**Name**____________________________

Apr. 27, 2006

# Phys 2020, NSCC
## Exam #3 — Spring 2006

| | | |
|---|---|---|
| **1.** | __________________ | (12) |
| **2.** | __________________ | (10) |
| **3.** | __________________ | (9) |
| **4.** | __________________ | (8) |
| **5.** | __________________ | (6) |
| **6.** | __________________ | (8) |
| **7.** | __________________ | (6) |
| **8.** | __________________ | (8) |
| **9.** | __________________ | (9) |
| **10.** | __________________ | (10) |
| **MC** | __________________ | (16) |
| **Total** | __________________ | (102) (!) |

## Multiple Choice

*Choose the best answer from among the four!*

**1.** The purpose of the corrective lenses of a farsighted person (trouble seeing near objects) is to

**a)** Take an object at about 25 cm and make an image at the near point.

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

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

**d)** Take an object at the near point and make an image at about 25 cm.

**2.** In a single–slit diffraction pattern, the fringes on the screen move farther apart if

**a)** The wavelength of the light is decreased or the width of the slit is decreased.

**b)** The wavelength of the light is decreased or the width of the slit is increased.

$\boxed{\textbf{c)}}$ The wavelength of the light is increased or the width of the slit is decreased.

**d)** The wavelength of the light is increased or the width of the slit is increased.

**3.** Einstein successfully explained the photoelectric effect using the idea of

**a)** The wave nature of "matter".

**b)** The quantization of angular momentum.

$\boxed{\textbf{c)}}$ The particle nature of light.

**d)** The uncertainty principle.

**4.** When we discuss particle waves, we understand that we are talking about

**a)** The oscillatory motion of atomic particles.

$\boxed{\textbf{b)}}$ Waves of probability.

**c)** The fact that the particles are not points but are "smeared out" in space.

**d)** Particles represent disturbances in some background quantum medium.

**5.** Which of the following sets of qunatum numbers for an electron in the quantum-mechanical H atom is impossible?

$\boxed{\textbf{a)}}$ $n = 3,\ l = 2,\ m_l = 3$

**b)** $n = 5,\ l = 0,\ m_l = 0$

**c)** $n = 2,\ l = 1,\ m_l = -1$

**d)** $n = 4,\ l = 3,\ m_l = -3$

**6.** Roughly speaking, the size of the nucleus of an atom is about.

**a)** 10 times larger than the "orbits" of the electrons.

**b)** About 10 times smaller than the orbits of the electrons.

**c)** About 1000 times smaller than the orbits of the electrons.

$\boxed{\textbf{d)}}$ About 100,000 times smaller than the orbits of the electrons.

**7.** How do the number of protons and neutrons compare in stable nuclei?

**a)** For small nuclei there are more protons, while for large nuclei they are about equal.

**b)** For small nuclei there are more neutrons, while for large nuclei they are about equal.

**c)** For small nuclei they are about equal, while for large nuclei there are more protons.

$\boxed{\textbf{d)}}$ For small nuclei they are about equal, while for large nuclei there are more neutrons.

**8.** When the nucleus $^{226}_{88}\mathrm{Ra}$ emits an $\alpha$ particle, the resulting nucleus is

**a)** $^{226}_{89}\mathrm{Ac}$

$\boxed{\textbf{b)}}$ $^{222}_{86}\mathrm{Rn}$

**c)** $^{226}_{88}\mathrm{Ra}$

**d)** $^{226}_{87}\mathrm{Fr}$

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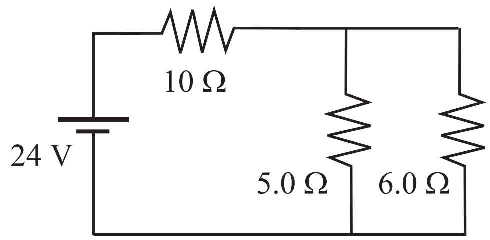
**Problems**

*Show your work and include the correct units with your answers!*

**1.** In the circuit shown here,




**a)** Find the current in the $10\,\Omega$ resistor. (6)

$5.0\,\Omega$ and $6.0\,\Omega$ resistors combine as

$$R_{\text{par}} = \left(\frac{1}{5.0\,\Omega} + \frac{1}{5.0\,\Omega}\right)^{-1} = 2.73\,\Omega$$

which is in series with the $10.0\,\Omega$ resistor so the circuit has an equivalent resistance

$$R_{\text{eq}} = 10.0\,\Omega + 2.73\,\Omega = 12.73\,\Omega$$

and the total current is

$$I = \frac{V}{R_{\text{eq}}} = \frac{24.0\ \text{V}}{12.73\,\Omega} = 1.89\ \text{A}$$

This is the same as the current in the $10.0\,\Omega$ resistor.

