Name________________________________

May. 8, 2002

10 am 11 am

Phys 2020 — Spring 2002
Final Exam

1.	____________	(5)
2.	____________	(10)
3.	____________	(7)
4.	____________	(6)
5.	____________	(11)
6.	____________	(12)
7.	____________	(11)
8.	____________	(9)
9.	____________	(9)
MC	____________	(20)
Total	____________	(100)

Multiple Choice

Pick the *best* answer from among the four.

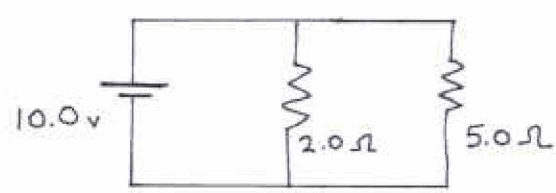
1. In the circuit shown at the right, the current in the $2.0\,\Omega$ resistor is

a) 1.43 A.

b) 2.0 A.

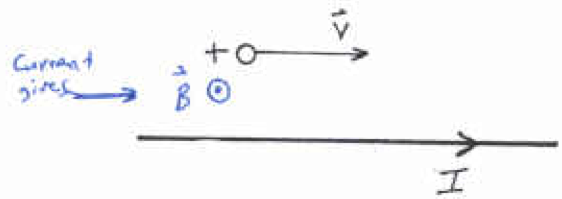
c) 5.0 A.

d) 7.0 A.



2. If the direction of the current in the wire is as shown and the velocity of the positively-charged particle is as shown and the current and velocity are both in the plane of the page, the force on the charge points:

a) Up. (↑).
b) Down (↓).
c) Out of the page. ⊙
d) Into the page. ⊗

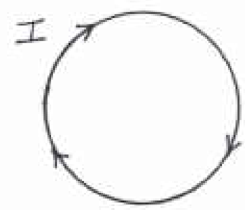


3. The Farad is a unit of

a) Magnetic flux.
b) Resistivity.
c) Capacitance.
d) Inductance.

4. The current ring at the right is in the plane of the page, and a changing magnetic field is inducing a clockwise current. The magnetic field might be:

a) Out of the page and decreasing.
b) Into the page and increasing.
c) Into the page and decreasing.
d) None of the above.



5. A farad is equal to

a) $1\,\frac{\mathrm{J}}{\mathrm{C}}$.
b) $1\,\frac{\mathrm{C}}{\mathrm{V}}$.
c) $1\,\frac{\mathrm{N}}{\mathrm{C}}$.
d) $1\,\frac{\mathrm{V}}{\mathrm{A}}$.

6. The "blackbody radiation" puzzle was "solved" by Planck using what new idea?

a) Wave/particle duality of electron motion.
b) The theory of special relativity.
c) The nuclear model of the atom.
d) Energy of an oscillator is quantized.

7. The electric charge of the nucleus of $^{208}_{82}\mathrm{Pb}$ is

a) $+82e$
b) $+126e$
c) $-126e$
d) $+208e$

8. In the experiments which involve the "photoelectric effect", the photons

a) Eject electrons from a metal surface.

b) Cause a current to flow in a semiconductor.

c) Are emitted by a current–carrying wire.

d) Are emitted by a hot solid object.

9. Bohr produced a successful model of the hydrogen atom by imposing a simple quantization condition on the orbiting electron's

a) Speed.

b) Angular momentum.

c) Linear momentum.

d) Kinetic energy.

10. In β–decay, the nucleus emits

a) A deuteron ($^2_1$H).

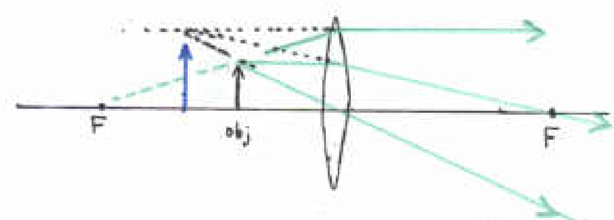
b) A proton.

c) A neutron.

d) An electron.

