PHYSICS 112 - EXAM 4 (first part of final exam) - SPRING 2003

Use only a right-handed coordinate system ($+x$, $+y$, $+z$ along thumb, forefinger, and middle finger of your right hand when these three fingers are perpendicular to one another).

Show your calculations to get full credit. Be sure to include correct units.

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1. [6 points total] A two-slit system consists of two slits, each of width a, whose centers are separated by a distance $d = 4a$.

(a) [2 points] What is sin θ for the angle corresponding to the eleventh diffraction minimum?

(b) [2 points] What is sin θ for the angle corresponding to the seventh interference maximum?

(c) [2 points] What number interference maximum coincides with the third diffraction minimum?

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2. [4 points] Light polarized parallel to the $-x$ axis is passed through two polarizers, first one with its transmission axis along at an angle of 135° (measured counterclockwise from the $+x$ axis), and then one with its transmission axis at an angle of 105° (measured the same way). Determine the fraction of the initially polarized light that passes through each polarizer:

Through the first polarizer ($\theta = 135°$): ________________________________

Through the second polarizer ($\theta = 105°$): _____________________________

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3. [10 points] Light of wavelength 650 nm is incident almost normally from air onto a thin oil film ($n = 1.30$) which is 500 nm thick which is floating on water ($n = 1.33$).

(a) [1 point] What is the approximate color of this light?

(b) [2 points] What is the frequency of this light?

(c) [2 points] What is the speed of light waves in the oil?

(d) [2 points] What is the wavelength of this light in the oil?

(e) [3 points] Will an observer in the air looking at the reflected light beams see constructive or destructive inteference? Be sure to show your calculation.

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4. [4 points] What is the energy, in eV and in joules, for a reddish photon corresponding to light of wavelength $\lambda = 650$ nm?

Energy in eV:

Energy in joules:

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5. [4 points] An atom has three energy levels which we will denote A, B, and C. The energies of A, B, and C are, respectively, -0.40 eV, -3.75 ev, and -8.85 eV.

(a) The maximum energy of a photon *emitted* in a transition from one of these levels to another is:

(b) The minimum frequency of a photon emitted in a transition from one of these levels to another is:

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6. [9 points] Consider this isotope of tin: $^{120}_{50}$Sn.

This isotope consists of __________ electrons, _________neutrons, and _________ protons.

In its nucleus are a total of __________ quarks.

This tin isotope above is the most abundant one in nature. The second most abundant differs only in having two fewer neutrons in its nucleus. The symbol for the atom for this second isotope is:

________________________ .

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7. [3 points] A radioactive isotope of mercury is $^{180}_{80}$Hg, which decays into platinum (symbol: Pt) by alpha-decay and has a half-life of about 6 seconds.

Write down the formula for this radioactive decay.

PHYSICS 112 - EXAM 4 Solutions - SPRING 2003

Use only a right-handed coordinate system ($+x$, $+y$, $+z$ along thumb, forefinger, and middle finger of your right hand when these three fingers are perpendicular to one another).

Show your calculations to get full credit. Be sure to include correct units.

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1. [6 points total] A two-slit system consists of two slits, each of width a, whose centers are separated by a distance $d = 4a$.

(a) [2 points] What is sin θ for the angle corresponding to the eleventh diffraction minimum?

$a \sin\theta = m\lambda$ so $\sin\theta = m\lambda/a$ so the 11th diffraction minimum is at $\sin\theta = 11\ \lambda/a$.

(b) [2 points] What is sin θ for the angle corresponding to the seventh interference maximum?

$d \sin\theta = m\lambda$ so $\sin\theta = m\lambda/d = m\lambda/4a$ so the 7th diffraction minimum is at

$\sin\theta = 7\ \lambda/d = 7\lambda/4a$.

(c) [2 points] What number interference maximum coincides with the third diffraction minimum?

The third diffraction minimum is at $\sin\theta = 3\lambda/a$ which is the same as $12\lambda/4a$, corresponding to the 12th interference maximum (using $\sin\theta = m\lambda/4a$).

