Optics – Problem Set # 1

Rest mass of the electron	$m_e = 9.11 \times 10^{-31}$ kilogram $= 9.11 \times 10^{-28}$ gram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb $= 4.80 \times 10^{-10}$ statcoulomb (esu)
Avogadro's number	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.32$ joules/(mole · K)
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ joule/K $= 1.38 \times 10^{-16}$ erg/K
Speed of light	$c = 3.00 \times 10^8$ m/s $= 3.00 \times 10^{10}$ cm/s
Planck's constant	$h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second
	$\hbar = h/2\pi$
Vacuum permittivity	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton · meter^2)
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram · second^2)
Acceleration due to gravity	$g = 9.80$ m/s$^2 = 980$ cm/s^2
atmosphere pressure	1 atm $= 1.0 \times 10^5$ newton/meter$^2 = 1.0 \times 10^5$ pascals (Pa)
1 angstrom	$1 \text{ Å} = 1 \times 10^{-10}$ meter

$$1 \text{ weber/m}^2 = 1 \text{ tesla} = 10^4 \text{ gauss}$$

20. 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) $3d = 2w$

35. 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°

21. 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

22 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
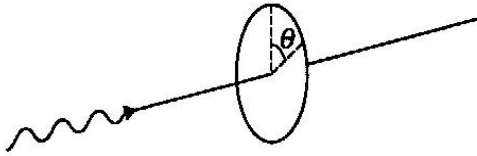
67. A steady beam of light is normally incident on a piece of polaroid. As the polaroid is rotated around the beam axis, the transmitted intensity varies as $A + B \cos 2\theta$, where θ is the angle of rotation, and A and B are constants with $A > B > 0$. Which of the following may be correctly concluded about the incident light?

(A) The light is completely unpolarized.
(B) The light is completely plane polarized.
(C) The light is partly plane polarized and partly unpolarized.
(D) The light is partly circularly polarized and partly unpolarized.
(E) The light is completely circularly polarized.

68. The angular separation of the two components of a double star is 8 microradians, and the light from the double star has a wavelength of 5500 angstroms. The smallest diameter of a telescope mirror that will resolve the double star is most nearly

(A)   1 mm
(B)   1 cm
(C)   10 cm
(D)   1 m
(E)   100 m

Movable
Mirror

5 cm

Source

To Vacuum
Pump

Observer
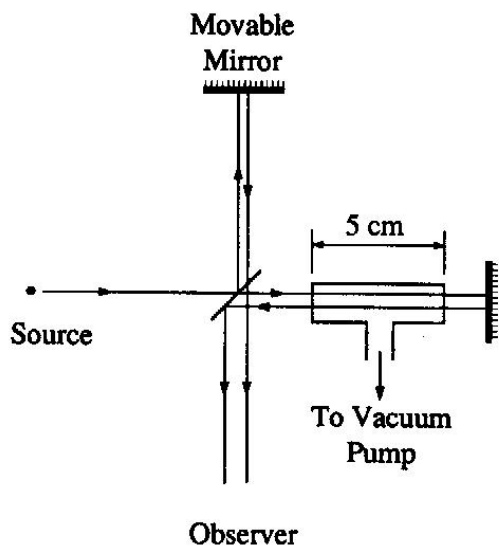
96. A gas-filled cell of length 5 centimeters is inserted in
one arm of a Michelson interferometer, as shown in
the figure above. The interferometer is illuminated
by light of wavelength 500 nanometers. As the gas
is evacuated from the cell, 40 fringes cross a point
in the field of view. The refractive index of this gas
is most nearly

(A) 1.02
(B) 1.002
(C) 1.0002
(D) 1.00002
(E) 0.98

16. An engine absorbs heat at a temperature of
727° C and exhausts heat at a temperature of
527° C. If the engine operates at maximum
possible efficiency, for 2000 joules of heat
input the amount of work the engine performs
is most nearly

(A)   400 J
(B) 1450 J
(C) 1600 J
(D) 2000 J
(E) 2760 J
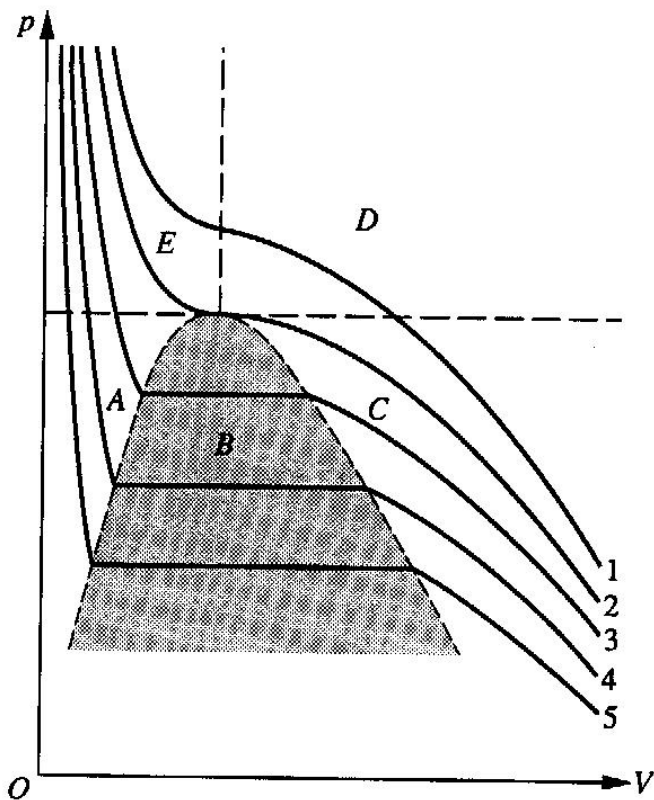
Isotherms and coexistence curves are shown in the pV diagram above for a liquid-gas system. The dashed lines are the boundaries of the labeled regions.

46. Which numbered curve is the critical isotherm?

    (A) 1
    (B) 2
    (C) 3
    (D) 4
    (E) 5

47. In which region are the liquid and the vapor in equilibrium with each other?

    (A) A
    (B) B
    (C) C
    (D) D
    (E) E

62. A mole of ideal gas initially at temperature T_0 and volume V_0 undergoes a reversible isothermal expansion to volume V_1. If the ratio of specific heats is $c_p/c_v = \gamma$ and if R is the gas constant, the work done by the gas is

(A) zero

(B) $RT_0 (V_1/V_0)^\gamma$

(C) $RT_0 (V_1/V_0 - 1)$

(D) $c_v T_0 \left[1 - (V_0/V_1)^{\gamma-1} \right]$

(E) $RT_0 \ln (V_1/V_0)$

63. Which of the following is true if the arrangement of an isolated thermodynamic system is of maximal probability?

(A) Spontaneous change to a lower probability occurs.
(B) The entropy is a minimum.
(C) Boltzmann's constant approaches zero.
(D) No spontaneous change occurs.
(E) The entropy is zero.