Units?, Units?

Name__________________________

May 12, 2004

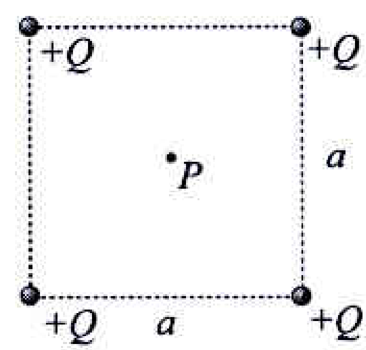
Phys 2020 — Spring 2004
Exam #3

1.	________________	(10)
2.	________________	(13)
3.	________________	(5)
4.	________________	(5)
5.	________________	(6)
6.	________________	(10)
7.	________________	(6)
8.	________________	(7)
9.	________________	(10)
10.	________________	(8)
MC	________________	(20)
Total	________________	(100)

Multiple Choice

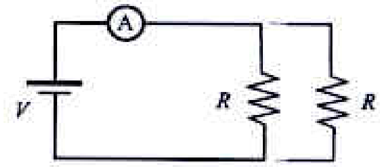
Choose the best answer from among the four!

1. Four point charges are placed at the corners of a square as shown in the figure. What is the magnitude of the electric field at P, the center of the square?



a) $kQ/(4a^2)$
b) kq/a^2
c) $4kQ/a^2$
d) Zero.

2. Consider the circuit shown at the right; when an identical resistor is added to the circuit in parallel with first, the current in the ammeter A will:



a) Increase.

b) Decrease.

c) Stay the same.

d) It is impossible to know without knowing the values of V and R.

3. For a charged particle with a given speed moving in a magnetic field, the magnitude of the magnetic force is greatest when the particle is moving

a) In the same direction as the field.

b) Opposite to the direction of the field.

c) At 45° from the direction of the field.

d) Perpendicular to the field.

4. When light passes from one transparent medium to another, what if anything remains the same?

a) The wavelength of the light.

b) The frequency of the light.

c) The speed of the light.

d) None of the above.

5. When a far–sighted (hyperopic) person uses corrective lenses, the lenses

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 a "close" distance (like 25 cm).

c) Take an object at some "close" distance (like 25 cm) and make an image at the near point.

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

6. If an object is on the left side of the lens and the image is on the right, then

a) The lens must be a converging lens.

b) The lens must be a diverging lens.

c) The lens could be either a converging lens or a diverging lens.

d) None of the above; the image must also be on the left, for any lens.

7. Which of the following pairs represents two isotopes?

a) ${}^{16}_{8}O$, ${}^{14}_{7}N$

b) ${}^{12}_{6}C$, ${}^{14}_{6}C$

c) ${}^{16}_{8}O$, ${}^{23}_{11}Na$

d) ${}^{14}_{7}N$, ${}^{14}_{6}C$

8. Of the following, which is the only possible set of quantum numbers for an atomic electron?

a) $n = 3 \quad \ell = 3 \quad m_\ell = -2 \quad m_s = +\frac{1}{2}$.

b) $n = 2 \quad \ell = 1 \quad m_\ell = 0 \quad m_s = +\frac{3}{2}$.

c) $n = 4 \quad \ell = 3 \quad m_\ell = -5 \quad m_s = +\frac{1}{2}$.

d) $n = 3 \quad \ell = 1 \quad m_\ell = 0 \quad m_s = -\frac{1}{2}$.

9. The atomic nucleus is held together

a) By a force called the "strong" force.

b) By magnetic forces.

c) By gravitational forces.

d) By a force involving neutrinos.

10. If the nucleus $^{15}_{8}O$ decays to give $^{15}_{7}N$, the radiation emitted is called

a) α radiation.

b) β^- radiation.

c) β^+ radiation.

d) γ radiation.