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2. [4 points] Light polarized parallel to the $-x$ axis is passed through two polarizers, first one with its transmission axis along at an angle of 135° (measured counterclockwise from the $+x$ axis), and then one with its transmission axis at an angle of 105° (measured the same way). Determine the fraction of the initially polarized light that passes through each polarizer:

Through the first polarizer ($\theta = 135°$): ______________________________

The initial direction of polarization is along the $-x$ axis, which is at angle $\theta = 180°$. The fraction that gets through the first polarizer is then $\cos^2(135° - 180°) = \cos^2(-45°) = 1/2$, or 50%.

Through the second polarizer ($\theta = 105°$): ____________________________

The fraction of the light that passed through the second polarizer was the 50% that passed through the first polarizer times $\cos^2(105° - 135°) = \cos^2(-30°) = 3/4$, or 37.5%.

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3. [10 points] Light of wavelength 650 nm is incident almost normally from air onto a thin oil film ($n = 1.30$) which is 500 nm thick which is floating on water ($n = 1.33$).

(a) [1 point] What is the approximate color of this light?

This is near the long-wavelength end of the visible spectrum, so it would be reddish in color.

(b) [2 points] What is the frequency of this light?

$f = c/\lambda = (3 \times 10^8 \text{ m/s})/(650 \times 10^{-9} \text{ m}) = 4.6 \times 10^{14}$ Hz.

(c) [2 points] What is the speed of light waves in the oil?

$v = c/n = (3 \times 10^8 \text{ m/s})/1.30 = 2.3 \times 10^8$ m/s

(d) [2 points] What is the wavelength of this light in the oil?

$\lambda_{\text{oil}} = \lambda_{\text{air}}/n = (650 \text{ nm})/1.30 = 500$ nm.

(e) [3 points] Will an observer in the air looking at the reflected light beams see constructive or destructive inteference? Be sure to show your calculation.

Both reflections, from the top and bottom of the oil film, will have a 180° phase change, so the reflections by themselves would ensure constructive interference. Next, let's compare the extra path length $2t$ with the wavelength of the light in oil:

$$2t = 2 \times 500 \text{ nm} = 1000 \text{ nm} \quad \text{and} \quad \lambda_{\text{oil}} = 500 \text{ nm}.$$

Thus $2t = 1000 \text{ nm} = 2\ \lambda_{\text{oil}}$. Since the factor in front of λ_{oil} is an integer, the extra path length (two trips across the film) does not change the phase, so this wavelength of light must exhibit constructive interference.

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4. [4 points] What is the energy, in eV and in joules, for a reddish photon corresponding to light of wavelength $\lambda = 650$ nm?

Energy in eV:

$E = hf = hc/\lambda = (6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3 \times 10^8 \text{ m/s})/(650 \times 10^{-9} \text{ m}) =$

3.1×10^{-19} J

Dividing by 1.6×10^{-19} J/eV gives $E = 1.9$ eV

Energy in joules:

Calculated above as $E = 3.1 \times 10^{-19}$ J.

5. [4 points] An atom has three energy levels which we will denote A, B, and C. The energies of A, B, and C are, respectively, -0.40 eV, -3.75 ev, and -8.85 eV.

(a) The maximum energy of a photon *emitted* in a transition from one of these levels to another is:

The maximum evergy must be between the two energies that are farthest apart. These would be -0.40 eV and -8.85 eV, whose difference is 8.45 eV. So the emitted photon with the maximum energy would have an energy of 8.45 eV.

(b) The minimum frequency of a photon emitted in a transition from one of these levels to another is:

The minimum frequency would occur for the minimum energy photon, which would result from a transition between the two closest energy levels. These are -0.40 eV and -3.75 eV, which are 3.35 eV apart.

This photon would have an energy of $3.35 \times 1.6 \times 10^{-19}$ J $= 5.36 \times 10^{-19}$ J.