Problems

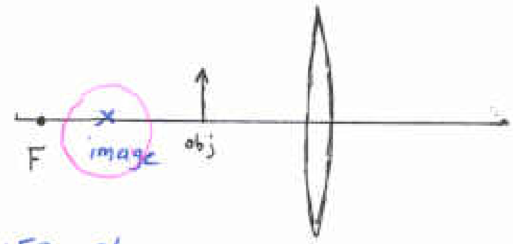
1. An object stands in front of a converging lens, as shown. Find the location and size of the image by tracing rays. (You will need at least two rays to accomplish this.) (5)



(Focal points of lens are as shown)

The three rays when traced backwards to their (virtual!) source give an image located in front of (to the left of) the object.

2. An object of height 1.5 cm stands 4.0 cm in front of a (converging) lens with focal length 10.0 cm.



a) Find the location of the image; Is the image on the same side of the lens as the object or the opposite side? (4)

With $f = 10.0$ cm and $d_o = 4.0$ cm,

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{(10.0\ \text{cm})} - \frac{1}{(4.0\ \text{cm})} = -0.150\ \text{cm}^{-1}$$

$\boxed{d_i = -6.67\ \text{cm}}$, meaning the image is on the left side of the lens.

b) Find the height of the image. (4)

$$m = -\frac{d_i}{d_o} = -\frac{(-6.67\ \text{cm})}{4.0\ \text{cm}} = 1.67$$

So $h_i = m h_o = (1.67)(1.5\ \text{cm}) = \boxed{2.5\ \text{cm}}$

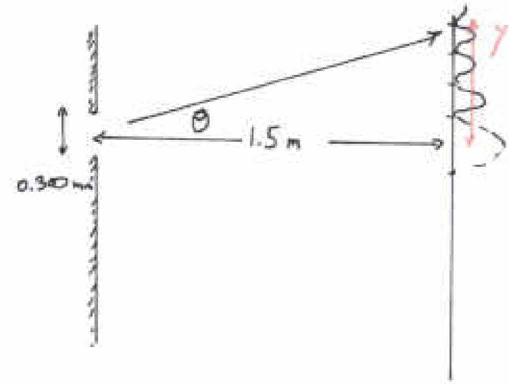
Note: This is basically the same lens / object configuration as in Prob. 1 !

c) Is the image Upright or Inverted? Real or Virtual? (2)

$m > 0 \longrightarrow$ $\boxed{\text{Upright}}$ image

$d_i < 0 \longrightarrow$ $\boxed{\text{Virtual}}$ image

3. In a single-slit diffraction experiment, the slit is 1.5 m from the screen; light of wavelength 600 nm illuminates a slit of width 0.300 mm.



a) If θ is the angle from the center point where the fourth minimum appears on the screen, find $\sin\theta$. (4)

Use formula for single-slit diffr,

$$\sin\theta = m\frac{\lambda}{w} = 4\,\frac{(600\times10^{-9}\,\text{m})}{(0.300\times10^{-3}\,\text{m})}$$

$$= \boxed{8.0\times10^{-3}}$$

b) Find the distance y from the center of the pattern to the point at which the fourth minimum appears on the screen. (3)

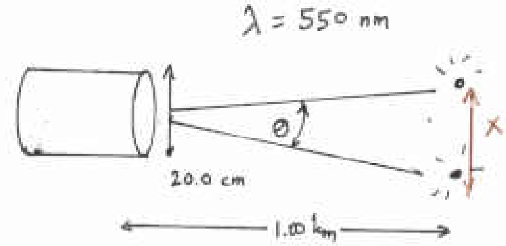
From small-angle approx,

$$\sin\theta \approx \tan\theta = \frac{y}{1.5\ \text{m}}, \quad \text{so}$$

$$y = (1.5\,\text{m})\sin\theta = (1.5\,\text{m})(8.0\times10^{-3}) = 1.20\times10^{-2}\ \text{m}$$

$$= \boxed{1.20\ \text{cm}}$$

4. A reflecting telescope has a mirror of diameter 20.0 cm. As with any light–collecting device, its resolving power is limited by its size. Here we will ignore other effects, such as those of the atmosphere.



