Early Booklet E.C.:	**+ 1**
Unit 6 Hwk. Pts.:	**/ 46**
Unit 6 Lab Pts.:	**/ 16**
Late, Incomplete, No Work, No Units **Fees**?	Y / N

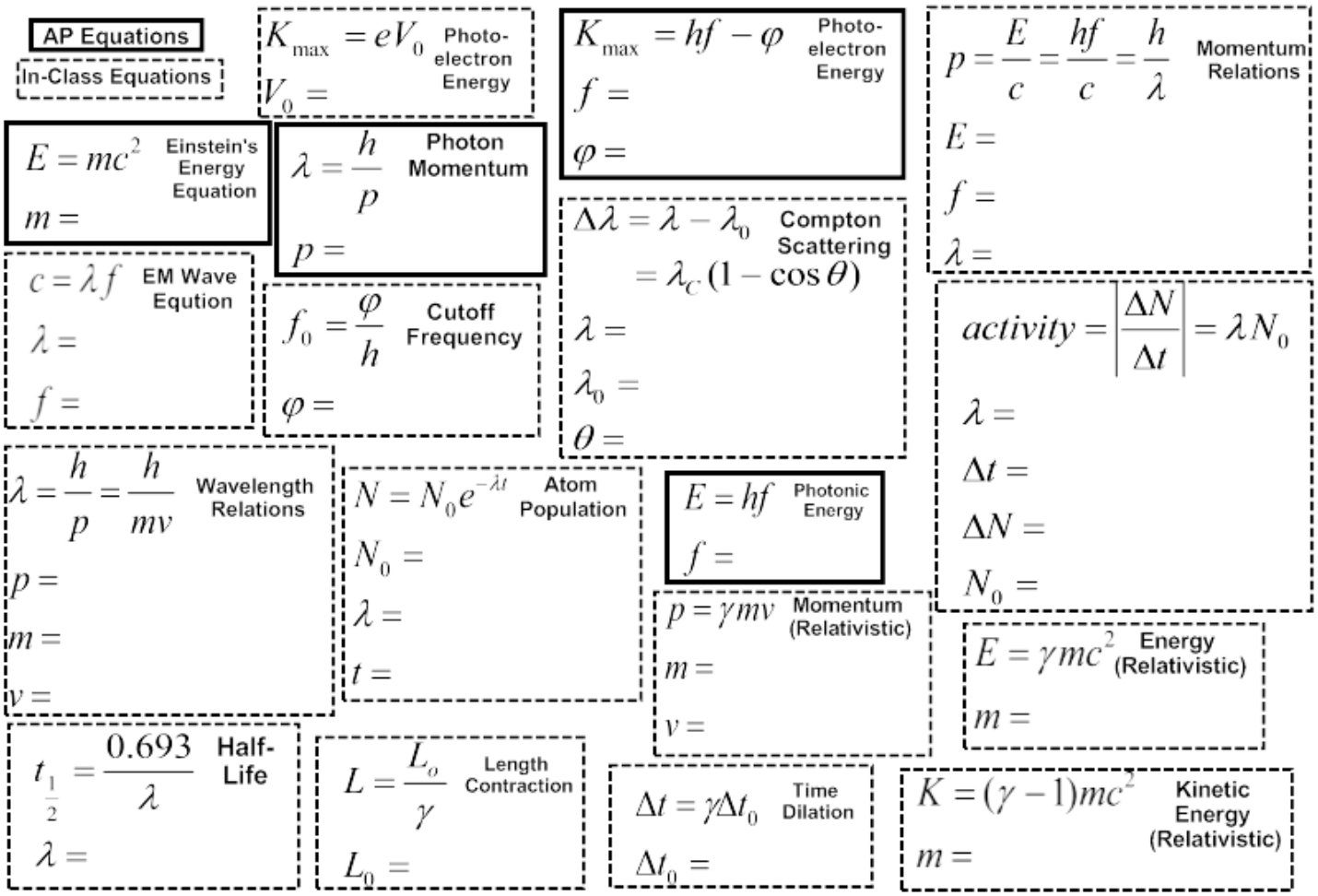
Unit 6 – Modern Physics

Essential Fundamentals of Modern Physics

1. A photon's energy depends on its frequency.
2. Light intensity is a measure of the number of photons reaching a target, not the energy per photon.
3. Below a certain energy, photoelectrons will not be ejected from a metal's surface, regardless of how intense the light source.
4. An element is defined by its number of protons.
5. Electrons are negative, protons are positive, and neutrons carry no charge.
6. Fusion involves joining nuclei, and fission involves splitting them.
7. To jump from one energy level to another, electrons require a specific quantum of energy.
8. Half-life is the amount of time a radioactive material takes to decay to half its original amount.
9. Photons of light have a characteristic momentum.