Problems

1. In the Bohr model of the hydrogen atom, the electron orbits the proton at a (constant) distance of 5.29×10^{-11} m.

a) At this distance, what is the magnitude of the electrical force of the proton on the electron? (5)

Use Coulomb's Law, $F = k\,|q_1 q_2|/r^2$.
Here the magnitude of each charge is e, so

$$F = k\,e^2/r^2 = \frac{(8.99\times10^9\,\frac{Nm^2}{C^2})(1.602\times10^{-19}C)^2}{(5.29\times10^{-11}m)^2} = \boxed{8.24\times10^{-8}\,N}$$

b) The force found in (a) is the centripetal force on the electron. Find the speed of the electron as it orbits. (5)

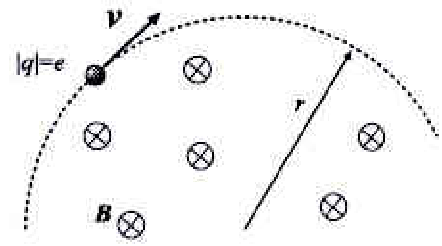
Since $F = F_c = \frac{mv^2}{r}$, solve for v:

$$v^2 = rF_c/m_e = \frac{(5.29\times10^{-11}m)(8.24\times10^{-8}N)}{(9.11\times10^{-31}kg)} = 4.79\times10^{12}\,\frac{m^2}{s^2}$$

$$\longrightarrow \boxed{v = 2.19\times10^6\,\frac{m}{s}}$$

(Roughly 1/100 of the speed of light.)

2. A particle with charge of *magnitude* e and mass 2.34×10^{-27} kg moves in a region of uniform magnetic field as shown at the right; the field has magnitude 0.250 T and points *into* the page. The particle moves perpendicularly to the field in a circular path of radius 12.0 cm.



a) Does the particle have a positive charge or a negative charge? Along with your answer *explain why* you made this choice. (4)

We know that the magnetic force must point inward to the center of the circle. If the charge was positive the RHR-1 would give a force outward, so it must be a $\boxed{\text{negative}}$ charge.

b) Find the speed of the particle. (4)

Use the relation for a circular orbit in a magnetic field, $\frac{mv}{r} = qB$

then: $$v = \frac{|q|Br}{m} = \frac{(1.602 \times 10^{-19}\,C)(0.250\,T)(0.120\,m)}{(2.34 \times 10^{-27}\,kg)} = \boxed{2.05 \times 10^{6}\,\frac{m}{s}}$$

c) Find the kinetic energy of the particle. Express the answer in eV. (4)

We have its mass and speed, so

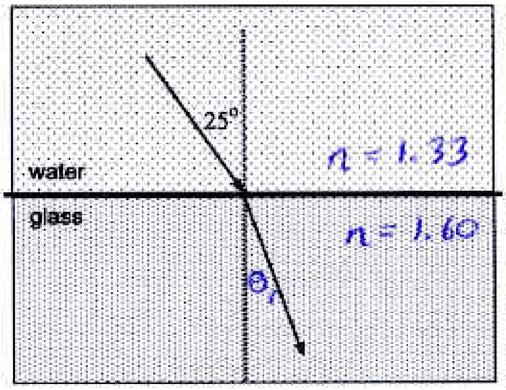
$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(2.34 \times 10^{-27}\,kg)(2.05 \times 10^{6}\,\tfrac{m}{s})^2 = 4.94 \times 10^{-15}\,J$$

$$= (4.94 \times 10^{-15}\,J)\left(\frac{1\,eV}{1.602 \times 10^{-19}\,J}\right) = \boxed{3.08 \times 10^{4}\,eV}$$

d) If these particles were accelerated from rest by moving through an electric potential difference, what is the magnitude of that potential difference? (1)

From $\Delta EPE = q\Delta V$ and the definition of the electron-volt it must have been $\Delta V = \boxed{3.08 \times 10^{4}\,V}$

3. A light ray passes from water (index of refraction 1.33) to glass (index of refraction 1.60). The incident ray makes an angle of 25.0° with the normal. What angle does the refracted ray make with the normal? (5)



