Exam 4.00
COMPREHENSIVE EXAM
8 May 2002
General Physics II (PHSX 2010)
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Multiple choice: Each question is worth 5 points.

1. How the universe ends depends upon its

<table>
<thead>
<tr>
<th>A. mass/gravity</th>
<th>B. charge/electric forces</th>
<th>C. total magnetism</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. total nuclear forces</td>
<td>E. None of these.</td>
<td>F. 42</td>
</tr>
</tbody>
</table>

2. Once in a magnetic field, an electron’s speed will:

<table>
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<tr>
<th>A. increase</th>
<th>B. decrease</th>
<th>C. remain constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. It depends on the direction the electron is moving.</td>
<td>E. It depends on the strength of the magnetic field.</td>
<td>F. 42</td>
</tr>
</tbody>
</table>

3. Forces with the greatest range will be the result of exchange particles with

<table>
<thead>
<tr>
<th>A. the greatest mass.</th>
<th>B. the least mass.</th>
<th>C. the greatest charge.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. the least charge.</td>
<td>E. the most charm.</td>
<td>F. 42</td>
</tr>
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</table>

4. In fission reactions, there are often several neutrons that are produced in addition to daughter nuclei. The production of these accounts for

<table>
<thead>
<tr>
<th>A. the conservation of some energy</th>
<th>B. the conservation of some nucleons.</th>
<th>C. the ability to produce chain reactions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. none of these</td>
<td>E. A, B, and C.</td>
<td>F. 42</td>
</tr>
</tbody>
</table>

5. If unpolarized light goes through a polarizer, by what percentage will the light’s intensity change?

<table>
<thead>
<tr>
<th>A. 0%</th>
<th>B. 10%</th>
<th>C. 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. 90%</td>
<td>E. 100%</td>
<td>F. It depends on the orientation of the polarizer.</td>
</tr>
</tbody>
</table>

6. “Quantum tunneling” is required for nuclear fusion to occur in the core of our Sun. Why can’t Adam quantum tunnel through the wall?

<table>
<thead>
<tr>
<th>A. His wavelength is too small.</th>
<th>B. His wavelength is too big.</th>
<th>C. His mass is too big.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. His mass is too small.</td>
<td>E. His charge is too big.</td>
<td>F. He just isn’t trying hard enough.</td>
</tr>
</tbody>
</table>
7. Two light bulbs of different resistance are connected in parallel to a battery. Which of the two will be the brightest?

A. The one closest to the ‘+’ side of the battery.
B. The one closest to the ‘−’ side of the battery.
C. The one with the least resistance.
D. The one with the most resistance.
E. More information is needed to answer this question.

8. Imagine that a physicist is holding a vertical spring, and from this spring hangs a bar magnet with the 'S' pole pointing down and the 'N' pole pointing up. Below the magnet is a loop of wire. As the magnet is moving upwards, away from the loop, in what direction does the magnet feel a force produced by the loop?

A. Up; opposing the motion of the magnet.
B. Down; the same direction as the motion of the magnet.
C. Left; perpendicular to the motion of the magnet.
D. Right; perpendicular to the motion of the magnet.
E. None of these.

9. The fact that electrons in the Bohr atom have quantized amounts of angular momentum (L) is due to the fact that

A. electrons are particles.
B. electrons are waves.
C. electrons have charge.
D. electrons have mass.
E. None of these.

10. You wish to store a large amount of potential energy in a bank of capacitors, each with the same capacitance for charge. How should you arrange these in a circuit?

A. A bunch of capacitors in series.
B. A bunch of capacitors in parallel.
C. Two capacitors in series.
D. Two capacitors in parallel.
E. Just one capacitor.

11. Consider a small, conducting sphere of 0.0010 kg mass. Extra electrons are placed on this sphere and on an identical sphere 3.0 m below it so the repulsion between these extra electrons provides a force equal to the weight of the top sphere. How many electrons must be added to each sphere?

A. $5.0 \times 10^{23}$
B. $1.7 \times 10^{6}$
C. $3.1 \times 10^{6}$
D. $2.0 \times 10^{13}$
E. $3.9 \times 10^{13}$

12. A lens has a focal length of +0.20 m. If an object is placed 2.00 m in front of this lens, the image will be located:

A. 0.11 m in front of the lens
B. 0.22 m behind the lens
C. 1.00 m behind the lens
D. 4.50 m behind the lens
E. 2.20 m behind the lens
Situation I
An electron has a wavelength of $5.00 \times 10^{-8}$ m.

A. What voltage ("potential difference") has the electron been accelerated through, if it was originally at rest?

\[
\frac{p}{\lambda} = \frac{\hbar}{m} \Rightarrow \lambda = \frac{\hbar}{p} = \frac{\hbar}{mv} \quad \text{so} \quad \lambda = \frac{\hbar}{mv} \quad \text{... so what?}
\]

To accelerate, conserve energy:

\[
P_E = K_E + qV
\]

\[
\frac{1}{2} mv^2
\]

\[
V = \frac{1}{2} \frac{m}{q} v^2 = \frac{1}{2} \frac{m}{q} \left( \frac{\hbar}{mv} \right)^2 = \frac{1}{2} \left( \frac{9.11 \times 10^{-31} \text{kg}}{1.6 \times 10^{-19} \text{C}} \right) \left( \frac{6.626 \times 10^{-34} \text{J s}}{9.11 \times 10^{-31} \text{kg} \times 5 \times 10^{-8} \text{m}} \right)^2
\]

\[
= 6.02 \times 10^{-4} \text{ V}
\]

