Physics 114 – Practice Test for the Final Exam
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Conceptual Question 1:

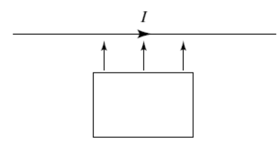
Consider the electric field inside a charged rubber (insulating) balloon. Is E necessarily zero inside the balloon if it is (*a*) spherical, or (*b*) sausage shaped? Assume the charge to be distributed uniformly over the surface for each shape. (*c*) How would the situation change, if at all, if the balloon were coated with a thick layer of conducting paint on its outside surface?

In either case (spherical or sausage shaped) the electric flux through the balloon is zero since the there are no charges inside the balloons.

(a) For the spherical balloon, symmetry dictates that the field is zero as well.
(b) However, since the flux integral cannot be simplified for the sausage shaped balloon, the field inside it is not necessarily zero.
(c) The conducting coating will redistribute the charges to make the field inside zero, regardless of shape.

Conceptual Question 2:

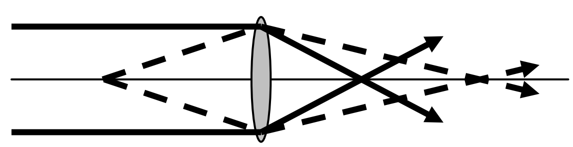
A long, straight wire carries a steady current I. A rectangular conducting loop lies in the same plane as the wire, with two sides parallel to the wire and two sides perpendicular. Suppose the loop is pushed toward the wire as shown. Given the direction of I, what is the direction of the induced current in the loop?



Since the loop is getting closer to the wire, the magnetic field (and therefore the magnetic flux) through it is getting stronger. This will induce an emf in the loop which will set up a current. Since this current will try to oppose the increase in flux. The magnetic field created by the wire is into the page at the loop. The induced current has to create a field that opposes this. In order to set up a field coming out of the page, the induced current has to be counterclockwise.

Conceptual Question 3:

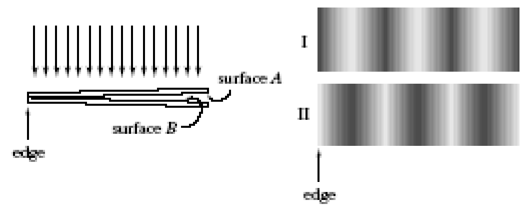
By changing the separation distance between lens and film, a camera can focus on subjects at a variety of distances. Suppose the proper lens-film separation for taking an in-focus picture of a distant object such as the moon is d_0. To take an in-focus picture of a nearby object, will the proper lens-film separation be greater than, equal to, or less than d_0? Explain using diagrams.



Far away objects can be taken to be at infinity, which will put their images at the focus of the lens. As the object is brought closer, the image distance will increase, therefore, the lens-film separation has to increase.

Conceptual Question 4:

Monochromatic light shines on a pair of microscope slides that form a very narrow wedge. The top slide is made of crown glass (n = 1.5) and the bottom slide of flint glass (n = 1.7). Both slides are immersed in sassafras oil, which has an index intermediate between those of the two slides. The top surface of the upper slide and the bottom surface of the lower slide have special coatings on them so that they reflect no light. The inner two surfaces (A and B) have nonzero reflectivities. How does the top view of the slides look like? Explain.



The interference will be between light reflected from A (wave 1) and the light reflected from B (wave 2). Upon reflection from A, wave 1 will undergo a π radian phase change since it is incident upon a medium with higher index of refraction than its current medium (sassafras oil vs. crown glass). Upon reflection from B, wave 2 will also undergo a π radian phase change (flint glass vs. sassafras oil). Since the relative phase change between waves 1 and 2 is zero,

For constructive interference: $\delta = 2nt = m\lambda$ and for destructive interference: $\delta = 2nt = \left(m + \frac{1}{2}\right)\lambda$

At the edge where the spacing between the slides, t, is zero, the condition for constructive interference is satisfied (bright fringe). As the spacing increases, there will be successive destructive (dark) and constructive (bright) interferences. The correct answer is II.

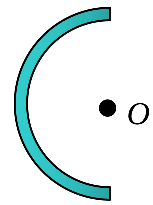
Conceptual Question 5:

A diffraction pattern is produced on a viewing screen by illuminating a long narrow slit with light of wavelength λ.

(a) If λ is increased and no other changes are made how does the pattern change?
(b) If the slit width is decreased and no other changes are made how does the pattern change?
(c) Which would undergo a more severe diffraction; blue light (λ = 400 nm) through a 40 µm pinhole or the voice of a baritone singer (f = 343 Hz) through a 1 m wide door? Take the speed of sound to be 343 m/s.

