Units?
Units?

Name______________________________

Dec. 10, 2003

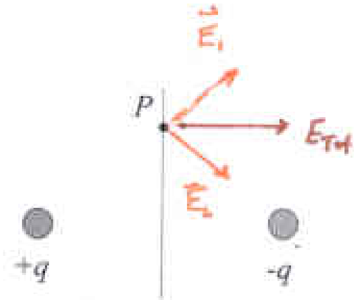
Phys 2020 — Fall 2003
Final Exam

1.	________________	(9)
2.	________________	(17)
3.	________________	(4)
4.	________________	(8)
5.	________________	(9)
6.	________________	(10)
7.	________________	(7)
8.	________________	(4)
9.	________________	(12)
MC	________________	(20)
Total	________________	(100)

Multiple Choice

Choose the best answer from among the four!

1. The point P is equidistant from the charges $+q$ and $-q$, as shown. Which one of the choices shown gives the direction of the electric field at P?



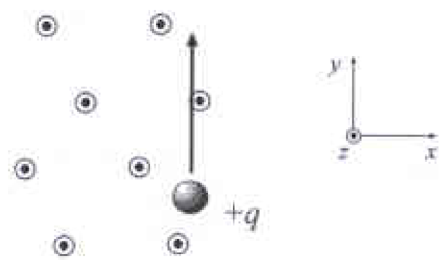
a)

b)

c)

d)

2. With the magnetic field coming out of the page, a positively charged particle moves in the direction shown. Using the given coordinate system, the force on the particle points in the



a) $+x$ direction.

b) $-x$ direction.

c) $+z$ direction.

d) $-y$ direction.

3. When a beam of light passes from one transparent medium to another

a) Both wavelength and frequency remain the same.

b) The frequency stays the same but the wavelength changes.

c) The wavelength stays the same but the frequency changes.

d) Both the wavelength and frequency change.

4. For a person with myopia (can't see things which are too far away) the corrective lenses are designed to:

a) Take an object at the near point and make an image at the far point.

b) Take an object at infinity and make an image at the near point.

c) Take an object at infinity and make an image at the far point.

d) Take an object at the far point and make an image at infinity.

5. In the Young two–slit experiment, the dark fringes occur where the difference of path lengths to the two slits is

a) $0,\ \lambda,\ 2\lambda,\ 3\lambda\ldots$ where λ is the wavelength of the light.

b) $\frac{1}{2}\lambda,\ \frac{3}{2}\lambda,\ \frac{5}{2}\lambda,\ \ldots$ where λ is the wavelength of the light.

c) $0,\ d,\ 2d,\ 3d\ldots$ where d is the spacing between the slits.

d) $\frac{1}{2}d,\ \frac{3}{2}d,\ \frac{5}{2}d\ldots$ where d is the spacing between the slits.

6. For which one of the following problems did Max Planck make contributions that eventually led to the development of the "quantum" hypothesis?

a) The motion of the earth in the "ether".

b) Uncertainty principle.

c) Blackbody radiation curves.

d) The visible spectrum of hydrogen.

7. The photoelectric effect indicated a failure in the classical laws of physics since according to the classical theory

a) No electrons should escape the metal plate.

b) Electrons should always escape the plate if the wavelength of the light is long enough.

c) Electrons should escape the plate if the light intensity is strong enough.

d) All electrons should escape from the plate with the same kinetic energy.

8. The "De Broglie wavelength" (as put forth in DeB.'s original theory) refers to the wavelength of

a) Low-energy photons.

b) High-energy photons.

c) Massive particles like electrons.

d) Neutrinos.

9. The visible ("Balmer") series of spectral lines in Hydrogen come from transitions where the electron

a) Starts off on the $n = 4$ level.

b) Starts off on the $n = 5$ level.

c) Ends up on the $n = 1$ level.

d) Ends up on the $n = 2$ level.

10. The Bohr model of the H stom was "fixed" by quantum mechanics (c. 1926) for all of the following *except:*

a) The number of possible "orbits" for each n.

