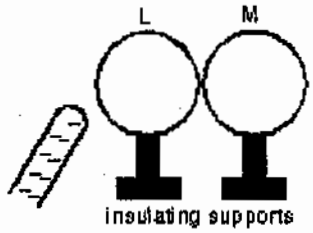
Physics 241 (Fall 2002) Final Exam December 11, 2002

Instructions:

1) The problems are NOT given in the order of their degrees of difficulty.
2) Each problem is worth 3 points.
3) Please find possibly useful formulae and constants on separate pages.
4) Two 8.5"x11" crib sheets (both sides) are allowed; the use of any additional material (except for those provided) is considered cheating.

1. Two uncharged metal spheres, L and M, are in contact. A negatively charged rod is brought close to L, but not touching it, as shown. The two spheres are slightly separated and the rod is then withdrawn. As a result:

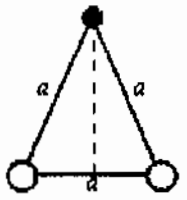


A) both spheres are neutral
B) both spheres are positive
C) both spheres are negative
D) L is negative and M is positive
E) L is positive and M is negative

2. Identical point charges are located at two vertices of an equilateral triangle. A third charge is placed so the electric field at the third vertex is zero. The third charge must:
   A) be on the perpendicular bisector of the line joining the first two charges
   B) be on the line joining the first two charges
   C) be identical to the first two charges
   D) have the same magnitude as the first two charges but may have a different sign
   E) be at the center of the triangle

3. Charge Q is distributed uniformly throughout an insulating sphere of radius R. The magnitude of the electric field at a point $R/2$ from the center is:
   A) $Q/4\pi\epsilon_0 R^2$
   B) $Q/\pi\epsilon_0 R^2$
   C) $3Q/4\pi\epsilon_0 R^2$
   D) $Q/8\pi\epsilon_0 R^2$
   E) none of these

4. The two charges Q are fixed at the vertices of an equilateral triangle with sides of length a. If $k = 1/4\pi\epsilon_0$, the work required to move q from the other vertex to the center of the line joining the fixed charges is:



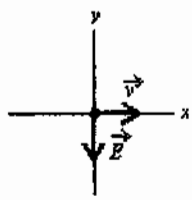
   A) 0
   B) kQq/a
   C) kQq/a^2
   D) $2kQq/a$
   E) $\sqrt{2}kQq/a$

5. A certain capacitor has a capacitance of 5 μF. While it is charged to 5 μC and isolated, the plates are pulled apart so its capacitance becomes 2 μF. The work done by the pulling agent is about:
   A) 0
   B) 4×10^{-6} J
   C) 8×10^{-6} J
   D) 9×10^{-6} J
   E) 18×10^{-6} J

6. A nichrome wire is 1 m long and 1×10^{-6} m^2 in cross-sectional area. When connected to a potential difference of 2 V, a current of 4 A exists in the wire. The resistivity of this nichrome is:
   A) $10^{-7}\ \Omega \cdot$ m
   B) $2 \times 10^{-7}\ \Omega \cdot$ m
   C) $4 \times 10^{-7}\ \Omega \cdot$ m
   D) $5 \times 10^{-7}\ \Omega \cdot$ m
   E) $8 \times 10^{-7}\ \Omega \cdot$ m

7. A certain capacitor, in series with a 720-Ω resistor, is being charged. At the end of 10 ms its charge is half the final value. The capacitance is about:
   A) 9.6 μF
   B) 14 μF
   C) 20 μF
   D) 7.2 F
   E) 10 F

8. An electron is travelling in the positive x direction. A uniform electric field $\vec{E}$ is in the negative y direction. If a uniform magnetic field with the appropriate magnitude and direction also exists in the region, the total force on the electron will be zero. The appropriate direction for the magetic field is:



   A) the positive y direction
   B) the negative y direction
   C) into the page
   D) out of the page
   E) the negative x direction

9. A long straight cylindrical shell carries current i uniformly distributed over its cross section. The magnitude of the magnetic field is greatest:
   A) at the inner surface of the shell
   B) at the outer surface of the shell
   C) inside the shell near the middle
   D) in hollow region near the inner surface
   E) near the center of the hollow region

10. An 6.0-mH inductor and a 3.0-Ω resistor are wired in series to a 12-V ideal battery. A switch in the circuit is closed at time 0, at which time the current is zero. 2.0 ms later the energy stored in the inductor is:
   A) 0
   B) 2.5×10^{-2} J
   C) 1.9×10^{-2} J
   D) 3.8×10^{-2} J
   E) 9.6×10^{-3} J

