Name______________________________

Feb. 21, 2008

Phys 2020
Exam #1 — Spring 2008

1.	____________________	(8)
2.	____________________	(6)
3.	____________________	(10)
4.	____________________	(11)
5.	____________________	(17)
6.	____________________	(6)
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8.	____________________	(9)
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10.	____________________	(10)
MC	____________________	(10)
Total	____________________	(100)

Multiple Choice

Choose the best answer from among the four! (2) each.

1. When a beam of monochromatic light (wave) goes from air to glass,

a) The frequency will change but the wave speed will stay the same.

b) The wave speed will change but the wavelength will stay the same.

$\boxed{\textbf{c)}}$ The wavelength will change but the frequency will stay the same.

d) The wavelength will change but the wave speed will stay the same.

2. In a plane (flat) mirror, the image is always

$\boxed{\textbf{a)}}$ Virtual and upright.

b) Virtual and inverted.

c) Real and upright.

d) Real and inverted.

3. To correct the vision of someone with hyperopia (farsightedness) we should use a lens which will

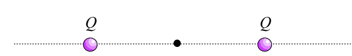
a) Take an object at the near point and make an image at 25 cm.

$\boxed{\textbf{b)}}$ Take an object at 25 cm and make an image at the near point.

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

d) Take an object at 25 cm and make an image at infinity.

4. At the midpoint of two identical point charges, the electric field



a) Has twice the value it would have from either charge alone.

b) Has four times the value it would have from either charge alone.

c) Has the same value it would have from either charge alone.

$\boxed{\textbf{d)}}$ Is zero.

5. The units of the electric field **E** are

$\boxed{\textbf{a)}}$ $\frac{\mathrm{N}}{\mathrm{C}}$

b) $\frac{\mathrm{J}}{\mathrm{C}}$

c) $\frac{\mathrm{J}}{\mathrm{C \cdot s}}$

d) $\frac{\mathrm{N}}{\mathrm{C \cdot m}}$

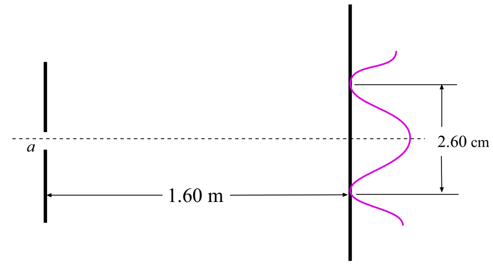
Problems

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

1. In a single–slit diffraction experiment, monochromatic coherent light of wavelength 650 nm is shone through a narrow slit and the pattern is observed on a screen 1.60 m from the slit.

It is found that the full width of the central maximum of the pattern is 2.60 cm.

What is the width of the slit? (8)



Get the angle to the first minimum using half the width of the central peak; thus

$$\theta_1 = \tan^{-1}\left(\frac{1.30\text{ cm}}{160\text{ cm}}\right) = 0.466^\circ$$

then use the formula for the angles to the dark fringes to get a:

$$\sin\theta_1 = (1)\frac{\lambda}{a} \qquad \Longrightarrow \qquad a = \frac{\lambda}{\sin\theta_1} = \frac{(650\times 10^{-9}\text{ m})}{\sin(0.466^\circ)} = 8.00\times 10^{-5}\text{ m} = 0.080\text{ mm}$$

Width of the slit is $\boxed{0.080\text{ mm}}$

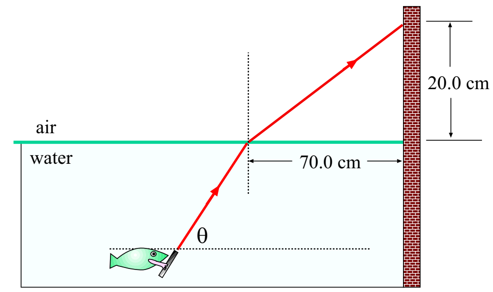
2. The *ideal* case of interference from two extremely narrow slits gives a pattern of light and dark fringes on a screen (as shown here; all peaks have the same width in this case).

Explain (in words) what is happening at the dark fringes. Why would we get no light at these particular points? (6)

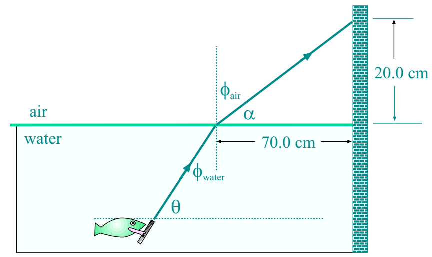
The dark places in the screen are those places where (total) destructive interference occurs. This means that as light originating from the two slits arrives at the screen, the maximum of one wave arrives at the same time as a minimum from the other wave. They cancel and no light arrives at that place on the screen.

3. A fish shines a laser pointer such that the refracted beam emerges at a point which is 70.0 cm from a wall which is at the edge of his tank. The beam hits the wall 20.0 cm above the surface of the water.

