

Exam 4.00

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College Physics II (PHYS 2020)

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**MAKE SURE TO PUT YOUR NAME ON THE
FIRST PAGE OF THE EXAM BEFORE YOU TURN
IT IN.**

Formulae:

$$K = \frac{1}{2}mv^2, \quad p = mv$$

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

$$E_0 = mc^2$$

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} = E_0 + K$$

$$K = \frac{1}{2}mv^2, \quad p = mv, \quad E = hf, \quad c = \lambda f, \quad hf = K_{\max} + E_0, \quad \lambda = \frac{h}{p}, \quad E_n = -\frac{(13.6\text{eV})}{n^2}$$

Constants and conversions:

$$|q_e| = 1.60 \times 10^{-19} \text{ C}, \quad k = 8.99 \times 10^9 \text{ N m}^2 / \text{C}^2$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}, \quad m_e = 9.11 \times 10^{-31} \text{ kg}, \quad 1\text{eV} = 1.60 \times 10^{-19} \text{ J}$$

$$c = 3.00 \times 10^8 \text{ m/s}, \quad hc = 1240\text{eVnm}$$

Advice/Info:

- Look both ways repeatedly before crossing the street.
- Make sure your name and your seat number are in the appropriate places.
- Show your work clearly for full credit.
- Ask questions if you have them.
- Circle your answers if you want me to find them.
- All numeric values are good to at least 3 significant figures.
- Take a deep breath and have fun.
- **You should have three (3) pages in this exam, not including the cover sheet.**
- 100 points are possible.

Poetry:

Pale, pubescent beasts
Roam through the streets
And coffee-shops
Their prey gather in herds
Of stiff knee-length skirts
And white ankle-socks
But while they search for a mate
My type hibernate
In bedrooms above
Composing their songs of love

Young, uniform minds
In uniform lines
And uniform ties
Run round with trousers on fire
And signs of desire
They cannot disguise
While I try to find words
As light as the birds
That circle above
To put in my songs of love

Fate doesn't hang on a wrong or right choice
Fortune depends on the tone of your voice
So sing while you have time
Let the sun shine down from above
And fill you with songs of love

-B. Folds

Multiple choice: Each question is worth 5 points.

1. The periodic table of elements is built and organized the way it is because an atom's electrons are

A. free to have any energy and any angular momentum.	B. free to have any energy, but restricted in their angular momentums.	C. restricted to specific energies and angular momentums.
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2. Electrons are emitted from a metal surface when the metal is illuminated by light of *frequency* f . How will the kinetic energy of each electron change if *more* photons of the same frequency shine upon the metal?

A. No change in each electron's kinetic energy.	B. Each electron will have a greater kinetic energy.	C. Each electron will have a lower kinetic energy.	D. No sure prediction can be made.	E. 42
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3. Electrons are emitted from a metal surface when the metal is illuminated by light of *frequency* f . How will the kinetic energy of each electron change if this *frequency* of the light is increased, while the intensity remains constant?

A. No change in each electron's kinetic energy.	B. Each electron will have a greater kinetic energy.	C. Each electron will have a lower kinetic energy.	D. No sure prediction can be made.	E. 42
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4. Bohr found that electrons could only "orbit" an atom at very specific energy levels and with very specific angular momentums. This is a consequence of electrons being

A. waves.	B. particles.	C. charges.	D. massless.	E. clever.
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5. An electron is one of nature's least massive particles. As its speed approaches the speed of light, its momentum approaches

A. zero	B. infinity	C. a finite momentum between zero and infinity	D. 42.
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6. As a particle, an electron is infinitely small (as far as we can tell). As it travels through a narrow slit, we limit its position. Therefore, its momentum (speed and direction) as it emerges from this slit will become

A. more predictable.	B. less predictable.	C. exactly as predictable as before.	D. For the love of all things beautiful, I have <i>no idea</i> what you're talking about, and even though I am <i>certain</i> that this is <i>not</i> the right answer to circle, I'm doing so out of pure frustration and desperation.
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SITUATION I: It's all relative