11. A current of 1 A is used to charge a parallel plate capacitor with square plates. If the area of each plate is 0.6 m^2 the displacement current through a 0.3 m^2 area wholly between the capacitor plates and parallel to them is:
   A) 1 A
   B) 2 A
   C) 0.7 A
   D) 0.5 A
   E) 0.25 A

12. An RLC series circuit is connected to an oscillator with $\epsilon_m = 100$ V. If the voltage amplitudes V_R, V_L, and V_C are all equal to each other, then V_R must be:
   A) 33 V
   B) 50 V
   C) 67 V
   D) 87 V
   E) 100 V

13. If the electric field in a plane electromagnetic wave is given by $E_m \sin[(3 \times 10^6\ rad/m)x - \omega t)]$, in SI the value of ω is:
    A) 0.01 rad/s
    B) 10 rad/s
    C) 100 rad/s
    D) 9×10^{14} rad/s
    E) 9×10^{16} rad/s

14. The light intensity 10 m from a point source is 1000 W/m^2. The intensity 100 m from the same source is:
    A) 1000 W/m^2
    B) 100 W/m^2
    C) 10 W/m^2
    D) 1 W/m^2
    E) 0.1 W/m^2

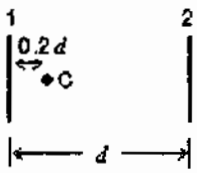
15. Light with an intensity of 1 kW/m^2 falls normally on a surface with an area of 1 cm^2 and is completely reflected. The force of the radiation on the surface is:
    A) 1.0×10^{-4} N
    B) 3.3×10^{-11} N
    C) 1.7×10^{-10} N
    D) 3.3×10^{-10} N
    E) 6.7×10^{-10} N

16. Three polarizing sheets are placed in a stack with the polarizing directions of the first and third perpendicular to each other. What angle should the polarizing direction of the middle sheet make with the polarizing direction of the first sheet to obtain maximum transmitted intensity when unpolarized light is incident on the stack?
    A) 0
    B) 30°
    C) 45°
    D) 60°
    E) 90°

17. A ray of light in water (index n_1) is incident on its surface (with air) at the critical angle. Some oil (index n_2) is now floated on the water. The angle between the ray in the oil and the normal is:
    A) $\sin^{-1}(1.00)$
    B) $\sin^{-1}(1/n_1)$
    C) $\sin^{-1}(1/n_2)$
    D) $\sin^{-1}(n_1/n_2)$
    E) $\sin^{-1}(n_2/n_1)$

18. The critical angle for total internal reflection at a diamond-air interface is 25°. Suppose light is incident at an angle of θ with the normal. Total internal reflection will occur if the incident medium is:
    A) air and $\theta = 25°$
    B) air and $\theta > 25°$
    C) air and $\theta < 25°$
    D) diamond and $\theta < 25°$
    E) diamond and $\theta > 25°$

19. A candle C sits between two parallel mirrors, a distance $0.2d$ from mirror 1. Here d is the distance between the mirrors. Multiple images of the candle appear in both mirrors. How far behind mirror 1 are the nearest three images of the candle in that mirror?



    A) $0.2d$, $1.8d$, $2.2d$
    B) $0.2d$, $2.2d$, $4.2d$
    C) $0.2d$, $1.8d$, $3.8d$
    D) $0.2d$, $0.8d$, $1.4d$
    E) $0.2d$, $1.8d$, $3.4d$

20. An erect object is located on the central axis of a spherical mirror. The magnification is –3. This means its image is:
    A) real, inverted, and on the same side of the mirror
    B) virtual, erect, and on the opposite side of the mirror
    C) real, erect, and on the same side of the mirror
    D) real, inverted, and on the opposite side of the mirror
    E) virtual, inverted, and on the opposite side of the mirror

21. A man stands with his nose 8 cm from a concave shaving mirror of radius 32 cm. The distance from the mirror to the image of his nose is:
    A) 8 cm
    B) 12 cm
    C) 16 cm
    D) 24 cm
    E) 32 cm

22. A concave spherical surface with radius r separates a medium with index of refraction 2 from air. As an object is moved toward the surface from far away along the central axis its image:
    A) changes from virtual to real when it is $r/2$ from the surface
    B) changes from virtual to real when it is $2r$ from the surface
    C) changes from real to virtual when it is $r/2$ from the surface
    D) changes from real to virtual when it is $2r$ from the surface
    E) remains virtual