a) For the smallest angle θ for which two points of light of wavelength 550 nm can be distinguished, give $\sin\theta$. (3)

With $D = 20.0\ \text{cm} = 2.00 \times 10^{-1}\,\text{m}$,

$$\sin\theta_{min} = (1.22)\frac{\lambda}{D} = (1.22)\frac{(550\times10^{-9}\,\text{m})}{(2.00\times10^{-1}\,\text{m})} = \boxed{3.36\times10^{-6}}$$

b) Find the smallest (linear) separation that two objects at a distance of 1.00 km can be distinguished with this telescope. (3) Using small-angle approx,

$$\sin\theta_{min} = \frac{x}{(1.00\ \text{km})} = \frac{x}{(1.00\times10^{3}\,\text{m})}$$, where x is the linear separation.

$$x = (1.00\times10^{3}\,\text{m})(3.36\times10^{-6}) = 3.36\times10^{-3}\,\text{m} = \boxed{3.36\ \text{mm}}$$

5. A freely–moving electron has a DeBroglie wavelength of 3.00×10^{-10} m.

a) What is the speed of the electron? (5)

$\lambda = h/p$, so $p = h/\lambda$ also, $p = mv$

so $mv = h/\lambda$

$$v = \frac{h}{m\lambda} = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})}{(9.11\times10^{-31}\,\text{kg})(3.00\times10^{-10}\,\text{m})} = \boxed{2.42\times10^{6}\ \frac{\text{m}}{\text{s}}}$$

b) What is the kinetic energy of the electron? Express the answer in units of eV. (4)

$$K = \frac{1}{2}mv^2 = \frac{1}{2}(9.11\times10^{-31}\,\text{kg})(2.42\times10^{6}\,\tfrac{\text{m}}{\text{s}})^2 = 2.68\times10^{-18}\,\text{J}$$

$$= (2.68\times10^{-18}\,\text{J})\left(\frac{1\ \text{eV}}{1.602\times10^{-19}\,\text{J}}\right) = \boxed{16.7\ \text{eV}}$$

c) If the electron was accelerated from rest to this speed by some electrical potential V, what is the magnitude of V? (2)

By cons. of energy, we have: $K = |\Delta EPE| = e|\Delta V| = 16.7\ \text{eV}$

Since eV = e·Volt, then: $\boxed{|\Delta V| = 16.7\ \text{V}}$

6. A hydrogen atom initially in the state $n_i = 5$ absorbs a photon and ends up in the state for which $n_f = 8$.

a) What is the wavelength of the absorbed photon? (4)

$$\frac{1}{\lambda} = R\left(\frac{1}{n_i^2} - \frac{1}{n_u^2}\right) = (1.097\times10^7\,m^{-1})\left(\frac{1}{25} - \frac{1}{64}\right) = 2.67\times10^5\,m^{-1}$$

$$\lambda = 3.74\times10^{-6}\,m = \boxed{3740\ nm}$$

b) What is the energy of the absorbed photon? (4)

$$E = hf = h\frac{c}{\lambda} = (6.626\times10^{-34}\,J\cdot s)\frac{(2.998\times10^8\,\frac{m}{s})}{(3.74\times10^{-6}\,m)}$$

$$= \boxed{5.31\times10^{-20}\,J} = 0.332\ eV$$

c) What is the maximum wavelength of the photon which the hydrogen atom in the $n = 5$ state can *emit*? (4)

For an emitted photon of max λ (lowest E), the electron ends up in the $n = 4$ state. λ for this is:

$$\frac{1}{\lambda} = (1.097\times10^7\,m^{-1})\left(\frac{1}{4^2} - \frac{1}{5^2}\right) = 2.47\times10^5\,m^{-1}$$

$$\lambda = 4.05\times10^{-6}\,m = \boxed{4050\ nm}$$

7. The $^{56}_{26}\mathrm{Fe}$ nucleus has a mass of 55.943940 u.

a) How many protons and how many neutrons are contained in this nucleus? (4)

