DO NOT OPEN THIS EXAM UNTIL TOLD TO DO SO.

MAKE SURE TO PUT YOUR NAME AND SEAT NUMBER ON THE FIRST PAGE OF THE EXAM BEFORE YOU TURN IT IN. EQUATIONS AND CONSTANTS CAN BE FOUND ON THE BACK OF THIS COVER PAGE.

Advice/Info:
This is not just a physics exam, it is a playful dance with the natural world to see what it will allow you to reveal. If you have learned anything these last few weeks, it should be that you – as a member of humanity – have the ability to understand the natural world. Enjoy and celebrate this ability. Show your work clearly; for this will make both Mother Nature and (more importantly) your grader happy. Ask questions if you have them. Take a deep breath. Double check that your answers have been circled and that everything is appropriately labeled. Sharpen your pencil. Inhale. Exhale. Good job. On this exam, the universe is very simple, so you can ignore things such as air resistance, resistance of conducting wires, the effects of air on the speed of light, and the gravitational field of the person sitting next to you. Have a great summer and beyond – keep in touch. **You should have five (5) pages in this exam, not including this cover sheet.** (Pages are copied front-back, so you only have 3 pieces of paper in addition to the cover sheet.) 150 points are possible. Relax. This is it. You may never have to take physics ever again (well, that depends on how you do on this exam, I guess) but you will always have to deal with physics. This exam should be a piece of cake compared to the rest of your life. Savor the experience.

Tarzan wasn't a ladies' man
He'd just come along and scoop 'em up under his arm
Like that, quick as a cat in the jungle
But Clark Kent, now there was a real gent
He would not be caught sittin' around in no
Junglescape, dumb as an ape doing nothing

Superman never made any money
For saving the world from Solomon Grundy
And sometimes I despair the world will never see
Another man like him

Hey Bob, Supe had a straight job
Even though he could have smashed through any bank
In the United States, he had the strength, but he would not
Folks said his family were all dead
Their planet crumbled but Superman, he forced himself
To carry on, forget Krypton, and keep going

Tarzan was king of the jungle and Lord over all the apes
But he could hardly string together four words: "I Tarzan, You Jane."

Sometimes when Supe was stopping crimes
I'll bet that he was tempted to just quit and turn his back
On man, join Tarzan in the forest
But he stayed in the city, and kept on changing clothes
In dirty old phonebooths till his work was through
And nothing to do but go on home

Brad Roberts

General Formulae:

$$F_{net} = ma, \quad KE = \tfrac{1}{2}mv^2, \quad a_c = \frac{v^2}{r}, \quad p = mv, \quad P = \frac{E}{t}, \quad I = \frac{P}{A}, \quad A = \pi r^2, \quad s = r\theta$$

Specific Formulae:

$$F = k\frac{q_1 q_2}{r^2}, \quad E = k\frac{Q}{r^2}, \quad E = -\frac{\Delta V}{\Delta s},$$

$$Q = CV, \quad E = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2, \quad \frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots, \quad C_P = C_1 + C_2 + C_3 + \cdots, \quad I = Q/t, \quad V = IR$$

$$P = IV, \quad R_S = R_1 + R_2 + R_3 + \cdots, \quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

$$V = \mathcal{E}\left(1 - e^{-t/RC}\right), \quad V = V_0 e^{-t/RC}$$

$$F = qvB\sin\theta, \quad F = I\ell B\sin\theta, \quad B = N\frac{\mu_0 I}{2R}, \quad \Phi = BA\cos\phi, \quad \mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3.00 \times 10^8 \frac{m}{s}, \quad I_{Avg} = c\varepsilon_0 E_0^2 = \frac{c}{\mu_0}B_0^2$$

$$d\sin\theta = \begin{cases} m\lambda \\ (m+\tfrac{1}{2})\lambda \end{cases}, \quad \theta = \frac{1.22\,\lambda}{D}, \quad I = I_0\cos^2\theta, \quad n_1\sin\theta_1 = n_2\sin\theta_2,$$

$$\sin\theta_c = n_2/n_1$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}, \quad m = -\frac{d_i}{d_o} = \frac{h_i}{h_o}, \quad \Delta phase_{total} = \Delta phase_{path} + \Delta phase_{reflection} = \begin{cases} m\lambda_n \\ (m+\tfrac{1}{2})\lambda_n \end{cases}$$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}, \quad \Delta t = \gamma\Delta t_0, \quad L = \frac{L_0}{\gamma}, \quad u = \frac{v+u'}{1+\frac{vu'}{c^2}}, \quad \lambda_{obs} = \lambda_s\sqrt{\frac{1+u/c}{1-u/c}}$$