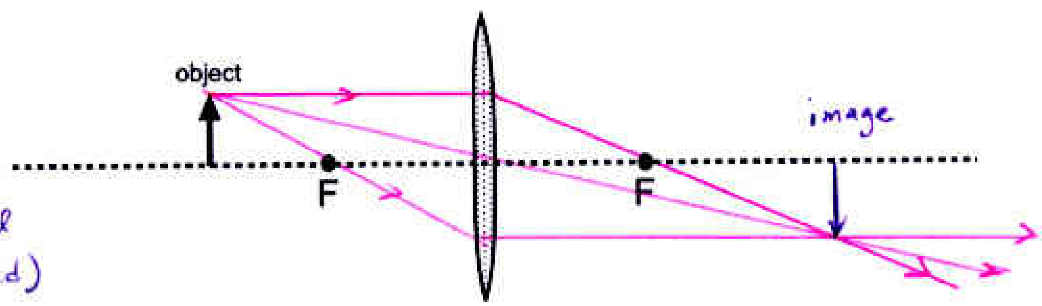
Using Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$ we find:

$$\sin\theta_r = \frac{n_1}{n_2}\sin\theta_1 = \frac{(1.33)}{(1.60)}\sin 25^\circ$$

$$= 0.351$$

$$\rightarrow \quad \theta_r = \boxed{20.6^\circ}$$

4. Shown here is a converging lens and an object which is farther than the focal length:



(Image is real and inverted)

Show by ray–tracing the location and orientation of the image. (5)

5. A lens has a focal length of 30.0 cm; an object is 45.0 cm to the left of it.

a) Where is the image? (Tell what this answer means; is it on the left or right side of the lens?) (4)

Use the lens eqn. with $d_o = +45.0$ cm and $f = 30.0$ cm. Then:

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{30\text{ cm}} - \frac{1}{45\text{ cm}} = 0.0111\text{ cm}^{-1}$$

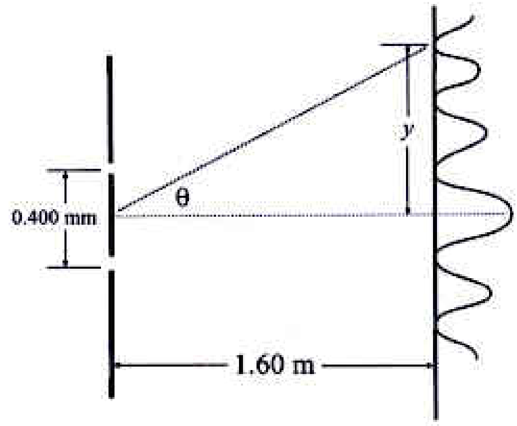
$$\Rightarrow \quad d_i = \boxed{90\text{ cm}}$$

d_i is positive, which means that the image is to the $\boxed{\text{right}}$ of the lens.

b) Find the magnification. (2)

$$m = -\frac{d_i}{d_o} = -\frac{(90\text{ cm})}{(45\text{ cm})} = \boxed{-2.0}$$

6. In an idealized Young's two–slit experiment, coherent light of wavelength 650 nm is incident on two very thin slits spaced by 0.400 mm. The transmitted light strikes a screen 1.60 m away to give an interference pattern.



a) Find the angle from the center of the pattern at which we will find the third dark fringe (see figure). (4)

Here, use $\sin\theta_{th} = (m+\frac{1}{2})\lambda/d$ with $m = 2$. Then:

$$\sin\theta = (2+\tfrac{1}{2})(650\times10^{-9}\,m)/(0.400\times10^{-3}\,m)$$

$$= 4.06\times10^{-3} \longrightarrow \boxed{\theta = 0.233^\circ}$$

b) Find the distance from the center at which we find this fringe. (2)

Since $\tan\theta = y/(1.60\,m)$, then

$$y = (1.60\,m)\tan\theta = 6.50\times10^{-3}\,m = \boxed{6.50\,mm}$$

c) Explain briefly why we get dark fringes in the interference pattern. (What is happening there?) (4)

Two slits serve as two sources of (EM) waves. Some points on the screen are so situated that they receive the max of one wave when they receive the minimum of the other. The wave cancel and there is no light at that point.