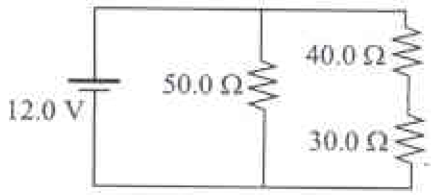
b) The values of the discrete energies E_n.

c) Consideration of the spin of the electron.

d) The notion of an "orbital" as opposed to an "orbit".

Problems

1. For the circuit shown at the right,



a) Find the current in the 50.0 Ω resistor. (3)

Potential drop across this resistor is 12.0 V so from Ohm's Law we have

$$I_{50\Omega} = \frac{V}{R} = \frac{12.0\,\text{V}}{50.0\,\Omega} = \boxed{0.240\text{A}}$$

b) Find the power dissipated in the 40.0 Ω resistor. (6)

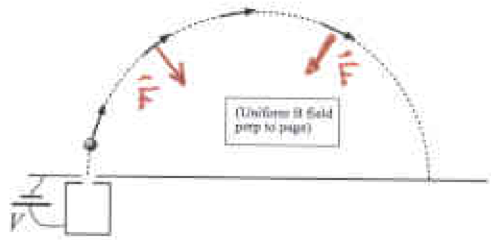
The equiv. resistance of this branch is $40\Omega + 30\Omega = 70\,\Omega$ and the voltage drop across it is (again) 12.0 V so the current in this branch is

$$I = \frac{V}{R_{equiv}} = \frac{12.0\,\text{V}}{70.0\,\Omega} = \boxed{0.171\ \text{A}}$$

This is the current thru the $40\,\Omega$ resistor so the power dissipated in that resistor is

$$P = I^2R = (0.171\,\text{A})^2\,(40.0\,\Omega) = \boxed{1.18\ \text{W}}$$

2. A positive ion of mass 2.00×10^{-26} kg and charge $+e$ moves perpendicular to a uniform magnetic which is perpendicular to the plane of the page. The ion moves in a circular path of radius 9.00 cm with speed $5.00 \times 10^4\ \frac{\text{m}}{\text{s}}$ in the direction shown.



a) Does the magnetic field point into or out of the page? *You must justify your answer; hint: in what direction is the force on the ion?* (4)

The net force on the ion is inward (toward center of circle)
From the direction of $\vec{v}$ and the fact that the charge is positive, by RHR-I the $\vec{B}$-field must point $\boxed{\text{out of the page}}$ in order to give force $\vec{F}$ in the proper direction.

b) Find the magnitude of the magnetic field. (5)

Use $\frac{mv}{r} = qB$ (relation for circ. orbit in B field), solve for B:

$$B = \frac{mv}{qr} = \frac{(2.00 \times 10^{-26}\,\text{kg})(5.00 \times 10^{4}\,\frac{\text{m}}{\text{s}})}{(1.602 \times 10^{-19}\,\text{C})(9.00 \times 10^{-2}\,\text{m})} = \boxed{6.94 \times 10^{-2}\,\text{T}}$$

c) What is the kinetic energy of the ion? (4)

$$KE = \tfrac{1}{2} mv^2 = \tfrac{1}{2}(2.00 \times 10^{-26}\,\text{kg})(5.00 \times 10^{4}\,\tfrac{\text{m}}{\text{s}})^2 = \boxed{2.5 \times 10^{-17}\,\text{J}}$$

d) Before entering the region of the magnetic field the ion was accelerated from rest though a potential V. Find V. (4)

When the ion was accelerated the gain in KE was $|qV|$.
This is the KE found in (c), so

$|qV| = 2.5 \times 10^{-17}\,\text{J}$ w/ $|q| = 1.602 \times 10^{-19}\,\text{C}$

$$V = \frac{2.5 \times 10^{-17}\,\text{J}}{1.602 \times 10^{-19}\,\text{C}} = \boxed{156\,\text{V}}$$

