2}{\frac{c}{\lambda_1}-\frac{c}{\lambda_2}} = 6.60 \times 10^{-34}$ J·s
(b) we have $eV_1 + \Phi = \frac{c}{\lambda_1} \cdot \frac{e(V_1-V_2)}{c(\frac{1}{\lambda_1}-\frac{1}{\lambda_2})} \Rightarrow \Phi = \frac{e(V_1\lambda_1-V_2\lambda_2)}{\lambda_2-\lambda_1} = 3.64 \times 10^{-19}$ J
(c) $\Rightarrow \Phi = h\frac{c}{\lambda_0}$ and from (a) and (b) we can get that $\frac{e(V_1\lambda_1-V_2\lambda_2)}{\lambda_2-\lambda_1} = \frac{c}{\lambda_0} \cdot \frac{e(V_1-V_2)}{c(\frac{1}{\lambda_1}-\lambda_2)}$

$\Rightarrow \lambda_0 = \frac{(V_1 - V_2)\lambda_1\lambda_2}{V_1\lambda_1 - V_2\lambda_2} = 544$ nm

6

Show that when a photon of energy E is scattered from a free electron at rest, the maximum kinetic energy of the recoiling electron is given by $\kappa_{max} = \frac{E^2}{E+mc^2/2}$.
Reference:

$$\Rightarrow \begin{cases} \frac{hc}{\lambda} + mc^2 = \frac{hc}{\lambda'} + \gamma mc^2 \\ \frac{h}{\lambda} = \frac{h}{\lambda'}\cos\phi + \gamma mv\cos\theta \\ 0 = \frac{h}{\lambda'}\sin\phi - \gamma mv\sin\theta \end{cases} \quad \Rightarrow \frac{h}{\lambda} + mc - \frac{h}{\lambda'} = \gamma mc$$

$\Rightarrow \gamma^2 m^2 v^2 = (\frac{h}{\lambda} - \frac{h}{\lambda'}\cos\phi)^2 + (\frac{h}{\lambda'}\sin\phi)^2 = \frac{h^2}{\lambda^2} + \frac{h^2}{\lambda'^2} - \frac{2h^2}{\lambda\lambda'}\cos\phi$,
$\gamma^2 m^2 c^2 = \frac{h^2}{\lambda^2} + \frac{h^2}{\lambda'^2} + m^2c^2 + 2mc(\frac{h}{\lambda} - \frac{h}{\lambda'}) - \frac{2h^2}{\lambda\lambda'}$
$\Rightarrow \lambda - \lambda' = \frac{h}{mc}(1-\cos\phi) \Rightarrow K = E - E' = \frac{\frac{h}{mc}(1-\cos\phi)}{\frac{hc}{E} + \frac{h}{mc}(1-\cos\phi)}E \leq \frac{\frac{2h}{mc}}{\frac{hc}{E} + \frac{2h}{mc}}E = \frac{E^2}{E+\frac{mc^2}{2}}$, when $\cos\phi = -1$, $\kappa_{\max} = \frac{E^2}{E+\frac{mc^2}{2}}$

7

The highest achievable resolving power of a microscope is limited only by the wavelength used; that is, the smallest item that can be distinguished has dimensions about equal to the wavelength. Suppose one wishes to "see" inside an atom. Assuming the atom to have a diameter of 100 pm, this means that one must be able to reslove a width of, sat, 10 pm.
(a) If an electron microscope is used, what minimum electron energy is required?
(b) If a light microscope is used, what minimum photon energy is required?
(c) Which microscope seems more practical? Why?
Reference:
(a) $\Rightarrow p = \gamma m_e v = \frac{h}{\lambda}$ in which $\gamma = \frac{1}{\sqrt{1-v^2/c^2}}$

$$\Rightarrow \begin{cases} \gamma = \sqrt{(h^2 + c^2m_e^2\lambda^2)/(c^2m_e^2\lambda^2)} \\ v = \sqrt{h^2c^2/(h^2 + c^2m_e^2\lambda^2)} \end{cases} \quad \Rightarrow v = 7.07 \times 10^7 \text{ m/s}$$

$\Rightarrow$ the energy of the electron is $E = \gamma m_e^2 = 8.44 \times 10^{-14}$ J
(b) $\Rightarrow E = \frac{hc}{\lambda} = 1.99 \times 10^{-14}$ J
(c) the electron microscope is more practical because the light used should be γ ray, which is unstable and not controllable; but with sufficiently high voltage, the electron can be accelerated to the required speed