Equation Sandbox

In Unit 6, some of the following equations will be used. Practice isolating variables to prepare for it.



Possible 6.1 Pts.: 8
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 8

6.1 Problems – Quantum Physics: The Photoelectric Effect
Section 27.2 of your textbook.

1. Each photon in a beam of light has an energy of 6.50×10^{-19} J. What is the light's wavelength? What type of light is this?

2. A. Compared with a quantum of red light (λ = 700 nm), a quantum of violet light (λ = 400 nm) has (1) more, (2) the same amount, (3) less energy. Why?

   B. Determine the ratio of the photon energy associated with the violet light to that related to red light.

3. A source of UV light has a wavelength of 150 nm. How much energy does one of its photons have expressed in (a) joules an (b) electron-volts?

4. The photoelectrons ejected from a surface require a stopping potential of 5.0 V. if the intensity of the light is tripled, what is the stopping voltage?

5. What is the longest wavelength of light that can cause the release of electrons from a metal that has a work function of 3.50 eV?

6. The work function of a material is 3.5 eV. If the material is illuminated with monochromatic light (λ = 300 nm), what are
   A. the stopping potential and

   B. the cutoff frequency?

Possible 6.2 Pts.: 4
Late, Incomplete, No work, No Units Fee: - 1 - 2
Final Score: / 4

6.2 Problems – The Compton Effect
Section 27.3 of your textbook.

1. What is half the maximum wavelength shift for Compton scattering from a free electron?

2. When the wavelength shift for Compton scattering from a free electron is a maximum, what is the scattering angle? What is the wavelength shift at that angle?

3. What is the change in wavelength when monochromatic X-rays are scattered by electrons through an angle of 30˚?

4. A monochromatic beam of X-rays with a wavelength of 0.280 nm is scattered by a metal foil. If the scattered foil beam has a wavelength of 0.281 nm, what is the observed scattering angle?

Possible 6.3 Pts.: 7
Late, Incomplete, No work, No Units Fee: - 1 - 2
Final Score: / 7

6.3 Problems – Atomic Physics
Section 27.4 of your textbook.

1. Find the energy of a hydrogen atom whose electron is in the
   A. n = 2 state

   B. n = 3 state.

2. Scientists are now beginning to study "large" atoms, that is, atoms with orbits that are almost large enough to be measured in our everyday units of measure. For what excited state (give an approximate principal quantum number) of a hydrogen atom would the diameter of the orbit be in the order of (10^{-5} m)-That is, close to the diameter of a human hair?

3. Find the binding energy of the hydrogen electron for states with the following principal quantum numbers:
   A. n = 5

   B. n = 7.

4. A hydrogen atom in its ground state is excited to the n = 5 level. It then makes a transition directly to the n = 2 level before returning to the ground state.
   A. What are the wavelengths of the emitted photons?

   B. Would any of the emitted light be in the visible region?

Possible 6.4 Pts.: 6
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 6

6.4 Problems – Wave/Particle Duality
Section 28.1 of your textbook.

1. What is the de Broglie wavelength associated with a 1000-kg car moving at 25 m/s?

2. If the de Broglie wavelength associated with an electron is 7.50×10^{-7} m, what is the electron's speed?

3. An electron and a proton are moving with the same speed.
   A. Compared with the proton, will the electron have (1) a shorter, (2) equal, or (3) a longer de Broglie wavelength? Why?

   B. If the speed of the electron and proton is 100 m/s, what are their de Broglie wavelengths?

4. An electron is accelerated from rest through a potential difference of 100 V. What is the de Broglie wavelength of the electron?

5. A scientist wants to use an electron microscope to observe details on the order of 0.25 nm. Through what potential difference (voltage) must the electrons be accelerated from rest so that they have a de Broglie wavelength of this magnitude?