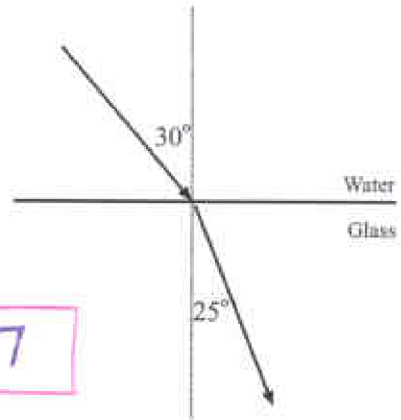
3. a) Identify (name) a common device in which a polarizing sheet (a polaroid) is used. (2)

LCD displays for calculators and watches
Polaroid sunglasses

b) Identify (name) a device or kind of technology in which the phenomenon of total internal reflection is used. (2)

Fiber optics, incl. optical fibers for viewing the insides of people!
Binoculars use total int. reflection to "fold" light rays.

4. A light ray passes from water into some kind of glass. (Index of refraction for water is 1.33.) In the water the ray makes an angle of 30.0° with the normal, while in the glass it makes an angle of 25.0° with the normal.



a) What is the index of refraction for the glass? (5)

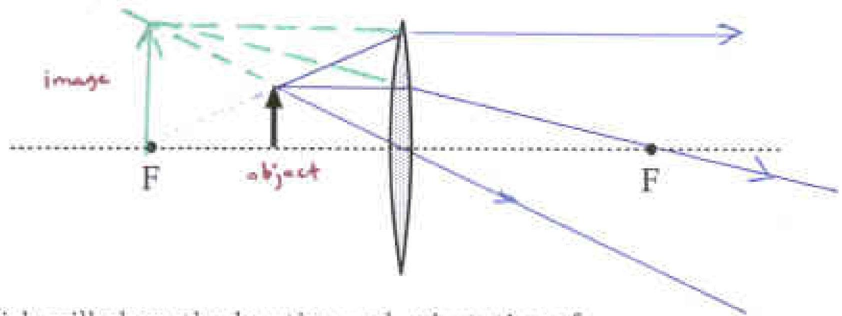
Use $n_w \sin\theta_w = n_g \sin\theta_g$ & solve for n_g

$$n_g = n_w \frac{\sin\theta_w}{\sin\theta_g} = (1.33)\frac{\sin 30°}{\sin 25°} = \boxed{1.57}$$

b) What is the speed of light in this kind of glass? (3)

$$v_g = \frac{c}{n_g} = \frac{2.998 \times 10^8 \frac{m}{s}}{1.57} = \boxed{1.91 \times 10^8 \frac{m}{s}}$$

5. An object is in front of a converging lens, between the lens and its focal point, as shown here:



a) Trace some rays which will show the location and orientation of the image (make a ray diagram) on this figure. (6)

Get an image as shown; rays seem to come from the virtual image, as shown.

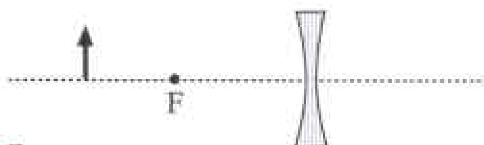
b) Is the image real or virtual? Is it upright or inverted? (3)

Image is $\boxed{\text{virtual}}$. It is $\boxed{\text{upright}}$

(This is the way a magnifying glass is used.)

6. An object of height 3.0 cm sits 30.0 cm in front of a diverging lens having a focal length of −20.0 cm.

a) Find the location of the image. Be very clear about this answer: Is the image on the left(near) side or the right (far) side of the lens? (6)



With $d_o = 30.0\text{ cm}$ and $f = -20.0\text{ cm}$,

use lens eqn to find d_i:

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{(-20.0\text{cm})} - \frac{1}{(30.0\text{ cm})} = -8.33\times10^{-2}\text{ cm}^{-1}$$

$d_i = \boxed{-12.0\text{ cm}}$ Negative sign says it is on the $\boxed{\text{left (near)}}$ side of the lens.

b) Find the height of the image. Be clear about the answer: Is the image upright or inverted? (4)