(a) Since diffraction is proportional to wavelength, as it is increased, diffraction will increase and the pattern will expand.
(b) Diffraction is inversely proportional to slit size. As it is decreased, again, diffraction increases and the pattern expands.
(c) The wavelength of the sound wave is $\lambda = v/f = (343 m/s)/(343 Hz) = 1 m$
Since the ratio λ / a is much larger for the sound wave, it undergoes more severe diffraction.

Problem 1:

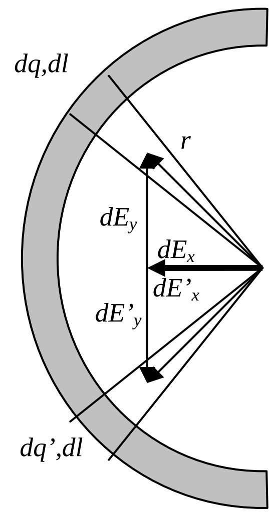


A uniformly charged insulating rod of length 10.0 cm is bent into the shape of a semicircle as shown in the figure. If the rod has a total charge of -7.50 μC, find the following at *O*, the center of the semicircle:

(a) Magnitude and direction of the electric field.

(b) The electric potential.

Hint: $arclength = R\theta$



Dividing the arc into infinitesimal pieces with length *dl*, charge *dq* and subtending an angle dθ, we can see that every piece above the horizontal has a symmetric counterpart below the horizontal for which the vertical components of the electric field cancel leaving only the horizontal (x) component. Also, since the charge is negative, the field points from *O* toward the charged rod.

(a) Since the length of the rod, *l*, is 10 cm, $r = 10/\pi = 3.18cm$

The charge density is, $\lambda = Q/l = -7.5\mu C/10cm = -75\,\mu C/m$

Then, $dq = \lambda dl = \lambda r d\theta$

$dE = k_e \frac{dq}{r^2}$ and $dE_x = k_e \frac{dq}{r^2}\cos\theta = k_e \frac{\lambda r d\theta}{r^2}\cos\theta$

The final field will be pointing in the –x direction with a magnitude of

$$E_x = \int_{-90^\circ}^{90^\circ} k_e \frac{\lambda r d\theta}{r^2}\cos\theta = k_e \frac{\lambda}{r}\int_{-90^\circ}^{90^\circ}\cos\theta d\theta = 2k_e\frac{\lambda}{r} = 42.4\,MN/C$$

(b) $dV = k_e \frac{dq}{r} = k_e \frac{\lambda r d\theta}{r}$ and $V = \int_{-\pi/2}^{\pi/2} k_e \frac{\lambda r d\theta}{r} = k_e\lambda\int_{-\pi/2}^{\pi/2} d\theta = k_e\pi\lambda = -2.12MV$

Problem 2:

A long solenoid (*n* = 1500 turns/m) has a cross-sectional area of 0.40 m^2 and a current given by $I = (4.0 + 3.0t^2)$ A, where *t* is in seconds. A flat circular coil (*N* = 300 turns) with a crosssectional area of 0.15 m^2 is inside and coaxial with the solenoid. What is the magnitude of the emf induced in the coil at *t* = 2.0 s?

The magnetic field of the solenoid is $B = \mu_0 nI = 4\pi\times10^{-7}(1500)(4+3t^2)$. This field is uniform and directed along the axis of the solenoid. Since all the cross-sectional area of the coil, A_{coil}, has this field going through it, the flux through the coil is: $\Phi_B = BA_{coil} = 4\pi\times10^{-7}(1500)(0.15)(4+3t^2)$.

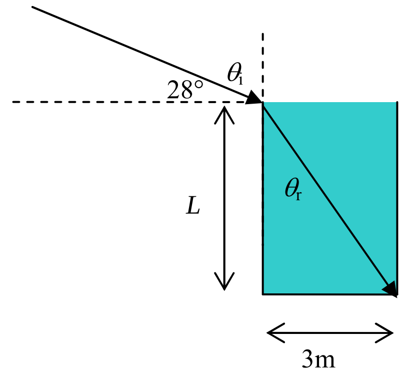
The induced emf in the coil is:

$$E = N_{coil}\frac{d\Phi_B}{dt} = 300\left[4\pi\times10^{-7}(1500)(0.15)\right]\frac{d}{dt}(4+3t^2) = (0.51V/s)t$$

$$E(t = 2\sec) = (0.51V/s)(2s) = 1.02V$$

Problem 3:

An opaque cylindrical tank with an open top has a diameter of 3.00 m and is completely filled with water. When the afternoon Sun reaches an angle of 28° above the horizon, sunlight ceases to illuminate any part of the bottom of the tank. How deep is the tank?