**b)** Find the current in the $6.0\,\Omega$ resistor. (6)

The potential drop across the parallel combination is

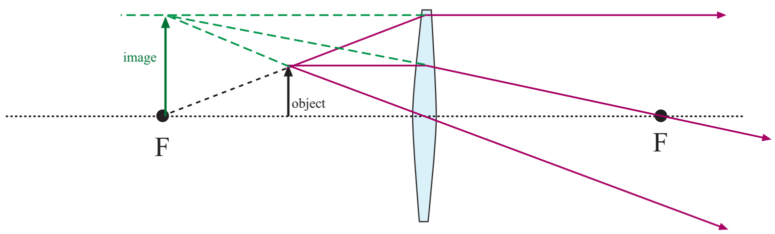
$$V_{\text{par}} = 24.0\ \text{V} - (1.89\ \text{A})(10.0\,\Omega) = 5.14\ \text{V}$$

which is the potential drop across the $6.0\,\Omega$ resistor so the current in that resistor is

$$I = \frac{V}{R} = \frac{5.14\ \text{V}}{6.0\,\Omega} = 0.857\ \text{A}$$

**2.** An object sits in front of a converging lens, as shown here; it is between the focal point and the lens.

Complete a ray diagram showing the formation of the image. (8)




(Rays added to diagram and extended backwards to meet at a point; this gives the location of the image.)

Is the image on the left or right side of the lens? Is it a real image or a virtual image? (2)

The image is on the left side of the lens. It is a virtual image.

**3.** Suppose an object with a height of 3.0 cm is 30.0 cm in front of a lens with a focal length of 18.0 cm.

Find the location of the image (say if the image is on the left or right side of the lens.) Find the height of the image. Say if the image is upright or inverted and if the image is real or virtual. (9)

Use the lens equation to get $d_i$:

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{18.0 \text{ cm}} - \frac{1}{30.0 \text{ cm}} = 0.022 \text{ cm}^{-1} \qquad \Longrightarrow \qquad d_i = 45.0 \text{ cm}$$

This says that the image is on the $\boxed{\text{right}}$ (opposite) side of the lens and so the image is $\boxed{\text{real}}$. The magnification is

$$m = -\frac{d_i}{d_o} = -\frac{45.0}{30.0} = -1.5 = \frac{h_i}{h_o}$$

then the height of the image is

$$h_i = (-1.5)(3.0 \text{ cm}) = -4.5 \text{ cm}$$

The image is $\boxed{\text{inverted}}$.

**4.** A certain nearsighted person cannot properly focus objects which are farther than 3.0 m from the eye.

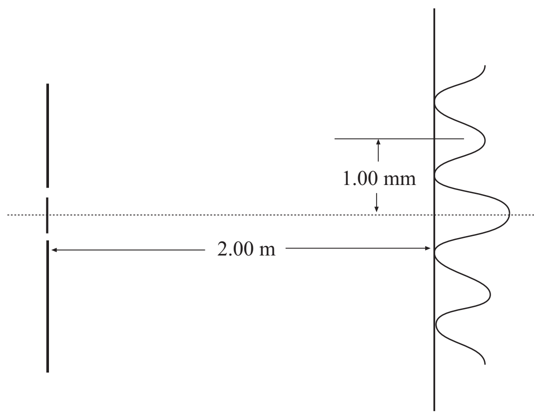
Give a brief description of how a lens can correct this problem (say something about objects with infinite distance...) and find the focal length of the lens which will correct the problem. (8)

Nearsighted person would like the see objects at infinity so the lens must take an object at infinity and make an image at the far point (so that $d_i = -3.0\ \mathrm{m}$) where the person can deal with an object. Putting these values into the lens equation,

$$\frac{1}{\infty} + \frac{1}{(-3.0\ \mathrm{m})} = \frac{1}{f} \qquad \Longrightarrow \qquad 0 - \frac{1}{3.0\ \mathrm{m}} = \frac{1}{f} \qquad \Longrightarrow \qquad f = -3.0\ \mathrm{m}$$

and so the lens must have a focal length of $-3.0\ \mathrm{m}$ (it is thus a diverging lens).