23. An erect object is $2f$ in front of a thin convex lens of focal length f. The image is:
    A) real, inverted, magnified
    B) real, erect, same size
    C) real, inverted, same size
    D) virtual, inverted, reduced
    E) real, inverted, reduced

24. A thin plano-convex glass ($n = 1.5$) lens has a curved side whose radius is 50 cm. If the image size is to be the same as the object size, the object should be placed at a distance from the lens of:
    A) 50 cm
    B) 100 cm
    C) 200 cm
    D) 400 cm
    E) 340 cm

25. The Sun subtends 0.5° as seen from the Earth. Its image, using a 1.0-m focal length lens, is about:
    A) 10 cm
    B) 2 cm
    C) 1 cm
    D) 5 mm
    E) 1 mm

26. An object is 20 cm to the left of a thin lens of focal length +10 cm. A second thin lens, of focal length +12.5 cm, is 30 cm to the right of the first lens. The distance between the original object and the final image is:
    A) 28 cm
    B) 50 cm
    C) 100 cm
    D) 0
    E) infinity

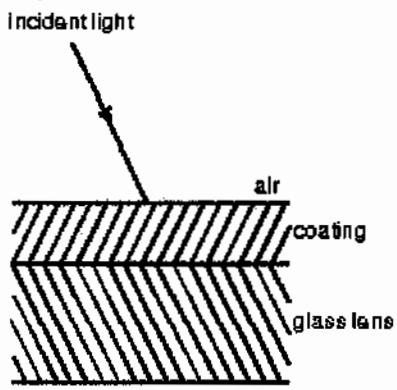
27. A thin converging lens of focal length 20 cm is placed in contact with a thin diverging lens of focal length 30 cm. The focal length of this combination is:
    A) +60 cm
    B) +25 cm
    C) +12 cm
    D) −10 cm
    E) +10 cm

28. One of the two slits in a Young's experiment is painted over so that it transmits only one-half the intensity of the other slit. As a result:
    A) the fringe system disappears
    B) the bright fringes get brighter and the dark ones get darker
    C) the fringes just get dimmer
    D) the dark fringes just get brighter
    E) the dark fringes get brighter and the bright ones get darker

29. A liquid of refractive index $n = 4/3$ replaces the air between a fixed wedge formed from two glass plates as shown. As a result, the spacing between adjacent dark bands in the interference pattern:

    A) increases by a factor of 4/3
    B) increases by a factor of 3
    C) remains the same
    D) decreases to 3/4 of its original value
    E) decreases to 1/3 of its original value

30. A lens with a refractive index of 1.5 is coated with a material of refractive index 1.2 in order to minimize reflection. If λ denotes the wavelength of the incident light in air, what is the thinnest possible such coating?



A) 0.5λ
B) 0.416λ
C) 0.3λ
D) 0.208λ
E) 0.25λ

31. In a thin film experiment, a wedge of air is used between two glass plates. If the wavelength of the incident light in air is 480 nm, how much thicker is the air wedge at the 16th dark fringe than it is at the 6th?
A) 2400 nm
B) 4800 nm
C) 240 nm
D) 480 nm
E) none of these

32. A parallel beam of monochromatic light is incident on a slit of width 2 cm. The light passing through the slit falls on a screen 2 m away. As the slit width is decreased:
A) the width of the pattern on the screen continuously decreases
B) the width of the pattern on the screen at first decreases but then increases
C) the width of the pattern on the screen increases and then decreases
D) the width of the pattern on the screen remains the same
E) the pattern on the screen changes color going from red to blue

33. Two slits in an opaque barrier each have a width of 0.020 mm and are separated by 0.050 mm. When coherent monochromatic light passes through the slits the number of interference maxima within the central diffraction maximum is:
A) 1
B) 2
C) 3
D) 4
E) 5

34. Monochromatic light is normally incident on a diffraction grating that is 1 cm wide and has 10,000 slits. The first order line is deviated at a 30° angle. What is the wavelength, in nm, of the incident light?
A) 300
B) 400
C) 500
D) 600
E) 1000

35. The "D line" in the spectrum of sodium is a "doublet" with wavelengths 589.0 nm and 589.6 nm. What is the minimum number of slits in a grating to just resolve this doublet in second order?
A) 982
B) 491
C) 245
D) 123
E) 61