There $Z = \boxed{26 \text{ protons}}$, and $N = A - Z = 56 - 26$

$= \boxed{30 \text{ neutrons}}$

b) What is the mass difference between the $^{56}_{26}\mathrm{Fe}$ nucleus and the individual protons and neutrons? (4)

$$\Delta m = 26\, m_p + 30\, m_n - 55.943940\,u$$

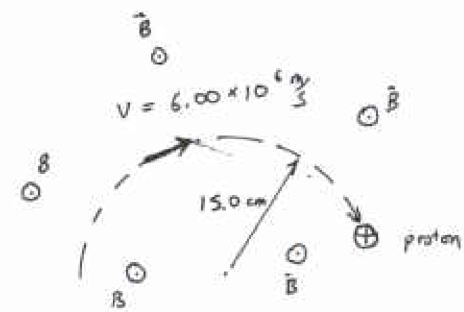
$$= 26(1.0078\,u) + 30(1.0087\,u) - 55.943940\,u$$

$$= \boxed{0.5199\,u} = 8.63 \times 10^{-28}\,kg$$

b) Find the binding energy of the $^{56}_{26}\mathrm{Fe}$ nucleus; express the answer in MeV. (3)

$$BE = \Delta m c^2 = (0.5199\,u)\,c^2$$

$$= (0.5199)(931.5\,MeV) = \boxed{484\,MeV}$$



$m_{proton} = 1.673 \times 10^{-27}\,kg$

8. A proton moves at a speed of $6.00 \times 10^6\,\frac{m}{s}$ perpendicular to a uniform magnetic field. The path is a circle of radius 15.0 cm.

a) What is the magnitude of the force on the proton? (5)

$$F_c = \frac{mv^2}{r} = \frac{(1.6726 \times 10^{-27}\,kg)(6.00 \times 10^6\,\frac{m}{s})^2}{(0.150\,m)}$$

$$= \boxed{4.01 \times 10^{-13}\,N}$$

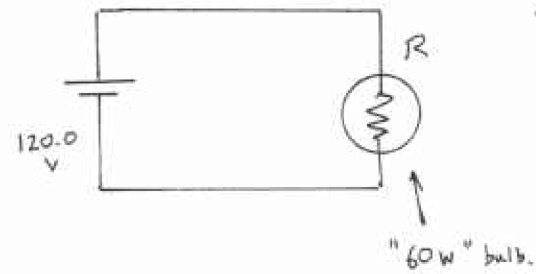
b) What is the magnitude of the magnetic field? (4)

Since $\vec{B}$ is perp to $\vec{v}$, can use:

$F = qvB$, w/ $q = +e$. So:

$$B = \frac{F}{qv} = \frac{(4.01 \times 10^{-13}\,N)}{(1.602 \times 10^{-19}\,C)(6.00 \times 10^6\,\frac{m}{s})} = \boxed{0.418\,T}$$

9. A light bulb is rated at "60.0 W" meaning that it dissipates 60.0 W of power when connected to a voltage of 120.0 V.



a) When the bulb operates under these conditions, what current flows through it? (3)

Voltage across bulb is $V = 120.0\ \text{V}$, so

$$P = VI \rightarrow I = \frac{P}{V} = \frac{60.0\ \text{W}}{120.0\ \text{V}}$$

$$= \boxed{0.500\ \text{A}}$$

b) What is the resistance of the bulb? (2)

Since $V = IR$,

$$R = \frac{V}{I} = \frac{120.0\ \text{V}}{0.500\ \text{A}} = \boxed{240\ \Omega}$$

c) If the resistance of the bulb is a piece of tungsten wire with cross-sectional area $2.00 \times 10^{-9}\ \text{m}^2$, how long is the wire? The resistivity of tungsten is $5.6 \times 10^{-8}\ \Omega \cdot \text{m}$. (4)