At what angle θ (as measured above the horizontal) did the fish aim the laser pointer? Use $n_{\text{water}} = 1.33$. (10)



We label some angles in the figure (as shown to the right) and do a little trig. Find the angle α from



$$\tan\alpha = \frac{20.0}{70.0} = 0.286 \qquad \Longrightarrow \qquad \alpha = 15.9^\circ$$

Then:

$$\phi_{\text{air}} = 90^\circ - 15.9^\circ = 74.0^\circ$$

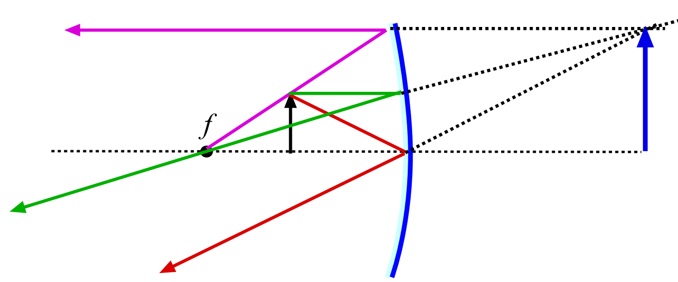
Use Snell's law to get ϕ_{water}

$$(1.33)\sin\phi_{\text{water}} = (1)\sin 74.0^\circ \qquad \Longrightarrow \qquad \sin\phi_{\text{water}} = 0.723 \qquad \Longrightarrow \qquad \phi_{\text{water}} = 46.3^\circ$$

But from simple geometry, the angle θ is the complement of this, thus

$$\theta = 90^\circ - 46.3^\circ = 43.7^\circ$$

4. An object sits in front of of a concave mirror; its distance from the mirror is *less than* the focal length , as shown.



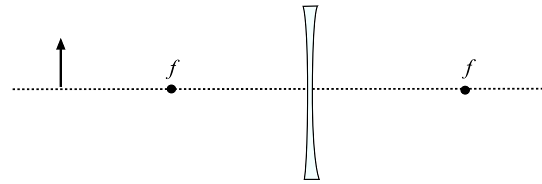
a) On the diagram, draw rays and locate the image. (Hint: This case was demonstrated in class when I put a concave mirror very *close* to someone's face.) (8)

The rays (drawn in different colors) have been added to the original diagram. They diverge, and to locate the image we have to trace them backwards to the point they (seem to) come from, and that is shown with dashed lines.

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

The image is behind the mirror, so it is virtual. As is clear from the diagram, it is upright.

5. A diverging lens has a focal length of −20.0 cm. An object of height 3.0 cm is placed 30.0 cm from (i.e. in front of) this lens.



a) Find the location of the image. Be clear about whether it is in front of the lens or on the other side and explain this answer. (8)

With $s = +30.0$ cm and $f = -20.0$ cm we have from the lens equation,

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = -0.0833\ \mathrm{cm}^{-1} \qquad \Longrightarrow \qquad s' = -12.0\ \mathrm{cm}$$

From the negative sign we know that the image is $\boxed{\text{in front}}$ of the lens (i.e. on the left) by $\boxed{12.0\ \mathrm{cm}}$.

b) Find the size of the image. (6)

With $h = 3.0$ cm we find

$$m = -\frac{s'}{s} = -\frac{-12.0}{30.0} = 0.40 = \frac{h'}{h} \qquad \Longrightarrow \qquad h' = mh = (0.40)(3.0\ \mathrm{cm}) = 1.20\ \mathrm{cm}$$

c) Is the image real or virtual? Upright or inverted? (3)

The image is $\boxed{\text{virtual}}$ since it is in front of the lens. Since m is positive, it is $\boxed{\text{upright}}$.

6. A nearsighted person can properly focus on objects only out to a distance of 3.50 m (but she would *like* to properly focus objects that are *very* far away.

What kind of lens should be prescribed for her, and what focal length should the lens have? (6)

The lens should take an object at infinity and make an image at 3.50 m, in front of the lens (so that $s' = -3.50$ m.) The lens equation gives

$$\frac{1}{\infty} + \frac{1}{(-3.50\ \mathrm{m})} = \frac{1}{f}$$

The first term is zero; (1 over infinity is really small) and then the equation gives $f = -3.50$ m. The needed lens is a $\boxed{\text{diverging}}$ lens of focal length -3.50 m.

7. A glass rod is charged to +8.0 nC by rubbing

a) Have electrons been removed from the rod or protons added? (2)

Only electrons (with negative charge) can be transfered so if the rod gains a positive charge then is has $\boxed{\text{lost electrons}}$.

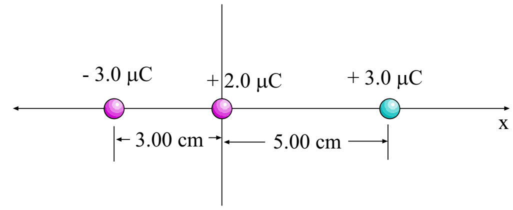
b) How many electrons have been removed or protons added? (5)

Since each lost electron contributes a charge of $e = 1.60 \times 10^{-19}$ C, the charge on the rod was produces by the loss of

$$(8.0 \times 10^{-9}\ \mathrm{C}) \left(\frac{1\ \text{electron lost}}{1.60 \times 10^{-19}\ \mathrm{C}} \right) = 5.0 \times 10^{10}\ \text{lost electrons}$$

8. Three charges are situated on the x axis. There is a $-3.00\,\mu$C charge at $x = -3.00$ cm, a $2.00\,\mu$C charge at the origin and a $+3.00\,\mu$C charge at $x = +5.00$ cm.