7. In a demonstration of the photoelectric effect, electrons are ejected when light of wavelength 558 nm is incident on the metal surface. The maximum kinetic energy of the electrons is 1.60 eV.

a) What is the energy of the photons (give the answer in eV). (4)

$$E_{photon} = hf = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,J\,s)(2.998\times10^{8}\,\frac{m}{s})}{(558\times10^{-9}\,m)} = 3.56\times10^{-19}\,J$$

$$= (3.56\times10^{-19}\,J)\left(\frac{1\,eV}{1.602\times10^{-19}\,J}\right) = \boxed{2.22\,eV}$$

b) What is the work function of the metal? (2)

Use $W_0 = E_{photon} - KE_{max}$, then

$$W_0 = (2.22\,eV) - (1.60\,eV) = \boxed{0.62\,eV}$$

8. The De Broglie wavelength of an electron is 1.20×10^{-8} m.

a) Find the momentum of the electron. (3)

From $\lambda = h/p$, get $p = h/\lambda$, then

$$p = h/\lambda = (6.626 \times 10^{-34}\ J \cdot s) / (1.20 \times 10^{-8}\ m) = \boxed{5.52 \times 10^{-26}\ kg \cdot \frac{m}{s}}$$

b) Find the kinetic energy of the electron. (4)

It's speed is $v = P/m = (5.52 \times 10^{-26}\ kg\frac{m}{s}) / (9.11 \times 10^{-31}\ kg) = 6.06 \times 10^{4}\ \frac{m}{s}$

Then $KE = \frac{1}{2} m v^2 = \frac{1}{2}(9.11 \times 10^{-31}\ kg)(6.06 \times 10^{4}\ \frac{m}{s})^2 = \boxed{1.67 \times 10^{-21}\ J = 1.04 \times 10^{-2}\ eV}$

9. The electron in a hydrogen atom makes the transition from the $n = 5$ state to the $n = 1$ state.

a) Find the wavelength of the photon emitted. (4)

$$\frac{1}{\lambda} = (R)\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = (1.097 \times 10^{7}\ m^{-1})\left(\frac{1}{1^2} - \frac{1}{5^2}\right) = 1.053 \times 10^{7}\ m^{-1}$$

$$\lambda = \boxed{9.50 \times 10^{-8}\ m = 95.0\ nm}$$

b) Find the energy of the photon emitted. (3)

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ Js)(3.00 \times 10^{8}\ \frac{m}{s})}{(9.50 \times 10^{-8}\ m)} = \boxed{2.09 \times 10^{-18}\ J = 13.1\ eV}$$

c) This photon is not in the visible range. What type of radiation could it be? (*Explain* for your answer.) (3)

The photons must have <u>more</u> energy than those in the visible range since the transition is to the $n=1$ level. The radiation has shorter λ and larger f than visible light. It could be

$\boxed{\text{UV or (possibly X-ray)}}$ radiation.

10. The consider the nucleus specified by $^{60}_{28}\mathrm{Ni}$. Its mass is 59.930788 u.

a) How many neutrons are in this nucleus? (2)

Since $A = 60$ and $Z = 28$ and $A = Z + N$ then

$$N = A - Z = 60 - 28 = \boxed{32 \text{ neutrons}}$$

b) Find the binding energy per nucleon in this nucleus. (Proton mass is 1.007825 u; neutron mass is 1.008665 u; use $(1\,\mathrm{u})c^2 = 931.494\,\mathrm{MeV}$.) Give the answer in MeV/(nucleon) (6)

Find the mass difference between the constituent nucleons and the nucleus:

$$\Delta m = 28(1.007825\,\mathrm{u}) + 32(1.008665\,\mathrm{u}) - 59.930788\,\mathrm{u}$$

$$= 0.5656\,\mathrm{u}$$

Then the total BE is

$$BE = \Delta m c^2 = (0.5656\,\mathrm{u})c^2 = (0.5656)(931.494\,\mathrm{MeV})$$

$$= 526.8\,\mathrm{MeV}$$

$$BE/A = (526.8\,\mathrm{MeV})/60 = \boxed{8.78\,\mathrm{MeV/nucleon}}$$

$$C = 2\pi R \qquad A = \pi R^2 \qquad \mathrm{m} = 10^{-3} \qquad \mathrm{n} = 10^{-9} \qquad k = \frac{1}{4\pi\epsilon_0} = 8.988 \times 10^{9}\,\frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}$$