Possible 6.5 Pts.: 9
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 9

6.5 Problems – Nuclear Decay
Section 29.1 – 29.2 of your textbook.

1. Determine the number of protons, neutrons, and electrons in a neutral atom with the following nuclei:
   A. ^{90}Zr B. ^{208}Pb

2. Complete the following nuclear decay equations by filling in the blanks:

   A. $^{8}_{4}Be \rightarrow \_\_ + {}^{4}_{2}He$

   B. $^{240}_{94}Pu \rightarrow \_\_ + {}^{139}_{56}\_\_ + 2({}^{1}_{0}n)$

   C. $\_\_ \rightarrow {}^{47}_{21}Sc + \gamma$

   D. $^{22}_{11}Na \rightarrow \_\_ + {}^{22}_{10}\_\_$

3. A sample of Fluorine-18 undergoes positron emission. Write the nuclear decay reaction for this process.

4. Beryllium-7 undergoes electron capture as it decays. Write the nuclear reaction for this process.

5. In a hypothetical fission reaction of Plutonium-244, two neutrons and two daughter products are produced.
   A. If the daughter products don't have fewer than 45 protons, which elements could form?

   B. Write one possible nuclear fission reaction of Pu-244.

Possible 6.6 Pts.: 6
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 6

6.6 Problems – Half-Lives and Stability
Section 29.3 – 29.4 of your textbook.

1. A particular radioactive sample undergoes 2.50 E 6 decays/s. compute the activity of the sample in
   A. becquerels

   B. curies

2. At present, a radioactive beta source with a long half-life has an activity of 20 mCi.
   A. What is the present decay rate in decays per second?

   B. Assuming that one beta particle is emitted per decay, how many are currently emitted per minute?

3. A 1.25μCi alpha source gives off alpha particles each with a kinetic energy of 2.78 MeV. At what rate (in watts) is kinetic energy being produced?

4. A sample of technetium-104, with a half-life of 18.0 minutes, has an initial activity of 10.0 mCi. Determine the activity of the sample after exactly 1 hour has elapsed.

Possible 6.7 Pts.: 6
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 6

6.7 Problems – Mass-Energy Equivalence
Section 26.4 of your textbook.

1. An electron travels at a speed of 0.600c.
   A. What is its kinetic energy?

   B. What is its total energy?

2. A. How much energy (expressed in keV) is required to accelerate an electron from rest to 0.50c?

   B. How much total energy would it have at that speed?

   C. What would be its momentum?

3. An average home uses about 1.5 E 4 kWh of electricity per year. How much matter would have to be converted to energy (assuming 33% efficiency) to supply energy for 1 year to a city with 250,000 such homes?

AP Physics 2	Unit 6.1 Lab - Nuclear Decay	
Reminder: Update Table of Contents		Correction Credit: Half

Lab Overview:

The entire class will use the same probability set to graph the decay of a parent isotope into a primary unstable daughter isotope, then secondary stable daughter isotope.

Nuclear Decay Lab (6.1) Guide		
Table of Contents, Title/Date, Complete Synopsis, Two Purposes, Legible		/ 2
Mission 1: Data Table	Organized, Labeled	/ 2
	25 time values	/ 2
Analysis 1: Graph	Titled, Labeled	/ 2
	Three Series	/ 3
Analysis 2: Half-life of parent.		/ 3
Question 1: Graph comparison		/ 2
Work Not Shown Fee:		-1 -2 -3
Late Lab Fee:		-3
Total:		**/ 16**

Materials List:

Dice Atom modeling set

Mission 1: Radioactive decay

As a class, we will roll the dice for 25 time increments, which should a sample set that works. Record values of parent, primary daughter, and stable daughter isotopes for each throw in a well-organized data table.

Analysis: Answer these completely in your Lab Books

1. Graph the three isotopes vs. time. While a graphing program (like Excel) is recommended, you can produce a hand-made graph.
   Be sure to have a graph title, label the axes, and have three series of data (one for each isotope).

2. Determine the average half-life of the parent isotope, showing your work.

Questions: Rephrase and answer each in at least three complete sentences for full credit.