Find the force on the charge at the origin; give its magnitude and direction. (9)



The $-3.00\,\mu$C charge on the left gives a force in the $-x$ direction which has magnitude

$$F_1 = 8.99 \times 10^9 \, \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}} \frac{(3.00 \times 10^{-6}\ \mathrm{C})(2.00 \times 10^{-6}\ \mathrm{C})}{(3.00 \times 10^{-2}\ \mathrm{m})^2} = 59.9\ \mathrm{N}$$

The $+3.00\,\mu$C charge on the right also gives a force in the $-x$ direction which has magnitude

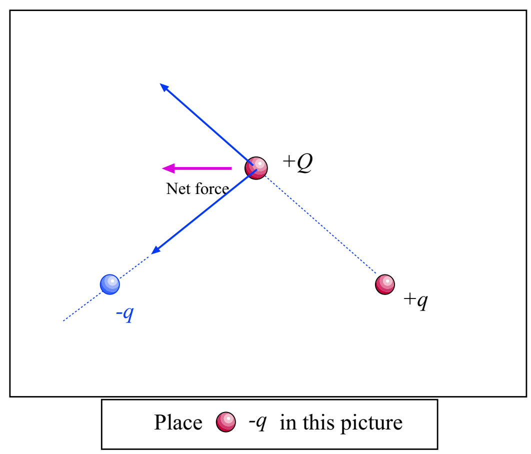
$$F_2 = 8.99 \times 10^9 \, \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}} \frac{(2.00 \times 10^{-6}\ \mathrm{C})(3.00 \times 10^{-6}\ \mathrm{C})}{(3.00 \times 10^{-2}\ \mathrm{m})^2} = 21.6\ \mathrm{N}$$

The net force then has

$$F_{x,\mathrm{net}} = -59.9\ \mathrm{N} - 21.6\ \mathrm{N} = -81.5\ \mathrm{N}$$

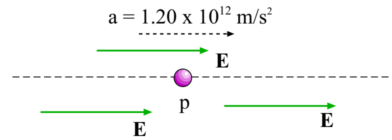
9. At the right is shown a positive charge $+Q$ and another positive charge $+q$. Where would you place a negative charge $-q$ in this picture so that the net force on $+Q$ points to the left?

Indicate the location of $-q$ on the figure and justify your choice. (6)



The position of $-q$ has been added to the figure; the forces on $+Q$ due to the other two charges are shown. These two forces add up to give a net force pointing to the right.

10. A proton is being accelerated by a uniform electric field which points along its direction of motion. The acceleration of the proton is $1.20 \times 10^{12} \frac{\text{m}}{\text{s}^2}$. (The mass of a proton is 1.67×10^{-27} kg.)



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

From Newton's 2nd law,

$$F = ma = (1.67 \times 10^{-27}\ \text{kg})(1.20 \times 10^{12} \tfrac{\text{m}}{\text{s}^2}) = 2.0 \times 10^{-15}\ \text{N}$$

b) What is the magnitude of the electric field? (5)

The magnitudes of the force and E field are related by $F = qE$. Here the charge of the proton is $q = +e$. Then

$$E = \frac{F}{q} = \frac{(2.0 \times 10^{-15}\ \text{N})}{(1.6 \times 10^{-19}\ \text{C})} = 1.25 \times 10^4\ \tfrac{\text{N}}{\text{C}}$$

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

$$c = 3.00 \times 10^8 \tfrac{\text{m}}{\text{s}} \qquad \text{Interference:} \quad \sin\theta_{\text{br}} = m\frac{\lambda}{d} \qquad \text{Diffraction:} \quad \sin\theta_{\text{dark}} = p\frac{\lambda}{a}$$

$$\lambda f = v \qquad n = \frac{c}{v} \qquad n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \sin\theta_c = \frac{n_2}{n_1} \qquad \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad m = \frac{h}{h} = -\frac{s'}{s}$$

$$e = 1.60 \times 10^{-19}\ \text{C} \qquad F = K\frac{|q_1 q_2|}{r^2} \qquad K = 8.99 \times 10^9\ \tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2} \qquad \epsilon_0 = 8.854 \times 10^{-12}\ \tfrac{\text{C}^2}{\text{N}\cdot\text{m}^2}$$

$$\mathbf{F} = m\mathbf{a} \qquad F = q\mathbf{E} \qquad E_{\text{pt}} = K\frac{|q|}{r^2} \qquad E_{\text{par-pl}} = \frac{Q}{\epsilon_0 A} = \frac{\sigma}{\epsilon_0} \qquad \Delta U_{\text{elec}} = q\Delta V \qquad K = \tfrac{1}{2}mv^2$$