Its frequency would be $f = E/h = (5.36 \times 10^{-19}\ \text{J})/(6.63 \times 10^{-34}\ \text{J} \cdot \text{s}) = 0.81 \times 10^{15}$ Hz.

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6. [9 points] Consider this isotope of tin: $^{120}_{50}$Sn.

This isotope consists of __________ electrons, _________neutrons, and _________ protons.

In its nucleus are a total of __________ quarks.

This tin isotope above is the most abundant one in nature. The second most abundant differs only in having two fewer neutrons in its nucleus. The symbol for the atom for this second isotope is:

_______________________ .

This isotope has 50 electrons, $120 - 50 = 70$ neutrons, and 50 protons.

It has a total of $3 \times 120 = 360$ quarks.

The isotope of tin with two fewer neutrons in its nucleus would have the same atomic number ($Z = 50$) but its atomic mass number is lower by 2: $^{118}_{50}$Sn

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7. [3 points] A radioactive isotope of mercury is $^{180}_{80}$Hg, which decays into platinum (symbol: Pt) by alpha-decay and has a half-life of about 6 seconds.

Write down the formula for this radioactive decay.

$^{180}_{80}\text{Hg} \rightarrow\ ^{4}_{2}\text{He} +\ ^{176}_{78}\text{Pt}.$

PHYSICS 112 - FINAL EXAM (second, comprehensive part) - SPRING 2003

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1. [2 points] A charge of $+2.0$ C is located at the origin and a charge of -3.0 C is located on the positive x axis at (3.0 m, 0). The electrical force on the negative charge is:

A. directed toward the positive-x direction, and has greater magnitude than the electrical force acting on the positive charge.

B. directed toward the positive-x direction, and has smaller magnitude than the electrical force acting on the positive charge.

C. directed toward the positive-x direction, and has magnitude equal to the electrical force acting on the positive charge.

D. directed toward the negative-x direction, and has greater magnitude than the electrical force acting on the positive charge.

E. directed toward the negative-x direction, and has smaller magnitude than the electrical force acting on the positive charge.

F. directed toward the negative-x direction, and has magnitude equal to the electrical force acting on the positive charge.

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2. [6 points] A 6.0-C charge is fixed at the origin. A -3.0 C charge is placed at point 2.0 m away. Determine the electric potential at this point due to the charge at the origin, and determine the electric potential energy of the system of the two charges.

Electric potential: _______________

Electric potential energy: ____________________

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3. [2 points] A battery is connected to a resistor; the resulting power dissipated through the resistor is P. Which of the following will result in power dissipation of $2P$?

A. Double the battery voltage and double the resistance.

B. Double the battery voltage and halve the resistance.

C. Halve the battery voltage and double the resistance.

D. Halve the battery voltage and halve the resistance.

E. Increase both the battery voltage and the resistance by a factor of 4.

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4. A 20-V battery is connected in series to a 2-ohm resistor and a 3-ohm resistor.

(a) [2 points] What is the potential difference across the 2-ohm resistor?

(b) [2 points] What is the power dissipated by the 3-ohm resistor?

(c) [2 points] What is the total power delivered by the battery?

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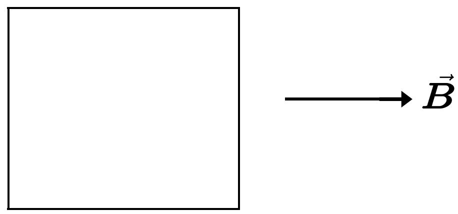
5. [3 points] A straight piece of wire 3.0 m long is carrying a 4.0-A current in the negative x direction. It is in a uniform external magnetic field of magnitude 3.0 teslas directed in the positive z direction. Determine the magnitude and the direction of the magnetic force acting on this wire.

Magnitude:

Direction: $+x$ $-x$ $+y$ $-y$ $+z$ $-z$

A current loop of area 4.0 m^2 and resistance 6.0 Ω is placed in a uniform external magnetic field $\vec{B}$ of magnitude 3.0 T, as shown in the diagram. The loop has a current of 2.0 A in the counterclockwise direction.