$$e = 1.602 \times 10^{-19}\,\mathrm{C} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\frac{\mathrm{C^2}}{\mathrm{N \cdot m^2}} \qquad \mu_0 = 4\pi \times 10^{-7}\,\frac{\mathrm{T \cdot m}}{\mathrm{A}} \qquad c = 2.998 \times 10^{8}\,\frac{\mathrm{m}}{\mathrm{s}}$$

$$1\,\mathrm{eV} = 1.602 \times 10^{-19}\,\mathrm{J} \qquad g = 9.80\,\frac{\mathrm{m}}{\mathrm{s^2}} \qquad m_{\mathrm{elec}} = 9.1094 \times 10^{-31}\,\mathrm{kg} \qquad h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$$

$$\mathbf{F} = m\mathbf{a} \qquad F_c = \frac{mv^2}{r} \qquad \mathrm{KE} = \tfrac{1}{2}mv^2 \qquad \mathbf{p} = m\mathbf{v} \qquad \mathbf{F} = q\mathbf{E}$$

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

$$\Delta\mathrm{EPE} = q\Delta V \qquad V_{\mathrm{pt-ch}} = k\frac{q}{r} \qquad E_x = -\frac{\Delta V}{\Delta x}$$

$$V = IR \qquad R_{\mathrm{ser}} = R_1 + R_2 + \ldots \qquad \frac{1}{R_{\mathrm{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \qquad P = VI = I^2 R$$

Sum of currents entering junction = 0 Sum of voltages around a loop = 0

$$F = qvB\sin\theta \qquad \frac{mv}{r} = qB \qquad m = \left(\frac{qr^2}{2V}\right)B^2 \qquad F = LIB\sin\theta \qquad 1\,\mathrm{gauss} = 10^{-4}\,\mathrm{T}$$

$$B_{\mathrm{wire}} = \frac{\mu_0 I}{2\pi r} \qquad B_{\mathrm{loop}} = \frac{\mu_0 I}{2R} \qquad B_{\mathrm{sol}} = \mu_0 n I$$

$$\mathcal{E} = vBL \qquad \Phi = BA\cos\phi \qquad \mathcal{E} = -N\frac{\Delta\Phi}{\Delta t} \qquad \mathcal{E} = -L\frac{\Delta I}{\Delta t} \qquad L_{\mathrm{sol}} = \mu_0 n^2 A\ell$$

$$\lambda f = c \qquad E_0 = cB_0 \qquad \overline{S} = \frac{c\epsilon_0}{2}E_0^2 = \frac{c}{2\mu_0}B_0^2 \qquad \overline{S} = \tfrac{1}{2}\overline{S}_{\mathrm{unpol}} \qquad \overline{S} = \overline{S}_0\cos^2\theta$$

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

$$n = \frac{c}{v} \qquad n_1\sin\theta_1 = n_2\sin\theta_2 \qquad \sin\theta_{\mathrm{crit}} = \frac{n_2}{n_1}$$

$$\sin\theta_{\mathrm{bright}} = m\frac{\lambda}{d} \qquad \sin\theta_{\mathrm{dark}} = (m + \tfrac{1}{2})\frac{\lambda}{d} \qquad m = 0, 1, 2, \ldots$$

$$\sin\theta_{\mathrm{dark}} = m\frac{\lambda}{w} \qquad m = 1, 2, 3, \ldots$$

$$\lambda f = c \qquad E_{\mathrm{photon}} = hf \qquad hf = W_0 + \mathrm{KE}_{\mathrm{max}} \qquad \lambda = \frac{h}{p}$$

$$\text{H atom:} \quad r_n = \frac{h^2}{4\pi^2 m k e^2}\left(\frac{n^2}{Z}\right) \qquad E_n = -\left(\frac{2\pi^2 m k^2 e^4}{h^2}\right)\frac{Z^2}{n^2}$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \qquad R = 1.097 \times 10^{7}\,\mathrm{m^{-1}}$$

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

$$E = (\Delta m)c^2 \qquad (1\,\mathrm{u})c^2 = 931.494\,\mathrm{MeV} \qquad 1\,\mathrm{u} = 1.6605 \times 10^{-27}\,\mathrm{kg}$$