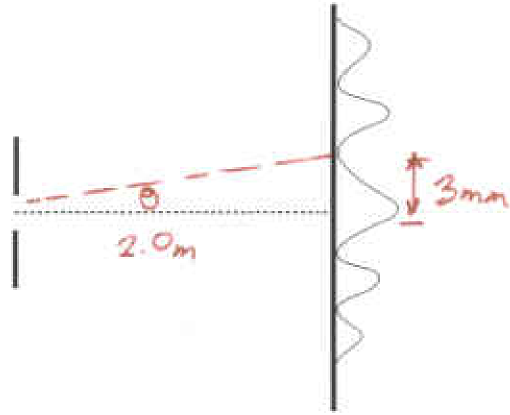
Use $m = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$ with $h_o = 3.0\text{ cm}$ Then:

$$h_i = -\frac{d_i}{d_o}h_o = -\frac{(-12.0)}{(30.0)}(3.0\text{ cm}) = \boxed{1.2\text{ cm}}$$

From positive sign of h_i, image is $\boxed{\text{upright}}$.

7. In a single–slit diffraction experiment, the slit has width 0.300 mm and it is 2.0 m away from the screen. The slit is illuminated by coherent laser light and it is found that the first dark fringe is a distance of 3.00 mm from the central bright maximum

Find the wavelength of the light. (7)



Geometry gives θ:

$$\tan\theta = \frac{3\,\text{mm}}{2\,\text{m}} = \frac{3\times10^{-3}\,\text{m}}{2\,\text{m}} \rightarrow \theta = 8.6\times10^{-2}\,\text{deg}$$

Then use $\sin\theta = n\frac{\lambda}{w} = (1)\frac{\lambda}{w}$, so:

$$\lambda = w\sin\theta = (0.300\times10^{-3}\,\text{m})\sin\theta = 4.50\times10^{-7}\,\text{m}$$

$$= \boxed{450\,\text{nm}}$$

8. On discussing the photoelectric effect we had to take account of the "work function" W_0 for a metal. What is the meaning of this term? (4)

The work function is the amount of energy required for an electron to be ejected from the metal. A photon must deliver at least this amt. of energy in order for the radiation to give "photoelectrons".

9. The electron in a hydrogen atom makes a transition from the 6^{th} to the 3^{rd} Bohr orbit.

a) Find the wavelength of the photon which is emitted. (5)

Use the "Balmer formula" w/ $n_1 = 3$, $n_2 = 6$. Get:

$$\frac{1}{\lambda} = (1.097 \times 10^{7}\ m^{-1})\left(\frac{1}{3^2} - \frac{1}{6^2}\right) = 9.14 \times 10^{5}\ m^{-1}$$

$$\lambda = \boxed{1.09 \times 10^{-6}\ m} = 1.09\ \mu m$$

b) Find the energy of this photon. (4)

$$E_{photon} = hf = h\frac{c}{\lambda} = (6.626 \times 10^{-34}\ J \cdot s)\frac{(2.998 \times 10^{8}\ \frac{m}{s})}{(1.09 \times 10^{-6}\ m)} = \boxed{1.82 \times 10^{-19}\ J}$$

$$= (1.82 \times 10^{-19}\ J)\left(\frac{1\ eV}{1.602 \times 10^{-19}\ J}\right) = \boxed{1.13\ eV}$$

c) What is the radius of the Bohr orbit for the $n = 6$ orbit? (3)

$$r_6 = (5.29 \times 10^{-11}\ m) \cdot \frac{6^2}{1} = 1.88 \times 10^{-9}\ m = \boxed{1.88\ nm}$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \, \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}} \qquad \epsilon_0 = 8.85 \times 10^{-12} \, \frac{\mathrm{C^2}}{\mathrm{N \cdot m^2}} \qquad e = 1.602 \times 10^{-19}\,\mathrm{C}$$

$$A = \pi r^2 \qquad \mathbf{F} = m\mathbf{a} \qquad \mathrm{KE} = \tfrac{1}{2} m v^2 \qquad g = 9.80\,\tfrac{\mathrm{m}}{\mathrm{s^2}} \qquad m_{\mathrm{elec}} = 9.1094 \times 10^{-31}\,\mathrm{kg}$$

$$F = k\frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2} \qquad \mathbf{F} = q\mathbf{E} \qquad E_{\mathrm{pt\ ch}} = k\frac{|q|}{r^2} \qquad E_{\mathrm{plates}} = \frac{q}{\epsilon_0 A} = \frac{\sigma}{\epsilon_0}$$

