Waves and optics

Problem 1:

A simple telescope consists of two convex lenses, the objective and the eyepiece, which have a common focal point P, as shown in the figure above. If the focal length of the objective is 1.0 meter and the angular magnification of the telescope is 10, what is the optical path length between objective and eyepiece?

(A) 0.1 m
(B) 0.9 m
(C) 1.0 m
(D) 1.1 m
(E) 10 m

Problem 2:

Unpolarized light is incident on two ideal polarizers in series. The polarizers are oriented so that no light emerges through the second polarizer. A third polarizer is now inserted between the first two and its orientation direction is continuously rotated through 180°. The maximum fraction of the incident power transmitted through all three polarizers is

(A) zero (B) $\frac{1}{8}$ (C) $\frac{1}{2}$ (D) $\frac{1}{\sqrt{2}}$ (E) 1

Problem 3:

In an ordinary hologram, coherent monochromatic light produces a 3-dimensional picture because wave information is recorded for which of the following?

I. Amplitude
II. Phase
III. Wave-front angular frequency

(A) I only
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III

Problem 4:

A soap film with index of refraction greater than air is formed on a circular wire frame that is held in a vertical plane. The film is viewed by reflected light from a white-light source. Bands of color are observed at the lower parts of the soap film, but the area near the top appears black. A correct explanation for this phenomenon would involve which of the following?

I. The top of the soap film absorbs all of the light incident on it; none is transmitted.
II. The thickness of the top part of the soap film has become much less than a wavelength of visible light.
III. There is a phase change of 180° for all wavelengths of light reflected from the front surface of the soap film.
IV. There is no phase change for any wavelength of light reflected from the back surface of the soap film.

(A) I only
(B) II and III only
(C) III and IV only
(D) I, II, and III
(E) II, III, and IV

Problem 5:

The screen of a pinhole camera is at a distance D from the pinhole, which has a diameter d. The light has an effective wavelength λ. ($\lambda << D$) For which of the following values of d will the image be sharpest?

(A) $\sqrt{\lambda D}$ (B) λ (C) $\frac{\lambda}{10}$
(D) $\frac{\lambda^2}{D}$ (E) $\frac{D^2}{\lambda}$

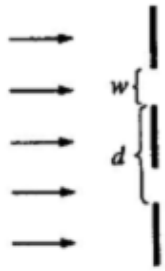
Problem 6:

The measured index of refraction of x-rays in rock salt is less than one. This is consistent with the theory of relativity because

(A) relativity deals with light waves traveling in a vacuum only
(B) x-rays cannot transmit signals
(C) x-ray photons have imaginary mass
(D) the theory of relativity predates the development of solid-state physics
(E) the phase velocity and group velocity are different

Problem 7:
Two harmonic transverse waves of the same frequency with displacements at right angles to each other can be represented by the equations
$y = y_0 \sin(\omega t - kx)$,
$z = z_0 \sin(\omega t - kx + \Phi)$,
where y_0 and z_0 are nonzero constants.
The equations represent a plane-polarized wave if Φ equals
(A) $2^{1/2}$
(B) $3\pi/2$
(C) $\pi/2$
(D) $\pi/4$
(E) 0

Problem 8:



In a double-slit interference experiment, d is the distance between the centers of the slits and w is the width of each slit, as shown in the figure above. For incident plane waves, an interference maximum on a distant screen will be "missing" when
(A) $d = \sqrt{2}w$
(B) $d = \sqrt{3}w$
(C) $2d = w$
(D) $2d = 3w$
(E) $3d = 2w$

Problem 9:
An object is located 5.0 cm in front of a concave mirror whose focal length is 20.0 cm. Where is the image located?
(A) 4.0 cm in front of the mirror
(B) 5.7 cm behind the mirror
(C) 6.7 cm behind the mirror
(D) 8.0 cm in front of the mirror
(E) 4.0 cm behind the mirror

Problem 10:
Two coherent sources of visible monochromatic light form an interference pattern on a screen. If the relative phase of the sources is varied from 0 to 2π at a frequency of 500 hertz, which of the following best describes the effect, if any, on the interference pattern?
(A) It is unaffected because the frequency of the phase change is very small compared to the frequency of visible light.
(B) It is unaffected because the frequency of the phase change is an integral multiple of π.
(C) It is destroyed except when the phase difference is 0 or π.
(D) It is destroyed for all phase differences because the monochromaticity of the sources is destroyed.
(E) It is not destroyed but simply shifts positions at a rate too rapid to be detected by the eye.

Problem 11:

Light of wavelength 5200 Angstroms is incident normally on a transmission diffraction grating with 2000 lines per centimeter.

The first-order diffraction maximum is at an angle, with respect to the incident beam, that is most nearly

(A) 3°
(B) 6°
(C) 9°
(D) 12°
(E) 15°

Problem 12:

For blue light, a transparent material has a relative permittivity (dielectric constant) of 2.1 and a relative permeability of 1.0. If the speed of light in a vacuum is c, the phase velocity of blue light in an unbounded medium of this material is

(A) $\sqrt{3.1}\,c$
(B) $\sqrt{2.1}\,c$
(C) $\frac{c}{\sqrt{1.1}}$
(D) $\frac{c}{\sqrt{2.1}}$
(E) $\frac{c}{\sqrt{3.1}}$

Problem 13:

The equation $y = A \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda}\right)$, where A, T, and λ are positive constants, represents a wave whose

(A) amplitude is $2A$
(B) velocity is in the negative x-direction
(C) period is $\frac{T}{\lambda}$
(D) speed is $\frac{x}{t}$
(E) speed is $\frac{\lambda}{T}$

Problem 14:

It is necessary to coat a glass lens with a non-reflecting layer. If the wavelength of the light in the coating is λ, the best choice is a layer of material having an index of refraction between those of glass and air and a thickness of

(A) $\frac{\lambda}{4}$ (B) $\frac{\lambda}{2}$ (C) $\frac{\lambda}{\sqrt{2}}$ (D) λ (E) 1.5λ

Problem 15:

A light source is at the bottom of a pool of water (the index of refraction of water is 1.33). At what minimum angle of incidence will a ray be totally reflected at the surface?

(A) 0°
(B) 25°
(C) 50°
(D) 75°
(E) 90°