03. Analysis Tools

Energy, Power and Intensity

Future lunar colonists may want to watch their favority earthly TV shows. Suppose a television station on Earth has a power of 1.0 MW and broadcasts isotropically.

1. *a. What is the intensity of this signal on the moon?*
2. *b. What total power would be received by a 20 cm radius "satellite" dish on the moon?*
3. *c. What is the maximum electric field strength of this signal on the moon?*

If the signal is broadcast isotropically (the same in all directions), its intensity should decrease as the surface area of the sphere over which the signal spreads increases. Since the distance to the moon is 3.82 x 10^8,

pic 1

The power received by the dish would be

pic 2

This corresponds to a maximum electric field of

pic 3

Pressure

High-power lasers are used to compress a small hydrogen pellet in an attempt to initiate fusion. A laser generating pulses of radiation of power 1.5 GW is focused isotropically onto the 0.5 mm radius pellet. What is the pressure exerted on the pellet if the pellet absorbs the incident light?

When an electromagnetic wave is absorbed by a surface, it exerts a pressure on the surface given by

pic 4

The intensity of the light on the surface of the pellet is

pic 5

Thus, the pressure on the pellet is

pic 6

Polarization

Initially unpolarized light is sent through three polarizing sheets with transmission axes oriented at q_1 = 0°, q_2 = 45°, q_3 = 90° measured counterclockwise from the x-axis. What percentage of the initial intensity is transmitted by the system of the three sheets?

If polarized light of intensity S_0 is incident on a polarizing sheet, the intensity transmitted by the sheet depends on the angle between the polarization direction of the light and the transmission axis of the sheet, q, via

pic 7

But what if the incident light is *unpolarized?*

If the incident wave is unpolarized, we can imagine that it is a combination of waves of all possible polarizations. Then, to determine the intensity that passes through the polarizer we can average over all of these different hypothetical polarization directions. Since the intensity that passes through the polarizer depends on the square of the cosine function, this means we must find the average value of the cosine-squared function. Since it's common knowledge[1]

that the average value of the cosine-squared functions is ½, the intensity after the first sheet is one-half of the initial intensity:

pic 8

and the wave is now polarized along the x-axis.

After the second sheet,

pic 9

and the wave is now polarized at 45° from the x-axis.

After the third sheet,

pic 9

and the wave is now polarized along the y-axis. (Notice that qis ***not*** the angle of the transmission axis (90°), but rather the angle *between* the previous polarization direction and the transmission axis.) Thus, 12.5% of the initial light intensity passes through the three sheets and the resulting light is vertically polarized.

Two Source Interference

Two radar sources are separated by d = 10 m. During testing, the two sources broadcast a test frequency perfectly in phase. If destructive interference occurs at x = 40 m, what are the possible values for the source wavelength?

pic 10

Destructive interference occurs when the two waves have a relative phase difference of p (one wave is "flipped over" relative to the other). Since the two waves are emitted in phase, this phase difference must be due to the different distances the waves travel to reach the point of destructive interference. For their phase difference to equal p, their path length difference must be a half-integer multiple of their wavelength.

With the top source labeled #1 and the bottom source #2:

pic 11

For destructive interference,

pic 12,13,14,15

The source could have any of the above (or many other) wavelengths.

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