$$\Delta \mathrm{EPE} = q\Delta V \qquad V_{\mathrm{pt\ ch}} = k\frac{q}{r} \qquad \mathrm{EPE} = k\frac{q_1 q_2}{r} \qquad |E_x| = \left|\frac{\Delta V}{\Delta x}\right|$$

$$q = CV \qquad C_{\mathrm{air}} = \frac{\epsilon_0 A}{d} \qquad C_{\mathrm{diel}} = \kappa C_{\mathrm{air}} \qquad \mathrm{Energy} = \tfrac{1}{2} C V^2$$

$$V = IR \qquad R = \rho\frac{L}{A} \qquad R_{\mathrm{ser}} = R_1 + R_2 + \dots \qquad \frac{1}{R_{\mathrm{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$P = VI = I^2 R = \frac{V^2}{R} \qquad \mathrm{Energy} = Pt \qquad 1\,\mathrm{eV} = 1.602 \times 10^{-19}\,\mathrm{J}$$

$$F = qvB\sin\theta \qquad \frac{mv}{r} = qB \qquad F = ILB\sin\theta \qquad \tau = NIAB\sin\phi$$

$$\mu_0 = 4\pi \times 10^{-7}\,\tfrac{\mathrm{T \cdot m}}{\mathrm{A}} \qquad B = \frac{\mu_0 I}{2\pi r} \qquad B_{\mathrm{loop}} = \frac{\mu_0 I}{2R} \qquad B_{\mathrm{sol}} = \mu_0 n I$$

$$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t} \qquad \mathcal{E}_2 = -M_{21}\frac{\Delta I_1}{\Delta t} \qquad \mathcal{E} = -L\frac{\Delta I}{\Delta t} \qquad \mathcal{E} = NAB\omega\sin\omega t$$

$$\lambda f = c \qquad c = 2.998 \times 10^8\,\tfrac{\mathrm{m}}{\mathrm{s}} \qquad \overline{S} = \frac{c\epsilon_0}{2}E_0^2 = \frac{c}{2\mu_0}B_0^2 \qquad \overline{S}_{\mathrm{pol}} = \tfrac{1}{2}\overline{S}_{\mathrm{unpol}} \qquad \overline{S} = \cos^2\theta\,\overline{S}_0$$

$$|f| = R/2 \qquad \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$v = \frac{c}{n} \qquad n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \sin\theta_c = \frac{n_2}{n_1}$$

$$\sin\theta_{\mathrm{light}} = n\frac{\lambda}{d} \qquad \sin\theta_{\mathrm{dark}} = (n + \tfrac{1}{2})\frac{\lambda}{d} \qquad n = 0, 1, 2, 3, \dots \qquad \sin\theta_{\mathrm{dark}} = n\frac{\lambda}{W} \qquad n = 1, 2, 3, \dots$$

$$h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$$

$$\text{Photons:} \qquad \lambda f = c \qquad E = hf = \frac{hc}{\lambda} = \frac{(1.23984 \times 10^{-6}\,\mathrm{eV \cdot m})}{\lambda} \qquad p = \frac{E}{c}$$

$$\text{Particles:} \qquad p = mv = \frac{h}{\lambda} \qquad KE = \tfrac{1}{2}mv^2 = \frac{p^2}{2m}$$

$$\mathrm{KE_{max}} = hf - W_0$$

$$\text{H atom:} \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad R = 1.097 \times 10^7\,\mathrm{m^{-1}}$$

$$E_{\mathrm{photon}} = \frac{hc}{\lambda} = hcR\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = (13.606\,\mathrm{eV})\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$r_n = \left(\frac{h^2}{4\pi^2 mke^2}\right)\frac{n^2}{Z} = (5.29 \times 10^{-11}\,\mathrm{m})\frac{n^2}{Z} \qquad E_n = -\left(\frac{2\pi^2 mk^2e^4}{h^2}\right)\frac{Z^2}{n^2} = -(13.6\,\mathrm{eV})\frac{Z^2}{n^2}$$