6. [2 points] Determine the direction of the magnetic force on each side of the loop (top, right, bottom, and left sides).

7. [2 points] Describe how this loop will tend to rotate.

8. [3 points] When the loop is positioned so there is no net torque acting on it, what is the magnetic flux through it due to the external magnetic field?

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9. [2 points] An electromagnetic wave has its electric field in the $-y$ direction and its magnetic field in the $-z$ direction. In what direction is the wave moving?

Direction: $+x$ $-x$ $+y$ $-y$ $+z$ $-z$

10. [2 points] If this wave has a frequency of 6.0×10^{16} Hz, what will be its wavelength (in air)?

11. [2 points] If this wave passes from air into a material with an index of refraction of 2.00, what will be its wavelength in that material?

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12. [8 points] An object is located on the principal axis of a concave spherical mirror with radius of curvature R, at a distance $2R$ from the vertex of the mirror. Sketch a diagram to scale (choosing whatever you want for R, so it fits on the page) for this situation, showing the center of curvature and the focal point, and using at least two rays to locate the image and describe it. (You do not need to use the mirror equation to calculate the image location.) Use the line below as the principal axis, with the dot marking the vertex of the mirror.

PHYSICS 112 - FINAL EXAM solutions - SPRING 2003

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1. [2 points] A charge of $+2.0$ C is located at the origin and a charge of -3.0 C is located on the positive x axis at (3.0 m, 0). The electrical force on the negative charge is:
A. directed toward the positive-x direction, and has greater magnitude than the electrical force acting on the positive charge.
B. directed toward the positive-x direction, and has smaller magnitude than the electrical force acting on the positive charge.
C. directed toward the positive-x direction, and has magnitude equal to the electrical force acting on the positive charge.
D. directed toward the negative-x direction, and has greater magnitude than the electrical force acting on the positive charge.
E. directed toward the negative-x direction, and has smaller magnitude than the electrical force acting on the positive charge.
F. directed toward the negative-x direction, and has magnitude equal to the electrical force acting on the positive charge.

F is correct. The force on the negative charge is towards the positive charge at the origin. The forces on the two charges are equal by Newton's Third Law of Motion.

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2. [6 points] A 6.0-C charge is fixed at the origin. A -3.0 C charge is placed at point 2.0 m away. Determine the electric potential at this point due to the charge at the origin, and determine the electric potential energy of the system of the two charges.

Electric potential: ______________

$V = kQ/r = (9 \times 10^9)(6.0)/(2)$ V $= 27 \times 10^9$ V.

Electric potential energy: ___________________

PE $= kQ_1Q_2/r = (9 \times 10^9)(6)(-3)/(2)$ J $= -81 \times 10^9$ J

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3. [2 points] A battery is connected to a resistor; the resulting power dissipated through the resistor is P. Which of the following will result in power dissipation of $2P$?

A. Double the battery voltage and double the resistance.

B. Double the battery voltage and halve the resistance.

C. Halve the battery voltage and double the resistance.

D. Halve the battery voltage and halve the resistance.

E. Increase both the battery voltage and the resistance by a factor of 4.

$P = V^2/R$ so only (A) will double the power.

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4. A 20-V battery is connected in series to a 2-ohm resistor and a 3-ohm resistor.

(a) [2 points] What is the potential difference across the 2-ohm resistor?

The total current in the series circuit is $I = \Delta V_{\text{bat}}/R_{\text{eq}} = (20\text{ V})/(2\ \Omega + 3\ \Omega) = 4$ A.

Then the potential difference across the 2-ohm resistor is $\Delta V = IR = (4\text{ A})(2\ \Omega) = 8$ V.

(b) [2 points] What is the power dissipated by the 3-ohm resistor?

$P = I^2R = (4\text{ A})^2(3\ \Omega) = 48$ W.