The angle of incidence is $\theta_i = 90 - 28 = 62°$

Then the angle of refraction will be

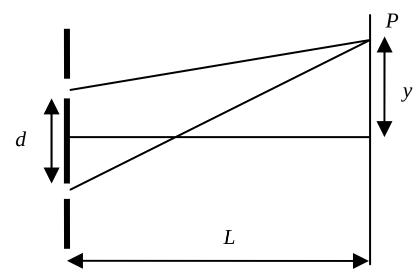
$$\sin\theta_r = \frac{1}{n}\sin\theta_i = \frac{1}{1.33}\sin 62° = 0.664$$

$$\theta_r = \arcsin(0.664) = 41.6°$$

Then, $\boxed{L = \frac{3m}{\tan\theta_r} = \frac{3}{\tan 41.6°} = 3.38m}$

Problem 4:

In the figure, let L = 1.20 m and d = 0.120 mm and assume that the slit system is illuminated with monochromatic 500 nm light.



(a) Calculate the phase difference between the two wave fronts arriving at P when θ = 0.500°.

(b) Calculate the phase difference between the two wave fronts arriving at P when y = 5.00 mm.

(c) What is the value of θ for which the phase difference is 0.333 rad?

(d) What is the value of θ for which the path difference is $\lambda/4$?

(a) $\delta = d\sin\theta = (0.120mm)\sin 0.5° = 1.05\mu m$

$$\boxed{\Delta\phi = \frac{2\pi}{\lambda}\delta = \frac{2\pi}{0.500\mu m}(1.05\mu m) = 13.2rad}$$

(b) $\sin\theta \approx \tan\theta = \frac{y}{L} = \frac{5mm}{1.2m} = 4.17\times10^{-3}$

$\delta = d\sin\theta = (0.12mm)(4.17\times10^{-3}) = 500nm = \lambda$ then $\boxed{\Delta\phi = 2\pi}$

(c) $\Delta\phi = \frac{2\pi}{\lambda}\delta = \frac{2\pi}{\lambda}d\sin\theta$ then $\boxed{\theta = \arcsin\left(\Delta\phi\frac{\lambda}{2\pi d}\right) = \arcsin\left(0.333\frac{0.500}{2\pi 120}\right) = 0.0127°}$

(d) $\delta = \frac{\lambda}{4} = d\sin\theta$ then, $\boxed{\theta = \arcsin\frac{\lambda}{4d} = \arcsin\frac{0.5}{4(120)} = 0.0597°}$

Problem 5:

A diffraction grating having 180 lines/mm is illuminated with a light beam containing only two wavelengths, λ_1 = 400 nm and λ_2 = 500 nm. The beam is incident perpendicularly on the grating.

(a) What is the angular separation between the second order maxima of these two wavelengths?

(b) What is the smallest angle at which two of the resulting maxima are superimposed?

(c) What is the highest order for which maxima for both wavelengths are present in the diffraction pattern? (Hint: in order for a maximum to be present, the diffraction angle has to be less than 90°.)

(a) $d = \frac{1}{N} = \frac{1}{180} = 5.56\mu m$

$$d \sin\theta_1 = 2\lambda_1 \text{ and } \theta_1 = \arcsin\left(\frac{2\lambda_1}{d}\right) = \arcsin\left(\frac{2(0.400)}{5.56}\right) = 8.27°$$

$$d \sin\theta_2 = 2\lambda_2 \text{ and } \theta_2 = \arcsin\left(\frac{2\lambda_2}{d}\right) = \arcsin\left(\frac{2(0.500)}{5.56}\right) = 10.4°$$

$$\boxed{\theta_2 - \theta_1 = 10.4 - 8.27 = 2.13°}$$

(b) Since the angles will be equal, $m\lambda_1 = n\lambda_2$. The smallest such angle will be the smallest n and m that satisfy this equation and that is when m=5 and n=4. Then,

$$d \sin\theta = m\lambda_1 \text{ and } \boxed{\theta = \arcsin\left(\frac{m\lambda_1}{d}\right) = \arcsin\left(\frac{5(0.400)}{5.56}\right) = 21.1°}$$

(c) For each wavelength, the maximum order possible should have a diffraction angle of 90° or less.

