Problem Set 11, 3 December 2018 Name: _______________ , Section: ___

Problem – (P38.14)*

The figure below shows a parallel-plate capacitor being charged.

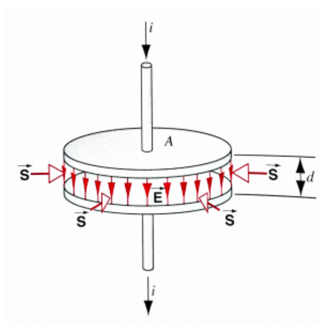
a) Show that the Poynting vector **S** points everywhere radially into the cylindrical volume.

b) Show that the rate at which energy flows into this volume, calculated by integrating the Poynting vector over the cylindrical boundary of this volume, is equal to the rate at which the stored electrostatic energy increases; that is,

$$\int \mathbf{S}\cdot d\mathbf{A} = Ad\frac{d}{dt}\left(\frac{1}{2}\epsilon_0 E^2\right)$$

where Ad is the volume of the capacitor and $\frac{1}{2}\epsilon_0 E^2$ is the energy density for all points within that volume.

This analysis shows that, according to the Poynting vector point of view, the energy stored in a capacitor does not enter it through the wires but through the space around the wires and the plates. (Hint: To find **S** we must first find **B**, which is the magnetic field set up by the displacement current during the charging process; see the figure below. Ignore fringing of the lines of **E**.)



Solution:

Problem – (E38.25) (*3 points*) The intensity of direct solar radiation not absorbed by the atmosphere on a particular summer day is 130 W/m^2. How close would you have to stand to a 1.0 kW electric heater to feel the same intensity? Assume that the heater radiates uniformly in all directions.

Solution:

Problem – (E38.28) (*2 points*) Sunlight strikes the Earth, just outside its atmosphere, with an intensity of 1.38 $\mathrm{kW/m^2}$. Calculate

a) E_m and

b) B_m for sunlight, assuming it to be a plane wave.

Solution:

Problem – Supplementary Problem 6 Light traveling in air ($n_1 = 1$) enters the smooth, flat surface of a pond ($n_2 = 1.33$) at normal incidence.

a) What fraction of the light is reflected and what fraction is transmitted?

b) If the maximum amplitude of the electric field in the incident light is E_0, what is the maximum amplitude of the electric field in the reflected light?

c) When you see scenery reflected in a still pond or lake, how is that situation different from the one you have just calculated?

Solution:

Problem – (P44.3) A stack of polarizing sheets is arranged so that the angle between any two adjacent sheets is α. The sheets are arranged so that N sheets rotate the plane of polarization by θ, where $\theta = N\alpha$. Calculate the fraction of light that will pass through the stack in the limit as $N \to \infty$. Assume that θ is fixed, so $\alpha \to 0$.

Solution:

Problem – (P44.4) It is desired to rotate the plane of vibration of a beam of polarized light by 90°.

a) How might this be done using only polarizing sheets?

b) How many sheets are required for the total intensity loss to be less than 5.0%?

Solution:

Problem – (E44.3) A beam of unpolarized light of intensity 12.2 mW/m^2 falls at normal incidence on a polarizing sheet.

a) Find the maximum value of the electric field of the transmitted beam.

b) Calculate the radiation pressure exerted on the polarizing sheet.

Solution:

Problem – Townsend (P1.4) ¶ A radio station broadcasts at a frequency $\nu = 91.5$ MHz with a total radiated power of $P = 20$ kW.

a) What is the wavelength λ of this radiation?

b) What is the energy of each photon in eV? How many photons are emitted each second? How many photons are emitted in each cycle?

c) A particular radio receiver requires 2.0 microwatts of radiation to provide intelligible reception. How many 91.5 MHz photons does this require per second? per cycle?

d) Do the answers to (b) and (c) indicate that the granularity of the electromagnetic radiation can be neglected in these circumstances?

Solution:

Problem – Townsend (P1.9) ¶*(3 points)* A beam of UV light of wavelength $\lambda = 197.0$ nm falls onto a metal cathode. The stopping potential needed to keep any electrons from reaching the anode is 2.08 V.

a) What is the work function W of the cathode surface, in eV?

b) What is the velocity v of the fastest electrons emitted from the cathode? *Note*: Since $K_{\text{max}}/mc^2 \ll 1$, the nonrelativistic expression for the kinetic energy can be utilized here.

c) If Avogadro's number of photons strikes each square meter of the surface in one hour, what is the average intensity I of the beam, in units of W/m^2?

Solution:

Problem – Townsend (P1.13) ¶ ***(2 points)*** The maximum kinetic energy of electrons ejected from sodium is 1.85 eV for radiation of 300 nm and 0.82 eV for radiation of 400 nm. Use this data to determine Planck's constant and the work function of sodium.

Solution: