Chapter 20
Light: Wave Nature
20.1 Electromagnetic Spectrum/Refraction of Light Homework # 161

Electromagnetic Spectrum

I

01. A radar signal has a frequency of 12.25 GHz (1 GHz = 1.0 x 10^9 Hz). What is its wavelength?

02. What is the frequency of a microwave whose wavelength is 2.75 cm?

03. What is the wavelength of K-Rock's carrier wave at 92.3 MHz on the FM dial? (1 MHz = 1.0 x 10^6 Hz)

04. An X-ray has a wavelength of 2.50 Å (1Å = 1 x 10^{-10} m). What is its frequency?

05. What is the wavelength range of the visible portion of the EM spectrum?

06. Find the frequency for each of the following colors of light.
a.) red (λ = 700 nm) b.) violet (λ = 400 nm) c.) yellow (λ = 589 nm) d.) green (λ = 550 nm)

07. What portion of the EM spectrum has wavelengths _____ than visible light?
a.) shorter b.) longer

Refraction of Light

For problems 08-10, refer to Homework #151 for the table of "Indices of Refraction (λ = 589 nm)" in "Chapter 19-Light: Geometric Optics".

I

08. A source of light has a wavelength of 650 nm in air. What is the wavelength of light in crown glass?

09. A source of light has a wavelength of 650 nm in air. What is the wavelength of light in water?

10. A source of light has a wavelength of 650 nm in air. What is the wavelength of light in diamond?

11. The wavelength of light from a sodium lamp is 589 nm when in air. If the light from this lamp is determined to have a wavelength of 366 nm when traveling through turquoise, what is the index of refraction of turquoise?

ANSWERS: **01.** 2.45 cm **02.** 10.9 GHz **03.** 3.25 m **04.** 1.20 x 10^{18} Hz **05.** 400-700 nm
06. a.) 4.29 x 10^{14} Hz b.) 7.50 x 10^{14} Hz c.) 5.09 x 10^{14} Hz d.) 5.45 x 10^{14} Hz
07. a.) ultraviolet b.) infrared **08.** 428 nm **09.** 489 nm **10.** 269 nm **11.** 1.61

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20.2 Diffraction and Interference-Double Slit Phenomenon — Homework # 162

I

01. A beam of 475-nm light strikes two closely-spaced slits. A third-order fringe is produced at angle of 32.5° to the direction of the initial beam. How far apart are the slits?

02. Monochromatic light falls on a two slits that are 12.3 μm apart. A diffraction and interference pattern is observed with a fifth-order fringe appearing at an angle of 12.4° with the original path of the light. What is the wavelength of this light?

II

03. A beam of 450-nm light strikes two slits that are 23.7 μm apart producing a diffraction and interference pattern on a screen 4.25 m away. How far apart are the fringes on the screen?

04. Monochromatic light falls on two slits that are 0.0525 mm apart producing a diffraction and interference pattern on a screen 6.50 m away with fringes that are 7.36 cm apart. What is the wavelength of light?

05. A parallel beam of 525-nm light passes through a double slit onto a screen that is 3.35 m away creating fringes that are 4.28 cm apart. How far apart are the slits?

06. Monochromatic light passes through two slits that are 0.025 mm apart onto a screen that is 2.85 m away. For each of the following wavelengths, determine the distance between fringes produced on the screen.
    a.) 400 nm b.) 500 nm c.) 600 nm d.) 700 nm

07. A beam of 550-nm light passes through a double-slit onto a screen that is 2.85 m away and the distance between the fringes is measured. Once the measurement is made, the first double-slit is replaced by a second with a different distance between the slits. This experiment is repeated with a third and fourth trial, each time changing the double-slit spacing distance. For each of the following double-slit spacings, determine the distance between fringes produced on the screen.
    a.) 25.0 μm b.) 50.0 μm c.) 75.0 μm d.) 100.0 μm

08. Light with a wavelength of 480 nm strikes two slits that are 5.35×10^{-2} mm apart and illuminate a screen 3.95 m away with a diffraction and interference pattern. How far from the central fringe will the sixth-order fringe appear?

09. Visible white light hits two slits that are 80.0 μm apart producing successive rainbow patterns on a screen 4.75 m away.
    a.) How far from the central fringe will the second order appear for the longest-wavelength red light?
    b.) How far from the central fringe will the third order appear for the shortest-wavelength violet light?
    c.) What can be said of the second and third "rainbows" produced?

10. Light with a wavelength of 650 nm strikes two slits that are 7.65×10^{-5} m apart and produce a diffraction and interference pattern on a screen 4.00 m away. How wide will the central fringe be that appears on the screen?

ANSWERS: **01.** 2.65 μm **02.** 528 nm **03.** 8.07 cm **04.** 594 nm **05.** 41.1 μm
06. a.) 4.56 cm b.) 5.70 cm c.) 6.84 cm d.) 7.98 cm **07.** a.) 6.27 cm b.) 3.14 cm c.) 2.01 cm
07. d.) 1.57 cm **08.** 21.3 cm **09.** a.) 8.31 cm b.) 7.13 cm c.) overlap of 2nd & 3rd rainbows **10.** 3.40 cm

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20.3 Diffraction and Interference-Single Slit Phenomenon — Homework # 163

I

01. What is the angular width of the central diffraction peak when 490-nm light falls on a slit 40 μm wide?

02. Monochromatic light passes through a slit with a width of 36.0×10^{-3} mm creating a diffraction and interference pattern where the angle between the dark fringes on either side of the central maximum is 1.80°. What is the wavelength of light used?

03. Monochromatic light with a wavelength of 630 nm passes through a slit creating a central angular width of 38.4°. What is the width of this slit?

II

04. How wide is a central diffraction peak on a screen 3.60 m behind a slit, with a width of 0.0344 mm, when illuminated by 440-nm light?

05. If 530-nm light diffracts through a single slit producing a central-fringe width of 6.42 cm on a screen 3.40 m away, what must be the width of the slit?

06. Monochromatic light passes through a single slit with a width of 38 μm creating a central fringe that is 9.30 cm wide on a screen 4.20 m away. What is the wavelength of light used?

ANSWERS: **01.** 1.40° **02.** 565 nm **03.** 1.92 μm **04.** 9.21 cm **05.** 56.4 μm **06.** 421 nm

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20.4 Diffraction and Interference-Multiple Slit Phenomenon Homework # 164

I

01. Light with a wavelength of 460 nm strikes a diffraction grating with slits that are 0.0180 mm apart. At what angle from the center of the interference pattern will the third-order maximum occur?

02. A beam of light with wavelength of 580 nm falls on a diffraction grating producing a second-order line at 27.65°.
a.) How far apart are the slits? b.) How many lines per centimeter does the grating have?

II

03. Light with a wavelength of 680 nm falls on a diffraction grating producing a third-order maximum at an angle of 30.67°. How many lines per centimeter does the grating have?

04. Monochromatic light passes through a grating with 1200 lines/cm and produces a second-order maximum at an angle of 9.22°. What is the wavelength of light used?

05. Light with a wavelength of 420 nm passes through a grating with 5500 lines/cm. At what angle from the central peak will the fourth-order maximum occur?

06. An experiment is done using light with a wavelength of 500 nm. The procedure calls for the student to measure the angle of the first-order maximum for four different diffraction gratings. Predict the results of this experiment if the four gratings used have the following lines/cm.
a.) 1000 lines/cm b.) 2000 lines/cm c.) 4000 lines/cm d.) 8000 lines/cm

07. A grating has 4000 lines/cm. How many **FULL** spectral orders can be seen when illuminated by white light?

ANSWERS: **01.** 4.40° **02.** a.) 2.50 μm b.) 4000 lines/cm **03.** 2500 lines/cm **04.** 668 nm **05.** 67.5° **06.** a.) 2.86° b.) 5.74° c.) 11.5° d.) 23.6° **07.** 6 [3 full spectra on either side of the central fringe. There will be 6 violet fringes, but only 3 red. None of the spectra on either side of the central fringe will appear without some overlap of the next higher order spectrum. E.g.: The longest red wavelength (λ = 700 nm) for the first order spectrum (m = 1, or 1½ wavelengths of red) will appear at angle of 24.8° from the center, while the shortest violet wavelength (λ = 400 nm) for the second order spectrum (m = 2, or 2½ wavelengths of violet) will appear at 23.6° form the center.]