**5.** In an (idealized) Young two–slit experiment, coherent light of wavelength 690 nm is incident on the (thin) slits and form an interference pattern on a screen 2.0 m from the slits and parallel to their plane. The distance between any two adjacent bright fringes is 1.00 mm. Find the separation of the two slits. (6)




The angle to the first-order bright fringe is

$$\tan\theta = \frac{1.00 \times 10^{-3}}{2.00} \qquad \Longrightarrow \qquad \theta = 2.86{\times}10^{-2}\ \mathrm{deg}$$

For the first-order bright fringe,

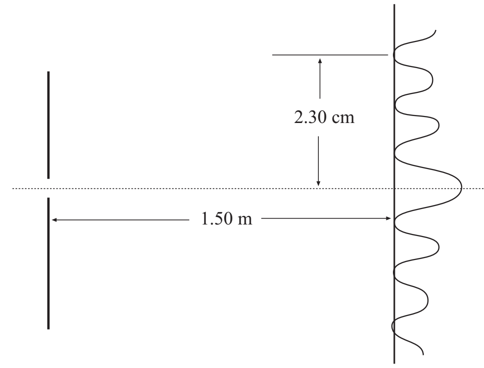
$$\sin\theta = (1)\frac{\lambda}{d}$$

then we get

$$d = \frac{\lambda}{\sin\theta} = \frac{(690 \times 10^{-9}\ \mathrm{m}}{\sin\theta} = 1.38 \times 10^{-3}\ \mathrm{m} = 1.38\ \mathrm{mm}$$

**6.** In a *single–slit* diffraction experiment, coherent light is incident on a slit of width 0.10 mm; a diffraction pattern is formed on a parallel screen 1.5 m from the slit. It is found the the distance between the central bright peak and the *third* dark fringe is 2.30 cm.

What is the wavelength of the light? (8)




The angle to the third dark fringe is

$$\tan\theta = \frac{2.30 \times 10^{-2}}{1.50} \qquad \Longrightarrow \qquad \theta = 0.878 \text{ deg}$$

For the third-order dark fringe we have

$$\sin\theta = (3)\frac{\lambda}{a} \qquad \Longrightarrow \qquad \lambda = \frac{d\sin\theta}{3}$$

This gives

$$\lambda = \frac{(0.10 \times 10^{-3} \text{ m})\sin\theta}{3} = 5.11 \times 10^{-7} \text{ m} = 511 \text{ nm}$$

**7.** What is the wavelength of a photon which has an energy of 2.0 MeV? (This is a typical energy for gamma rays.) (6)

The energy of the photon is

$$E = hf = 2.0 \times 10^{6} \text{ eV} \cdot \left(\frac{1.602 \times 10^{-19} \text{ J}}{1 \text{ eV}}\right) = 3.20 \times 10^{-13} \text{ J}$$

so the frequency is

$$f = \frac{E}{h} = \frac{3.20 \times 10^{-13} \text{ J}}{6.626 \times 10^{-34} \text{ J}\cdot\text{s}} = 4.84 \times 10^{20} \text{ Hz}$$

and then the wavelength is

$$\lambda = \frac{c}{f} = \frac{2.998 \times 10^{8} \frac{\text{m}}{\text{s}}}{4.84 \times 10^{20} \text{ s}^{-1}} = 6.20 \times 10^{-13} \text{ m}$$

**8.** A photoelectric effect experiment is performed with a certain metal which has a work function of 1.80 eV.
**a)** What is the maximum wavelength of light which can eject electrons from this metal? (5)

The photon must have at least an energy equal to the work function, so its energy would be

$$E = hf = 1.80 \text{ eV} = 2.88 \times 10^{-19} \text{ J}$$

This gives

$$f = \frac{E}{h} = 4.35 \times 10^{14} \text{ Hz}$$

for which the wavelength is

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \frac{\text{m}}{\text{s}}}{4.35 \times 10^{14} \text{ Hz}} = 6.88 \times 10^{-7} \text{ m} = 688 \text{ nm}$$