1. How do the three series compare?

AP Physics 2	Unit 6 - Modern Physics				
Application Problems, AP Test Preparation Questions					
Presentation Points:	/ 5	Late Fee:	-2	Completion (Booklet Check)	/ 5

Your grade on this problem set depends on the presentation you provide for your assigned problems, and whether **all** problems are complete when you submit your Booklet at the end of the Unit.

Application Problems

1. Polonium-214 can undergo alpha decay.
   A. The product of its decay has how many fewer protons than polonium-214: (A) zero, (B) one, (C) two, or (D) four? Explain how you got your value.

   B. Determine the daughter isotope and write the nuclear equation for this decay.

2. Write the nuclear equations for:
   A. the beta decay of ^{60}Co

   B. the alpha decay of ^{222}Rn

   C. the electron capture of ^{230}Ra

   D. the γ decay of ^{42}K from an excited nuclear state to the ground state (not excited).

3. An isotope of potassium has the same number of neutrons as argon-40. Write this potassium isotope in both mass number and isotope notation.

4. Only two isotopes of Sb (antimony, Z = 51 (Z = atomic number)) are stable. Pick the two most likely stable isotopes listed, and explain your rationale:
   (a) ^{120}Sb (b) ^{121}Sb (c) ^{122}Sb (d) ^{123}Sb (e) ^{124}Sb.

5. A 15.50 g sample of radioactive material decays for 12.5 hours, and at the end of that time 15.49 g remain.
   A. What is the half-life of the isotope?

   B. What was the activity (in Bq) of the sample at t = 0 hours?

   C. What is the activity (in Bq) at t = 12.5 hours?

   D. How much sample will remain after 30 days?

   E. If each decay releases 1.2 keV of energy, how much energy on average was released during the 12.5 hours?

AP Multiple Choice Questions

1. The single electron in an atom has an energy of -40 eV when it's on the ground state, and the first excited state for the electron is at -10 eV. What will happen to this electron if the atom is struck by a stream of photons, each of energy 15 eV?
   A. The electron will absorb the energy of one photon and become excited halfway to the first excited state, then quickly return to the ground state, without emitting a photon.

   B. The electron will absorb the energy of one photon and become excited halfway to the first excited state, then quickly return to the ground state, emitting a 15 eV photon in the process.

   C. The electron will absorb the energy of one photon and become excited halfway to the first excited state, then quickly absorb the energy of another photon to reach the first excited state.

   D. The electron will absorb two photons and be excited to the first excited state.

   E. Nothing will happen.

2. A metal whose work function is 6.0 eV is struck with light of frequency 7.2 x 10^{15} Hz. What is the maximum kinetic energy of photoelectrons ejected from the metal's surface?

A. 7 eV B. 13 eV C. 19 eV D. 24 eV E. No photoelectrons will be produced.

3. What is the de Broglie wavelength of a proton whose linear momentum has a magnitude of 3.3 x 10^{-23} kg•m /s?

A. 0.0002 nm B. 0.002 nm C. 0.02 nm D. 0.2 nm E. 2 nm

4. A partial energy-level diagram for an atom is shown below. What photon energies could this atom emit if it begins in the *n* = 3 state?

-3 eV _____ n = 4
-5 eV _____ n = 3
-8 eV _____ n = 2
-12 eV _____ n = 1 ground state