$$p = \gamma mu, \quad E = \gamma mc^2, \quad E_0 = mc^2, \quad KE = (\gamma-1)mc^2, \quad E^2 = (pc)^2 + (mc^2)^2$$

$$E = hf, \quad KE_{e,max} = hf - BE, \quad \lambda = \frac{h}{p}, \quad (\Delta x)(\Delta p) \geq \frac{h}{4\pi}, \quad (\Delta E)(\Delta t) \geq \frac{h}{4\pi}$$

$$L_n = mv_n r_n = n\frac{h}{2\pi}, \quad r_n = \frac{n^2}{Z}a_B, \quad E_n = -\frac{Z^2}{n^2}(13.6\,eV), \quad \frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$L = \sqrt{\ell(\ell+1)}\frac{h}{2\pi}, \quad L_Z = m_\ell\frac{h}{2\pi}, \quad E = (\Delta m)c^2, \quad N = N_0 e^{-\lambda t}, \quad \lambda = \frac{.693}{t_{1/2}}$$

Constants and conversions:

$|q_e| = 1.60 \times 10^{-19}$ C, $\quad k = 8.99 \times 10^9$ N $\cong$ m^2/C^2, $\quad c = 3.00 \times 10^8$ m/s

$\mu_0 = 4\pi \times 10^{-7}$ T$\cong$m/A, $\quad \gamma_0 = 8.854 \times 10^{-12}$ C^2/(N $\cong$ m^2)

$n_{air} = 1.000$, $n_{water} = 1.333$, $n_{glass} = 1.520$, $n_{diamond} = 2.419$

$h = 6.626 \times 10^{-34}$ J $\cdot$ s, $\quad hc = 1240$ eV nm, $\quad 1\,eV = 1.602 \times 10^{-19}$ J

1 Ci $= 3.70 \times 10^{10}$ Bq

$m_{electron} = 9.11 \times 10^{-31}$ kg $= 5.485\,799 \times 10^{-4}$ u $= .511$ Mev/c^2, $\quad m_{proton} = 1.007\,276$ u

$m_{neutron} = 1.008\,665$ u, $\quad 1\,eV = 1.602 \times 10^{-19}$ J, $\quad 1\,u = 1.660\,540 \times 10^{-27}$ kg $= 931.5$ MeV/c^2

Multiple choice: Each question is worth 5 points.

1. This exam is for a course in _____.

A. Music appreciation.	**B**. Alchemy.	**C.** Cosmetology.
D. Feline anatomy.	**E.** Physics.	**F**. I never knew nor cared. I just showed up at 8:00 AM everyday for the doughnuts.

2. The universe is currently expanding. Whether or not it will continue to expand is most directly determined by the universe's

A. net charge.	**B.** total mass.	**C.** production of visible light.
D. total number of neutrinos.	**E.** average temperature.	**F.** color.

3. The wavelength of a bowling ball rolling down a bowling alley is

A. very very very small compared to most physical quantities.	**B.** very very very big compared to most physical quantities.	**C.** about the same physical size as the bowling ball itself.
D. about the same as the width of the bowling alley.	**E.** non-sensical. (There is no such thing as a wavelength for physical objects.)	**F**. 42

4. A photon has zero rest mass. Therefore it is allowed to

A. travel at the speed of light.	**B.** travel faster than the speed of light.	**C.** travel infinite distances.
D. both A & B.	**E.** both A & C.	**F**. all A, B, & C.

5. In a fission reaction, the total mass of the products must be

A. the same as the original materials.	**B**. greater than the original materials.	**C.** less than the original materials.
D. none of these	**E.** There is no way to predict this.	**F**. 42

6. If *polarized* light goes through a polarizer, to what percentage of the original intensity will the polarized light's intensity be?

A. 0 %	**B**. 10%	**C.** 50%
D. 90%	**E.** 100%	**F.** It depends on the orientation of the polarizer.

7. Adam is riding his bicycle, traveling past you at a constant speed measuring 0.750 c. When he stops his bike, he says that he was riding for exactly one hour. How long do you say that he was riding his bike?

A. Exactly one hour.	**B**. Less than one hour.	**C.** More than one hour.
D. Zero time.	**E.** More information is needed to know the answer.	**F**. 42

8. Three light bulbs of the same resistance are connected in *series* to a single battery, as shown. Which of the three will be the brightest?

A. Light bulb 'A'.	**B**. Light bulb 'B'.	**C.** Light bulb 'C'.	**D**. All three will be exactly the same brightness.	**E.** More information is needed to answer this question.

