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:
Just in case 4 exams did not give you enough advice, here it is again:
• Show your work clearly.
• Ask questions if you have them.
• Breathe deeply.
• Double check that your answers have been circled and that everything is appropriately labeled.
• 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.)
• This exam should be a piece of cake compared to the rest of your life. Savor the experience.

Being but men, we walked into the trees
Afraid, letting our syllables be soft
For fear of waking the rooks,
For fear of coming
Noiselessly into a world of wings and cries.

If we were children we might climb,
Catch the rooks sleeping, and break no twig,
And, after the soft ascent,
Thrust out our heads above the branches
To wonder at the unfailing stars.

Out of confusion, as the way is,
And the wonder, that man knows,
Out of the chaos would come bliss.

That, then, is loveliness, we said,
Children in wonder watching the stars,
Is the aim and the end.

Being but men, we walked into the trees.

Dylan Thomas
Formulae:

\[ F_{net} = ma, \quad w = mg, \quad a_c = \frac{v^2}{r}, \quad K = \frac{1}{2}mv^2, \quad p = mv, \quad P = \frac{E}{t}, \quad E_0 = m_0c^2 \]

\[ F_e = k \frac{q_1q_2}{r^2}, \quad \vec{E} = \frac{\vec{F}}{q}, \quad E = k \frac{q}{r^2}, \quad E = -\frac{\Delta V}{\Delta s}, \quad \Delta U = q\Delta V, \quad V = \frac{kq}{r} \]

\[ C = \frac{Q}{V}, \quad C = \frac{\varepsilon_0 A}{d}, \quad U = \frac{1}{2}QV \]

\[ V = IR, \quad P = IV, \quad R_{eq} = R_1 + R_2 + R_3 + \ldots, \quad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots, \quad V = IR, \quad P = IV \]

\[ F = qvB\sin\theta, \quad F = I\ell B\sin\theta, \quad B = \frac{\mu_0I}{2\pi r}, \quad B = \frac{N\mu_0I}{2R}, \quad B = \frac{N}{L}I \]

\[ \Phi = BA\cos\phi, \quad E = -N \frac{\Delta \Phi}{\Delta t}, \quad E = NAB\omega \sin\omega t, \quad \frac{V_p}{V} = \frac{N_p}{N} = \frac{I_s}{I_p} \]

\[ f = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}, \quad c = f\lambda, \quad E = cB, \quad I = I_0\cos^2\theta \]

\[ n_1\sin\theta_1 = n_2\sin\theta_2 \]

\[ m = \frac{d}{d_0}, \quad d\sin\theta = m\lambda, \quad W\sin\theta = m\lambda, \quad \Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ \Delta s = \frac{\Delta s_0}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad \Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ \lambda = \frac{\hbar}{p}, \quad p = \frac{m_0v}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ E_n = nhf, \quad E = hf, \quad c = \lambda f, \quad K_{\text{max}} = hf - W_0, \quad p = \frac{h}{\lambda}, \quad \lambda = \frac{h}{p} \]

\[ \Delta p, \Delta y \geq \frac{\hbar}{2\pi}, \quad \Delta E\Delta t \geq \frac{\hbar}{2\pi}, \quad \frac{1}{\lambda} = R \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right), \quad E_n = -(13.6\text{eV}) \frac{Z^2}{n^2} \]

\[ N = N_0e^{-\lambda t}, \quad R = \frac{\Delta N}{\Delta t} = \Delta \lambda = R_0e^{-\lambda t}, \quad T_\frac{1}{2} = \frac{\ln 2}{\lambda} \]

Constants and conversions:

\[ e_0 = 8.85 \times 10^{-12} \text{ F/m}, \quad \mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m} / \text{A}, \quad k = 8.99 \times 10^9 \text{ N} \text{ m}^2 / \text{C}^2, \quad |e| = 1.60 \times 10^{-19} \text{ C} \]

\[ h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}, \quad \text{eV} = 1.60 \times 10^{-19} \text{ J}, \quad c = 3.00 \times 10^8 \text{ m/s} \]

1 Ci = 3.70 \times 10^{10} \text{ decays/second}

m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg} = 5.486 \times 10^{-4} \text{ u} = .511 \text{ MeV/c}^2

m_{\text{proton}} = 1.007 276 \text{ u}, \quad m_{\text{neutron}} = 1.008 665 \text{ u} \]

1 u = 1.660 540 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV/c}^2
Multiple choice: Each question is worth 5 points. Circle the answer that is most correct.