A. 5 eV only B. 7 eV only C. 3 eV or 7 eV only D. 2 eV, 3 eV, or 7 eV
E. 3 eV, 4 eV, or 7 eV

5. What's the missing particle in this nuclear reaction? $^{2}_{1}H + ^{63}_{29}Cu \rightarrow ^{64}_{30}Zn + \_\_\_\_$

A. Proton B. Neutron C. Electron
D. Positron E. Deuteron

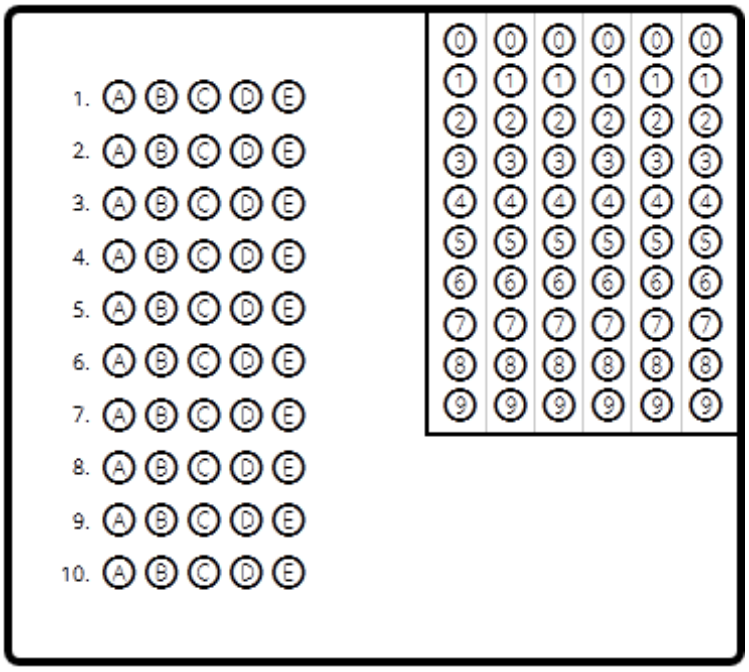
6. What's the missing particle in this nuclear reaction? $^{196}_{78}Pt + ^{1}_{0}n \rightarrow ^{197}_{78}Pt + \_\_\_\_$

A. Proton B. Neutron C. Electron
D. Positron E. Gamma

AP Physics 2		Unit 6 Review - Modern Physics					
Points:	/ 20	Late or Incomplete Fee:	-2 -4 -6	Correction Credit:		Final Score:	

Solve these problems here, THEN enter your responses in the bubble sheet provided.

Each question is worth two points.



1. What's the energy of a photon whose wavelength is 2.07 nm?

A. 60 eV B. 600 eV C. 960 eV
D. 6000 eV E. 9600 eV

2. How would a photon's energy change if its wavelength were reduced by a factor of 2?

A. It would decrease by a factor of 4.
B. It would decrease by a factor of 2.
C. It would increase by a factor of 2.
D. It would increase by a factor of 4.
E. It would increase by a factor of 2*h*.

3. Electrons are emitted from a surface when light of wavelength 500 nm is shone on the surface but electrons are not emitted for longer wavelengths of light. The work function of the surface is

A. 4.0 eV B. 0.40 eV C. 0.60 eV D. 5.0 eV E. 2.5 eV

4. In a particular case of Compton scattering, a photon collides with a free electron and scatters backwards. The wavelength after the collision is exactly double the wavelength before the collision. What is the wavelength of the incident photon?

A. 4.8 E -12 m B. 6.0 E -12 m C. 1.2 E -12 m D. 2.4 E -12 m E. 3.6 E -12 m

5. Consider an atom with four accessible energy levels. What is the maximum number of different wavelengths that could be emitted by such an atom?

A. 5 B. 7 C. 8 D. 4 E. 6

6. An atom with one electron has an ionization energy of 25 eV. How much energy will be released when the electron makes the transition from and excited energy level, where E = -16 eV, to the ground state?

A. 9 eV B. 11 eV C. 16 eV D. 25 eV E. 41 eV

7. What is the momentum of a 600. nm photon?

A. 0.28 eV/c B. 2.58 eV/c C. 3.25 eV/c D. 1.17 eV/c E. 2.07 eV/c

8. The de Broglie wavelength of an electron is 380 nm. What is the speed of this electron?

A. 3.83 E 3m/s B. 1.92 E 3m/s C. 4.12 E 3m/s D. 2.04 E 3m/s E. 5.22 E 3m/s

9. A radioactive substance with a half-life of 3 days has an initial activity of 0.24 Ci. What is its activity after 6 days?

A. 0.06 Ci B. 0.12 Ci C. 0.02 Ci D. 0.48 Ci E. 0.23 Ci

10. What is the missing term in this fission reaction:

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}n = {}^{99}_{41}\mathrm{Nb} + \_\_\_\_ + 4\,{}^{1}_{0}n$$

A. $^{139}_{51}\mathrm{Sb}$ B. $^{133}_{47}\mathrm{Ag}$ C. $^{133}_{51}\mathrm{Sb}$ D. $^{136}_{51}\mathrm{Sb}$ E. $^{136}_{47}\mathrm{Ag}$