A. [10 points] You bring your pet electron to lab to show all your friends. Unfortunately, as soon as you open its case, it races from one side of the room to the other at a speed of $.886c$. Fortunately, your friend on the other side of the room catches the electron. From your point of view, this was the longest amount of time you've ever been apart from your pet electron: 5.00×10^{-8} second. From the point of view of your negative electron, for how much time had it been traveling?

oops! I mistyped! .866c would have been nicer
NAME: Ben Folds

↳ proper time - time for the electron's trip

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - v^2/c^2}} \rightarrow \Delta t_0 = \Delta t \sqrt{1 - v^2/c^2}$$

$$= 5 \times 10^{-8} \text{ s} \sqrt{1 - \frac{.886^2 c^2}{c^2}}$$

$$= \boxed{2.32 \times 10^{-8} \text{ s}}$$

B. [5 points] How long is the room from your reference frame?

$$\Delta x = v \Delta t = .886 \left(3 \times 10^8 \frac{\text{m}}{\text{s}} \right) \left(5 \times 10^{-8} \text{ s} \right) = \boxed{13.3 \text{ m}}$$

C. [5 points] How long was the room from your pet electron's reference frame?

(Should be shorter. Two ways to get this...)

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}} = 13.3 \text{ m} \sqrt{1 - \frac{.886^2 c^2}{c^2}} = \boxed{6.6 \text{ m}}$$

(OR $\Delta x = v \Delta t_0 = (.886c)(2.32 \times 10^{-8} \text{ s}) = \boxed{6.17 \text{ m}}$)

D. [15 points] After this incident, you decide that you're going to go find yourself a better electron, one that doesn't move quite so fast. You find one advertised as having a deBroglie wavelength of 10.0 nm. You have a vague memory from a physics course you took long ago that this tells you something about how fast this electron is moving. What's the speed of this new electron?

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(9.11 \times 10^{-31} \text{ kg})(10 \times 10^{-9} \text{ m})} = \boxed{7.28 \times 10^5 \frac{\text{m}}{\text{s}}}$$

E. [5 points] Explain why, with this new electron, you wouldn't have had to have done as many calculations or hard thinking for parts A, B, and C. of this page.

It's moving at about $10^5 \frac{\text{m}}{\text{s}}$, which is less than $.001c$, so it isn't anywhere close to being relativistic. e.g. $\sqrt{1 - \frac{.001^2 c^2}{c^2}} \approx 1$

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SITUATION II: Lots o' particles

1. [15 points] Light of wavelength 180 nm is incident upon a metal that has a work function of 1.20 eV. What is the *speed* of the emitted electrons?

$$\frac{hc}{\lambda} = K + \Phi_0 \rightarrow K = \frac{hc}{\lambda} - \Phi_0 = \frac{1240 \text{ eV nm}}{180 \text{ nm}} - 1.20 \text{ eV}$$

$$K = (5.6889 \text{ eV}) (1.6 \times 10^{-19} \frac{\text{J}}{\text{eV}}) = 9.10 \times 10^{-19} \text{ J}$$

$$K = \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(9.10 \times 10^{-19} \text{ J})}{9.11 \times 10^{-31} \text{ kg}}}$$

$$v = 1.41 \times 10^6 \frac{\text{m}}{\text{s}}$$

2. [15 points]. Find the wavelength of the light emitted when a hydrogen atom makes a transition from the $n=3$ state to the $n=1$ state. (Show your work using conservation of energy.)

$$\Delta E = \frac{-13.6 \text{ eV}}{n_1^2} - \frac{-13.6 \text{ eV}}{n_2^2} = 12.0889 \text{ eV}$$

$n=3 \nearrow n_1^2$ $n=1 \nearrow n_2^2$

$$\frac{hc}{\lambda} = \Delta E$$

$$\lambda = \frac{hc}{\Delta E} = \frac{1240 \text{ eV nm}}{12.0889 \text{ eV}} = \boxed{103 \text{ nm}}$$