(c) [2 points] What is the total power delivered by the battery?

$P = I\,\Delta V = (4\text{ A})(20\text{ V}) = 80$ W.

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5. [3 points] A straight piece of wire 3.0 m long is carrying a 4.0-A current in the negative x direction. It is in a uniform external magnetic field of magnitude 3.0 teslas directed in the positive z direction. Determine the magnitude and the direction of the magnetic force acting on this wire.

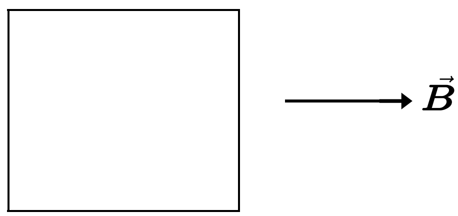
Magnitude:

$F = BIL \sin\theta = (3\text{ T})(4\text{ A})(3\text{ m}) \sin 90° = 36\text{ N}.$

Direction: $+x$ $-x$ $+y$ $-y$ $+z$ $-z$

Direction, using right-hand rule, is $+y$ direction.

A current loop of area 4.0 m^2 and resistance 6.0 Ω is placed in a uniform external magnetic field $\vec{B}$ of magnitude 3.0 T, as shown in the diagram. The loop has a current of 2.0 A in the counterclockwise direction.



6. [2 points] Determine the direction of the magnetic force on each side of the loop (top, right, bottom, and left sides).

Force on top and bottom sides will be zero (as $\theta = 0°$ or $180°$).

Force on left side is up (out of the plane of the paper) and force on the right side is down (down into the plane of the paper).

7. [2 points] Describe how this loop will tend to rotate.

The loop will tend to rotate clockwise as viewed from below in the plane of the paper.

8. [3 points] When the loop is positioned so there is no net torque acting on it, what is the magnetic flux through it due to the external magnetic field?

The external magnetic field will be perpendicular to the plane of the loop, so the magnetic field is parallel to the normal of the loop's plane, so the flux will be

$\Phi = BA \cos\theta = (3\text{ T})(4\text{ m}^2) \cos 0° = 12\text{ T} \cdot \text{m}^2.$

9. [2 points] An electromagnetic wave has its electric field in the $-y$ direction and its magnetic field in the $-z$ direction. In what direction is the wave moving?

Direction: $+x$ $-x$ $+y$ $-y$ $+z$ $-z$

By the right-hand rule, the wave must be moving in the $+x$ direction.

10. [2 points] If this wave has a frequency of 6.0 × 10^{16} Hz, what will be its wavelength (in air)?

$\lambda_{\text{air}} = c/f = (3 \times 10^8 \text{ m/s})/(6 \times 10^{16} \text{ Hz}) = 0.5 \times 10^{-8} \text{ m} = 5 \times 10^{-9} \text{ m} = 5 \text{ nm}$.

11. [2 points] If this wave passes from air into a material with an index of refraction of 2.00, what will be its wavelength in that material?

The wavelength will be the wavelength in air divided by the index of refraction, or

$\lambda = \lambda_{\text{air}}/n = (5 \text{ nm})/(2.00) = 2.5 \text{ nm}$.

12. [8 points] An object is located on the principal axis of a concave spherical mirror with radius of curvature R, at a distance $2R$ from the vertex of the mirror. Sketch a diagram to scale (choosing whatever you want for R, so it fits on the page) for this situation, showing the center of curvature and the focal point, and using at least two rays to locate the image and describe it. (You do not need to use the mirror equation to calculate the image location.) Use the line below as the principal axis, with the dot marking the vertex of the mirror.

Let's use the mirror equation to figure out what the diagram should look like. The focal length of the mirror is $f = +R/2$ (positive because it is a concave mirror).

$1/o + 1/i = 1/f$ becomes $1/2R + 1/i = 2/R$ so $1/i = 2/R - 1/2R = 1.5R = 3R/2$ and $i = 2R/3$.

Since i is positive, the image is real and inverted.