B. If, instead of accelerating the electron through this voltage, you shone light on sodium metal (BE = 2.28 eV) to bump this electron off and give it the above deBroglie wavelength, what wavelength of light should you use?

\[
K_{E_{\text{max}}} = \frac{hc}{\lambda} - BE
\]

\[
\uparrow \lambda \text{ of photon, not electron}
\]

\[
\lambda = \frac{hc}{K_{E} + BE} = \frac{hc}{\frac{1}{2} m \left( \frac{\hbar}{mv} \right)^2 + BE} = 5.45 \times 10^{-7} \text{ m} = 545 \text{ nm}
\]

C. What is your favorite color, and what is its wavelength?

A variety of answers are reasonable, as long as they are well justified — 50 pages or more.
Situation II
You have created a circuit in which a light bulb is connected. The light bulb is specially designed to go underwater, in your bathtub.

A. The light bulb is located 0.080m away from the side of the tub, and 0.100m beneath the surface of the water. (The side of the tub is at the exact same height as the surface of the water.) What is the maximum angle (from "normal") at which you can still see your light bulb from outside the tub?

\[
\tan \theta_1 = \frac{0.080 \text{m}}{0.100 \text{m}} \rightarrow \theta_1 = 38.66^\circ
\]

\[
\sin \theta_1 = \frac{L}{R} = 1.33 \rightarrow \sin 38.66^\circ
\]

\[
\theta = 56.2^\circ
\]

B. The light bulb has a resistance of 2.00 ohms. What voltage needs to be applied across the light bulb if it is to emit energy at the rate of 10 watts?

\[
P = IV \rightarrow P = \frac{V^2}{R}
\]

\[
V = \sqrt{PR} = \sqrt{(10 \text{ W})(2.00 \text{ V})} = 4.47 \text{ V}
\]

C. To produce the above voltage, you connect to the circuit a 50-turn coil with an area of 0.250 m². You also (thankfully!) have a magnetic field. If you crush the coils so that their cross-sectional area drops to 0 m² in 1.00 second, what size of magnetic field is necessary to induce the necessary voltage?

\[
\Delta t = 1.00 \text{ s}, \ N = 50, \ A = 0.250 \text{ m}^2, \ B = ?, \ E = 4.47 \text{ V}
\]

\[
\vec{E} = BA \omega \hat{t}
\]

\[
\vec{E} = -N \frac{d \Phi}{dt} = -NBA \omega \Rightarrow B = -\frac{E \omega}{NA} \Rightarrow |B| = \frac{(4.47 \text{ V})(1.00 \text{ s})}{50 \times 0.250 \text{ m}^2}
\]

\[
|B| = 0.358 \text{ T}
\]
Situation III

In a nuclear reaction, 4 Hydrogen nuclei are fused to produce 1 Helium nucleus and some other products.

A. Write the equation for this reaction, including all of the above-mentioned nuclei and the non-mentioned products.

\[
4 \, ^1\text{H}_0 \longrightarrow ^2\text{He}_2 + 2 \, ^0\text{Be} + 2 \, ^0\text{e} + \gamma \text{'s}
\]

\[\text{need to conserve } Z \text{ and } \text{electron family } \#\n\]

\[\text{He's in this mass}\]

\[\text{too many } e^- \text{ in the hydrogen}\]

\[\text{compared to He on other side, } (4-2=2)\]

\[\text{2e's in this mass, canceled by } e's \text{ in } Z \, ^4\text{He}.
\]

\[
\Delta M = \frac{4 \, m (^1\text{H}) - m (2^0\text{e}^-)]}{c^2} - \frac{m (^2\text{He}) + m (2^0\text{e}^-)]}{c^2}
\]

\[
\Delta M = 4 \left(1.007825\right) 931.5 \, \text{MeV} - 4 \left(1.511 \, \text{MeV} \right) = 4.002603 (931.5 \, \text{MeV})
\]

\[
\Delta M = 24.7 \, \text{MeV} \frac{c^2}{c^2}
\]

\[
E = mc^2 = \left(24.7 \, \text{MeV} \right) c^2 = \boxed{24.7 \, \text{MeV}}
\]

B. Calculate the energy obtained from the fusion described in the above reaction. The mass of an atom of \(^4\text{He}\) is 4.002603 \(u\), and the mass of an atom of \(^1\text{H}\) is 1.007825 \(u\). (Remember that these given masses include electrons that are not considered in nuclear reactions.)

C. If all of the above energy is given to the \(^4\text{He}\) nucleus, what radius of circular path will it travel in when traveling perpendicular to a magnetic field of 2.50 \(T\)?

\[
24.7 \, \text{MeV} = (24.7 \times 10^6 \, \text{eV}) \left(1.6 \times 10^{-19} \, \text{J/ev} \right) = 3.95 \times 10^{-12} \, \text{J} \right(= KE)
\]

\[KE = \frac{1}{2} \, mv^2\]

\[v = \sqrt{\frac{2 \, KE}{m}}\]

\[F = qvB = ma = mv^2 \Rightarrow r = \frac{mv}{qB}\]

\[r = \frac{9.11 \times 10^{-31} \, \text{kg}}{1.6 \times 10^{-19} \, \text{C} \times 2.5 \, \text{T}} \sqrt{\frac{2 \, 3.95 \times 10^{-12}}{9.11 \times 10^{-31} \, \text{kg}}} \]

\[r = 0.71 \times 10^{-3} \, \text{m}\]