For λ_1, $d \sin 90° = m\lambda_1$ and $m = \text{int}\left(\frac{d}{\lambda_1}\right) = \text{int}\left(\frac{5.56}{0.4}\right) = \text{int}(13.9) = 13$

For λ_2, $d \sin 90° = n\lambda_2$ and $n = \text{int}\left(\frac{d}{\lambda_2}\right) = \text{int}\left(\frac{5.56}{0.5}\right) = \text{int}(11.12) = 11$, where int(x) is the greatest integer less than or equal to x.

So the maximum order for which both wavelengths are present is 11.

Multiple Choice Questions:

1. The units of capacitance are equivalent to:
   a) J/C
   b) V/C
   c) J^2/C
   d) C/J
   e) C^2/J

   Stored energy in a capacitor (J) is equal to charge squared (C^2) over capacitance (F).

2. Current is a measure of:
   a) force that moves a charge past a point
   b) resistance to the movement of a charge past a point
   c) energy used to move a charge past a point
   d) amount of charge that moves past a point per unit time
   e) speed with which a charge moves past a point

   Current is the rate of change of charge passing through a given area.

3. Two long parallel straight wires carry equal currents in opposite directions. At a point midway between the wires, the magnetic field they produce is:
   a) zero
   b) non-zero and along a line connecting the wires
   c) non-zero and parallel to the wires
   d) non-zero and perpendicular to the plane of the two wires
   e) none of the above

   The magnetic fields produced by each will be equal and in the same direction so they will adda dnbe directed perpendicular to the wires.

4. In a purely inductive circuit, the current lags the voltage by:
   a) 1/4 cycle
   b) 1/2 cycle
   c) 3/4 cycle
   d) 1 cycle
   e) an amount that depends on the frequency

   The current lags the voltage by $\pi/2$ which is ¼ cycles.

5. An electromagnetic wave is generated by:
   a) any moving charge
   b) any accelerating charge
   c) only a charge with changing acceleration
   d) only a charge moving in a circle
   e) only a charge moving in a straight line

   EM waves are generated by accelerating charges.

6. Where must an object be placed in front of a concave mirror so that the image and object are the same size? (F is the focal point and C is the center of curvature.)
   a) at F
   b) at C
   c) between F and the mirror
   d) between F and C
   e) beyond C

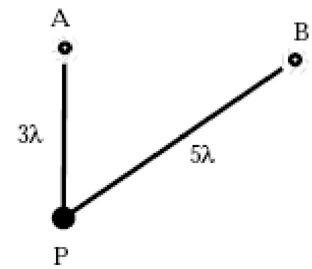
   For unity magnification, image and object distances have to be the same. This happens when the object is at C.

7. Waves from two slits are in phase at the slits and travel to a distant screen to produce the second minimum of the interference pattern. The difference in the distance traveled by the wave is:
   a) half a wavelength
   b) a wavelength
   c) three halves of a wavelength
   d) two wavelengths
   e) five halves of a wavelength

   $\delta = (m + 1/2)\lambda$ for destructive interference, where m=0, ±1, ±2, …

   The 2nd minimum occurs for m=1 and $\delta = 3\lambda/2$

8. The figure shows two point sources of light, A and B. B emits light waves that are +π radians out of phase with the waves from A. A is 3λ from P. B is 5λ from P. (λ is the wavelength.) The phase difference between waves arriving at P from A and B is
   a) 0 rad.
   b) π rad.
   c) 2π rad.
   d) 3π rad.
   e) 4π rad.



   The path length difference is 2λ which means A leads B by 4π. Subtracting the initial π phase difference of B we get a phase difference of 3π.

9. In a stack of three polarizing sheets the first and third are crossed while the middle one has its axis at 45° to the axes of the other two. The fraction of the intensity of an incident unpolarized beam of light that is transmitted by the stack is:
   a) 1/2
   b) 1/3
   c) 1/4
   d) 1/8
   e) 0

   The first polarizer transmits half the intensity. The second one also transmits $\cos^2(45) = 0.5$ of the intensity. The last one has its axis 45° from the axis of the second so it also transmits 0.5 of the intensity. Overall, the transmitted intensity is $(0.5)(0.5)(0.5) = 0.125$

10. You could determine the index of refraction for visible light of a dark but reflective medium such as black glass by measuring the
    a) angles of incidence and refraction.
    b) angle of reflection for an arbitrary angle of incidence.
    c) angle at which reflected light is completely polarized.
    d) smallest angle at which X-ray diffraction occurs in the glass.
    e) smallest angle at which diffraction occurs for visible light when a diffraction pattern is scratched onto the surface.

    We can use the Brewster's angle to find the index of refraction.