1. My physics teacher’s name is

2. If you were to be a theoretical particle physicist, you would search for particles that are responsible for transmitting forces between two bodies. A force such as gravity reaches out infinite distances. The particle responsible for transmitting such a force should be
   A. infinite in mass.   B. finite in mass.   C. zero mass.

3. An electron has which of the following properties?
   A. wavelength   B. charge   C. mass
   D. charge AND mass   E. wavelength AND charge AND mass
   F. none of these

4. Neutrinos are small, chargeless particles created in nuclear reactions. It was recently determined that these objects must have some mass to them. Evidence for this would be that
   A. neutrinos travel slower than the speed of light.   B. neutrinos travel at exactly the speed of light.
   C. neutrinos travel faster than the speed of light.
   D. both A & B.   E. both A & C.
   F. both B & C.

5. Once in a magnetic field, an electron’s speed will:
   A. increase   B. decrease   C. remain constant
   D. It depends on the direction the electron is moving.   E. It depends on the strength of the magnetic field.
   F. 42

6. If unpolarized 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. A spherical conductor is given a net positive charge. The electric field inside this conductor will be

| A. positive. | B. zero. | C. negative. |
| D. More information is needed to answer this question. | E. Less information is needed to answer this question. | 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. For the above question, when will the loop of wire conduct a current?

| A. whenever the magnet is moving. | B. whenever the magnet is motionless. | C. whenever the magnet is creating a flux through the loop. | D. A, B, & C are all correct. | E. None of these. |

11. Imagine an object that is farther from a converging lens than the focal point. Which of the following accurately describe the image?

| A. real & upright | B. real & inverted | C. virtual & upright |
| D. virtual & inverted | E. More information is needed. | F. None of these. |

12. A ray of light in air (n=1.00) enters water (n=1.33) at an angle of 30.0° from the surface of the water. The ray refracts so that when in the water its angle from the normal is

| A. 60.0° | B. 30.0° | C. 22.1° |
| D. 40.6° | E. 41.7° | F. None of these. |
Situation I: The life of an electron (in and out of circuits)
A. [15 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 work function of the metal?

B. [10 pts.] Considering the electrons in the above problem, calculate their kinetic energy and use this to calculate the electric potential (“voltage”) necessary to stop them.

C. [15 pts.] In lab, you enjoyed drawing electric field maps. Draw an electric field between two parallel plates, and calculate this constant electric field if the plates are separated by 0.100 m and the voltage you calculate above.
Situation II: The life of a photon

A. [10 pts.] You need to light a light bulb. You need this bulb to emit light at a rate of 40.0 W when it has 120 V of electric potential across it. What is the resistance of this light bulb?

B. [5 pts.] After this exam, you go to a restroom to wash all of the sweat and tears from your face. You look in the mirror, and to your horror you see that you look smaller than you did when you started the physics exam. (Physics tests do this to people, apparently.) You realize that you are looking into a diverging mirror. Draw a ray diagram with at least two rays that clearly shows where your image will be seen. (Hint: The focal point is inside the mirror.)

C. [10 pts.] If the focal length of this mirror is -0.500m and you are standing a distance of 1.00m away from the mirror, what is your magnification?
Situation III: The (half)life of a subatomic particle

A. [10 pts.] A muon is a subatomic particle that is produced when cosmic rays interact with Earth’s atmosphere, about 5,000 m above the ground. A muon can travel this distance at a rate of 0.995c. What is the minimum time, from the muon’s frame of reference, that the muon must travel in order to reach the ground?

B. [10 pts.] Calculate the binding energy of a $^4\text{He}$ nucleus ($Z = 2$). This element’s atomic mass is listed in the appendix of your text and in the CRC handbook to be 4.002 603 u. Some other atomic masses that might be useful to you are listed on your cover sheet.

C. [5 pts.] One example of beta decay is the following:

$$^{98}_{41}\text{Nb} \rightarrow ^{A}_{Z}\text{Mo} + \beta^- + \nu$$

Even though you probably don’t know what Nb and Mo are, you can still make several predictions. How many electrons should a neutral Mo atom have?