**b)** Suppose the metal is illuminated with light of wavelength of 440 nm. What is the maximum kinetic energy of the ejected electrons? (5)

The energy of these photons would be

$$E = hf = h\frac{c}{\lambda} = (6.626 \times 10^{-34} \text{ J} \cdot \text{s})\frac{3.00 \times 10^8 \frac{\text{m}}{\text{s}}}{440 \times 10^{-9} \text{ m}} = 4.5 \times 10^{-19} \text{ J} = 2.82 \text{ eV}$$

then the maximum kinetic energy of the electrons would be

$$\text{KE}_{\text{max}} = hf - W_0 = (2.82 \text{ eV}) - (1.80 \text{ eV}) = 1.02 \text{ eV}$$

**9.a)** When the electron in a hydrogen atom makes a transition from the $n = 4$ orbit to the $n = 3$ orbit, what is the wavelength of the photon which is emitted? (6)

$$\frac{1}{\lambda} = R\left(\frac{1}{9} - \frac{1}{16}\right) = 5.33 \times 10^5 \text{ m}^{-1} \qquad \Longrightarrow \qquad \lambda = 1.88 \times 10^{-6} \text{ m}$$

**b)** What is the energy of that photon in eV? (3)

$$E = hf = h\frac{c}{\lambda} = (6.626 \times 10^{-34} \text{ J} \cdot \text{s})\frac{(3.00 \times 10^8 \frac{\text{m}}{\text{s}}}{1.88 \times 10^{-6} \text{ m}} = 1.06 \times 10^{-19} \text{ J} = 0.661 \text{ eV}$$

**10.** Calculate the total binding energy and the binding energy *per nucleon* for the nucleus $^{20}_{10}\mathrm{Ne}$. The $^{20}_{10}\mathrm{Ne}$ *atom* has a mass of 19.992434 u (10)

$\Delta m = 10(m_H)+10(m_n)-19.992434\ \mathrm{u} = 10(1.0078\ \mathrm{u})+10(1.0087\ \mathrm{u})-19.992434\ \mathrm{u} = 0.172\ \mathrm{u}$

Then the total binding energy is the energy-equivalent of this mass,

$$E_{\mathrm{bind}} = \Delta mc^2 = (0.172\ \mathrm{u})c^2 = (0.172)(931.5\ \mathrm{MeV}) = 160\ \mathrm{MeV}$$

and the binding energy per nucleon is

$$\frac{\mathrm{BE}}{A} = \frac{160\ \mathrm{MeV}}{20} = 8.03\ \mathrm{MeV}$$

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**You must show all your work and include the right units with your answers!**

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

$$\lambda f = v \qquad v = \frac{c}{n} \qquad c = 3.00\times 10^8 \tfrac{\mathrm{m}}{\mathrm{s}} \qquad n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \frac{1}{d_o}+\frac{1}{d_i} = \frac{1}{f} \qquad m = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$$

$$\text{Interf:} \quad \sin\theta_{\mathrm{br}} = m\frac{\lambda}{d} \qquad \sin\theta_{\mathrm{dk}} = (m+\tfrac{1}{2})\frac{\lambda}{d} \qquad \text{Diff:} \quad \sin\theta_{\mathrm{dk}} = m\frac{\lambda}{a}$$

$$h = 6.626\times 10^{-34}\ \mathrm{J\cdot s} \qquad E = hf \qquad hf = \mathrm{KE}_{\mathrm{max}} + W_0 \qquad 1\ \mathrm{eV} = 1.602\times 10^{-19}\ \mathrm{J}$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \qquad R = 1.097\times 10^7\ \mathrm{m}^{-1} \qquad E_n = -(13.6\ \mathrm{eV})\frac{Z^2}{n^2} \qquad r_n = (5.29\times 10^{-11}\ \mathrm{m})\frac{n^2}{Z^2}$$

$$A = Z+N \qquad m_H = 1.0078\ \mathrm{u} \qquad m_n = 1.0087\ \mathrm{u} \qquad (1\ \mathrm{u})c^2 = 931.5\ \mathrm{MeV} \qquad E_{\mathrm{bind}} = \Delta mc^2$$