Physics 25 Practice Problems Chapter 24

Electromagnetic Waves

1. The Sun is about 1.5×10^{11} m (93 million miles) away. When light from the Sun eventually is extinguished, how long after it goes dark on the Sun will Earth go dark, too?

2. What frequency of electromagnetic waves will have a wavelength comparable to the diameter of a nucleus, 1.0×10^{-15} m?

3. In astronomy, distances are often expressed in "light-years." One light year (LY) is the distance traveled by light in one year. The distance to Alpha Centauri, the closest star outside our solar system that can be seen by the naked eye, is 4.3 light-years away. Express this distance in meters. Assume one year = 365 days, rather than 365.25 days.

4. A light source emitting green light of frequency 6.0×10^{14} Hz is traveling toward Earth at 0.30 times the speed of light, i.e., $v/c = 0.30$.

(a) What is the emitted wavelength in nanometers (nm)?
(b) What frequency is observed on earth?
(c) What wavelength (in nm) is observed?
(d) Is the light "blue-shifted," or "red-shifted"?

5. A certain component of light from a distant galaxy has a frequency of 5.0×10^{14} Hz. On Earth, the observed frequency is 5.6×10^{14} Hz. What is the speed of the galaxy relative to Earth? Is this galaxy moving toward, or away from, Earth? Is the light red-shifted, or blue-shifted?

6. A mixture of beams of light consists of 30 W/m^2 of yellow light and 30 W/m^2 of magenta light. What is the resulting color and intensity of the mixture?

7. What color of light, and in what intensity, must be mixed with 20 W/m^2 of magenta light and 20 W/m^2 of cyan light to create a mixture that is white?

8. A mixture of light consists of 60 W/m^2 of yellow, 30 W/m^2 of blue, and 5 W/m^2 of green. What is the resulting color?

9. After magenta light passes through a cyan filter, the transmitted light is incident on a green apple. What color is the apple to the eye of an observer?

10. White light passes through a magenta filter, then that transmitted light passes through a cyan filter, and, finally, that transmitted light is incident on a yellow filter. Does any light make it through the yellow filter?

11. What color of paint results when magenta paint is mixed with yellow paint?

12. The intensity of light at a particular distance away from the spherically-symmetric light source is 600 W/m^2. What is the intensity at a point six times as far from the source?

Solutions

1. Distance/speed = time $1.5 \times 10^{11}/3 \times 10^{8} = 499$ s	**2.** $f = c/\lambda$ $= 3 \times 10^{8}/1 \times 10^{-15}$ $= 3 \times 10^{23}$ Hz	**3.** Number of seconds in a year: $(365)(24)3600 = 3.15 \times 10^{7}$ s In 4.3 years: $4.3\ (3.15 \times 10^{7}\ s) = 1.36 \times 10^{8}$ s $(3 \times 10^{8})\ (1.36 \times 10^{8}) = 4.1 \times 10^{16}$ m
4. (a) $\lambda_s = 3.0 \times 10^{8}/6 \times 10^{14}$ $= 5.0 \times 10^{-7}$ m $= 500 \times 10^{-9}$ m $= 500$ nm **4. (b)** $f_o = 6.0 \times 10^{14}(1 + 0.3)$ $= 7.8 \times 10^{14}$ Hz A positive sign is used above because the source is moving *toward* the observer, and therefore the observed frequency will be greater than the source frequency. If a negative sign were incorrectly chosen, the observed frequency would be *less* than 6.0×10^{14} Hz.	**4. (c)** $\lambda_o = 3 \times 10^{8}/7.8 \times 10^{14}$ $= 3.8 \times 10^{-7}$ $= 380 \times 10^{-9}$ m $= 380$ nm **4. (d)** Observed wavelength is shorter than the source wavelength; it's shifted toward the "blue" end (the short end) of the visible portion of the electromagnetic spectrum.	**5.** $5.6 = 5.0\ (1 + v/c)$ $v/c = 0.11$ $v = 0.11\ (3.0 \times 10^{8})$ $= 0.33 \times 10^{8}$ m/s A positive sign has to be used above in order that (1 + v/c) be less than 1.0. The galaxy is moving toward Earth; the light is blue-shifted.

6. 30 Y + 30 M = [15R + 15 G] + [15 B + 15 R] = [15 R + 15 G + 15 B] + 15 R = 45 W + 15 R = 60 watts/m^2 of pale red (or, pink) (Other descriptions, such as "light red" would be acceptable.)

7. Add 20 W/m^2 Y to get 60 W/m^2 of white light:	**8.** 60 Y = 30 R +30 G [(30 R + 30 G) + 30 B] + 5 G = 90 RGB + 5 G = 90 W + 5 G = 95 pale green	
9. Only the blue part of the magenta light makes it through the cyan filter. Green apples absorb blue, so there is no light reflected off the apple: it appears black.	**10.** No. The blue light that makes it through the magenta filter is absorbed by the yellow filter, which only allows red and green through, but absorbs blue.	**11.** The magenta paint absorbs green, while the yellow paint absorbs blue. Magenta and yellow together absorb green and blue. When white light is incident on the paint mixture, the reflected light is red.

12.

$I_1 = P/4\pi r_1^2$
$= 600\ W/m^2$

If the observation point becomes six times as far, then r^2 becomes $6^2 = 36$ times greater, which means the intensity at this farther point would be:

$(1/36)\ 600 = 16.67\ W/m^2$

Another way to get this answer:

$I_1 = P/4\pi r_1^2$
$I_2 = P/4\pi r_2^2$

Ratio:

$I_2/I_1 = (r_1/r_2)^2$
$= (r_1/6r_1)^2$
$= 1/36$

$I_2 = (1/36)\ I_1$
$= (1/36)\ 600\ W/m^2$
$= 16.67\ W/m^2$