R, ρ, L and A related by $\rho \frac{L}{A} = R$, so

$$L = \frac{R \cdot A}{\rho} = \frac{(240\ \Omega)(2.00 \times 10^{-9}\ \text{m}^2)}{(5.6 \times 10^{-8}\ \Omega \cdot \text{m})} = \boxed{8.6\ \text{m}}$$

$$v_x = v_{0x} + a_x t \qquad v_y = v_{0y} + a_y t \qquad x = x_0 + v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad y = y_0 + v_{0y}t + \tfrac{1}{2}a_y t^2$$

$$v_x^2 = v_{0x}^2 + 2a_x x \qquad v_y^2 = v_{0y}^2 + 2a_y y$$

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

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\,\frac{\mathrm{N{\cdot}m^2}}{\mathrm{C^2}} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\frac{\mathrm{C^2}}{\mathrm{N{\cdot}m^2}} \qquad F = k\frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2}$$

$$g = 9.80\,\tfrac{\mathrm{m}}{\mathrm{s^2}} \qquad m_{\mathrm{elec}} = 9.1094 \times 10^{-31}\,\mathrm{kg} \qquad e = 1.602 \times 10^{-19}\,\mathrm{C} \qquad 1\,\mathrm{eV} = 1.602 \times 10^{-19}\,\mathrm{J}$$

$$\mathbf{F} = q\mathbf{E} \qquad E_{\mathrm{pt\ ch}} = k\frac{|q|}{r^2} \qquad E_{\mathrm{p-plates}} = \frac{\sigma}{\epsilon_0} \qquad \Delta\mathrm{EPE} = q\Delta V \qquad V_{\mathrm{pt\ ch}} = k\frac{q}{r} \qquad E_x = -\frac{\Delta V}{\Delta x}$$

$$A_{\mathrm{circ}} = \pi R^2 \qquad Q = CV \qquad E = \tfrac{1}{2}CV^2 \qquad C_{\mathrm{p-plates}} = \epsilon_0\frac{A}{d} \qquad I = \frac{\Delta q}{\Delta t}$$

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

$$F = qvB\sin\theta\ \text{, w/ RHR–1} \qquad F = ILB\sin\theta \qquad r = \frac{mv}{qB} \qquad \tau = NIAB\sin\phi = mB\sin\phi$$

$$\mu_0 = 4\pi \times 10^{-7}\,\frac{\mathrm{T{\cdot}m}}{\mathrm{A}} \qquad B_{\infty-\mathrm{wire}} = \frac{\mu_0 I}{2\pi r}\ \text{with RHR–2} \qquad B_{\mathrm{sol}} = \mu_0 n I$$

$$\mathcal{E} = vBL \qquad \Phi = BA\cos\phi \qquad \mathcal{E} = -N\frac{\Delta\Phi}{\Delta t} \qquad \mathcal{E} = -L\frac{\Delta I}{\Delta t}$$

$$\lambda f = c \qquad \overline{S}_{\mathrm{pol}} = \tfrac{1}{2}\overline{S}_{\mathrm{unpol}} \qquad \overline{S} = \overline{S}_0\cos^2\theta \qquad n_1\sin\theta_1 = n_2\sin\theta_2 \qquad \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$c = 2.998 \times 10^8\ \mathrm{m/s}$

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

$$\sin\theta_{\mathrm{br}} = m\frac{\lambda}{d} \qquad \sin\theta_{\mathrm{dark}} = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{d} \qquad \sin\theta_{\mathrm{dark}} = m\frac{\lambda}{w} \qquad \sin\theta_{\mathrm{min}} = (1.22)\frac{\lambda}{D}$$

Small-angle approx: $\theta(\mathrm{rad}) \approx \sin\theta \approx \tan\theta$

$$E = hf \qquad p = \frac{h}{\lambda} \qquad \lambda = \frac{h}{p} \qquad h = 6.626 \times 10^{-34}\,\mathrm{J\cdot s}$$

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

$$A = Z + N \qquad \Delta E = \Delta mc^2 \qquad (1\,\mathrm{u})c^2 = 931.5\,\mathrm{MeV} \qquad 1\,\mathrm{u} = 1.6605 \times 10^{-27}\,\mathrm{kg}$$

$$m_{\mathrm{proton}} = 1.0078\,\mathrm{u} = 1.6726 \times 10^{-27}\,\mathrm{kg} \qquad m_{\mathrm{neutron}} = 1.0087\,\mathrm{u} = 1.6749 \times 10^{-27}\,\mathrm{kg}$$