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20.5 Thin Films — Homework # 165

Refer to the table of "Indices of Refraction (λ = 589 nm)" found on Homework #151 in "Chapter 19-Light: Geometric Optics".

I

01. A soap bubble, with $n \approx 1.34$, is 125.0 nm thick. When white light strikes the surface normally, what color (wavelength) will appear at the center? Assume the thickness of the soap bubble is the minimum thickness to see this color (wavelength).

02. Monochromatic light with a wavelength of 540 nm encounters a hollow glass ball ($n = 1.50$) filled with air. If the light hits the surface of the glass normally and is visible to the eye at the surface, what is the minimum thickness of the glass?

II

03. Two long, flat pieces of glass plates are placed one on top of the other separated only by a thin piece of plastic at one end (See diagram below). If there are 37 dark and 37 bright lines from one end of the pair of glass plates to the other (where the thin piece of plastic is located) when illuminated by a sodium lamp (λ = 589 nm), how thick is the piece of plastic?

04. What is the minimum thickness of air between two flat glass plates if light with a wavelength of 580 nm is to appear _____ when it is incident normally?
a.) bright b.) dark

05. If thickness of the air trapped between two flat glass plates is 0.166 μm, and a monochromatic light is visible at its surface when incident normally, what is the wavelength of light?

06. A layer of motor oil ($n = 1.78$) is spread over a puddle of water on the blacktop. If orange (λ = 625 nm) light is visible when normally incident, what is the minimum thickness of the layer of oil?

III

07. A thin film of ethyl alcohol is spread over a flat piece of light flint glass. Monochromatic light, whose wavelength can be varied, is slowly increased from 400-700 nm and is directed normally to the surface of the alcohol. The reflected light is a minimum (darkest) for λ = 512 nm and a maximum (brightest) λ = 640 nm, what is the thickness of the film?

Problem 03

ANSWERS: **01.** 670 nm **02.** 90 nm **03.** 10.7 μm **04.** a.) 145 nm b.) 290 nm **05.** 664 nm **06.** 0.0878 μm **07.** 471 nm

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20.6 Polarization of Light — Homework # 166

Refer to the table of "Indices of Refraction (λ = 589 nm)" found on Homework #151 in "Chapter 19-Light: Geometric Optics".

I

01. Two polarizers have polarizing axes at a 45.0° angle to one another. What fraction of unpolarized light directed at this pair of polarizers will be transmitted through the pair?

02. Light passes through a polarizer blocking half of the light. What fraction of this **REMAINING** light will pass through a second polarizer at an angle of 45.0° to the first?

03. What is Brewster's angle for a flat piece of glass crown glass sitting in a room filled with air?

04. What is Brewster's angle for a flat piece of glass crown glass submerged in water?

II

05. At what angle should the polarizing axes of two polarizers be oriented so that one-eighth of the original intensity of light passes through?

06. Unpolarized light with an intensity of 240 foot-candles strikes two polarizers with polarizing axes at 35.0° to one another. What intensity of light will pass through the two polarizers?

07. The intensity of light that passes through a polarizer is 25.0 candelas. What intensity of this light will pass through an analyzer with a polarizing axis oriented at a 25.0° angle to the axis of the polarizer?

08. Polarized light with an intensity of 4200 foot-candles encounters a polarizer with an axis that is 18.0° with direction of the oscillating electric field of the polarized light. What intensity of this light will pass through the polarizer?

09. If 340 foot-candles of light falls upon a pair of polarizers reducing the intensity of light that exits the pair to 120 foot-candles, what is the angle between the polarizing axes of these two polarizers?

10. Sunlight strikes the surface of a lake.
    a.) At what incident angle will light be totally polarized?
    b.) What is the angle of refraction for the incident angle determined in part a.)?

ANSWERS: **01.** ¼ **02.** ½ **03.** 56.7° **04.** 48.8° **05.** 60.0° **06.** 80.5 ft-can **07.** 20.5 cd **08.** 3800 ft-can **09.** 32.8° **10.** a.) 53.1° b.) 36.9°