9. You push a magnet into a complete loop of wire. As a result, the wire exerts a force on the magnet that is

A. "backward," pushing away from the wire.	**B**. "forward," pulling towards the wire.	**C.** left; perpendicular to the motion of the magnet.
D. right; perpendicular to the motion of the magnet.	**E.** More information is needed; specifically the orientation of the magnet.	**F**. None of these.

10. The "Bohr atom" is a model of an atom which shows

A. how multiple electrons must obey the Pauli exclusion principle.	**B**. how electrons behaving as waves exhibit quantized energy states.	**C**. how nuclear reactions lose mass and convert this to energy.	**D**. A, B, & C are all correct.	**E.** None of these.

11. A neutral conducting sphere is placed within an electric field. Inside the conducting sphere, the electric field is

A. greater in magnitude than the field outside the sphere.	**B**. zero.	**C**. less in magnitude than the field outside the sphere (but not zero).	**D**. unable to be determined from the information given.	**E.** 42

12. Imagine that you are basking in the sun next to cool, clear lake, celebrating your summer vacation and having a much deserved and relaxing break. You look down into the water of the lake and see a fish. If you can see the fish, then you know that

A. the fish can see you.	**B**. the fish cannot see you.	**C.** the fish may or may not be able to see you – it depends on some other factor.	**D**. you're not sure whether or not that wretched fish can see you, but you're bitter that you're wasting a perfectly good relaxing moment of your summer vacation thinking about physics.	**E.** soon you will wake up from your little dream and you'll realize that you're really living a nightmare: Taking a PHSX 2020 final exam.

Situation I: *The life of an electron*

A. [10 pts.] Imagine that you shine some light on an unknown metal and electrons are detected coming off the metal. If the electrons have a deBroglie wavelength of 1.50 nm when you shine light of 650 nm on this metal, what is the binding energy of the metal?

B. [10 pts.] The electrons emitted in the previous problem (with a deBroglie wavelength of 1.50 nm) must be stopped! In order to do this, you have two parallel plates with a *constant electric field* between them measuring 0.500 V/m. What is the minimum distance required to bring these electrons to rest in between these parallel plates?

C. The parallel plates that you use in the previous problem are given their own charge by connecting them, as a capacitor, to a circuit that is shown below.

1. [5 pts.] If the charge on the capacitor is initially zero, show on the 'voltage versus time' graph how the voltage across this capacitor would change once the switch has been connect to allow current to flow in the circuit.

2. [5 pts.] Show on the circuit diagram where/how you would connect a voltmeter to measure the voltage describe in your graph.

Situation II: *The life of a photon*

A. [10 pts.] Remember that light from Situation I with a wavelength of 650 nm? In order to obtain this particular wavelength, you used a diffraction grating. How many lines (i.e., the scratches imbedded on this grating) per centimeter are on this particular diffraction grating if the first order of this 650 nm wavelength is viewed at an angle of 25.0° from the normal?

B. [10 pts.] Remember that fish that you were looking at in multiple choice question #12? You are shining your red laser pointer so that the red light (with a wavelength of 650 nm . . . hey, what a coincidence!) hits the fish. From the fish's perspective, the laser beam is coming down through the water at an angle of 60.0° below the surface of the water. At what angle (as measured from the "normal", perpendicular to the surface of the water) does your laser beam point in air?

C. [10 pts.] You turn around and come face-to-face with . . .yourself! You (a very handsome individual standing at 1.50 m tall) are looking at "you" in a converging mirror that is 2.00 m away. Your image is right-side-up and appears to be twice as tall as you are in reality. What is the focal length of this mirror?

A. [10 pts.] A Plutonium nucleus ('Pu', A = 239, Z = 94) alpha decays into Uranium. Write the equation for this reaction, including all of the above-mentioned nuclei and any other products and their values for 'A' (total number of nucleons) and 'Z' (total charge).

B. [10 pts.] Calculate the energy released from above reaction. Some atomic masses that might be useful to you are listed.

Helium-4	4.002603 u
Plutonium-239	239.052157 u
Uranium-235	235.043924 u
Uranium-238	238.050784 u
Hydrogen-1	1.007825 u

C. [10 pts.] Let's say your alpha particle (Z = 2), with a mass of 6.68×10^{-27} kg, is traveling through a magnetic field. If the velocity of this alpha particle is 4.00×10^5 m/s, what is the minimum magnetic field required for this alpha particle to navigate a circular path whose radius is 1.99×10^{-4} m? (Round your answer to 3 significant figures for full credit.)