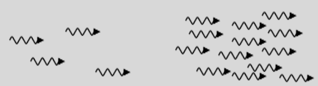
Modern Physics Review Checklist

Photoelectric Effect and Particle Nature of Light

6.1.1A – Explain the discrepancies between the Classical Wave Model of Light and the Photoelectric Effect. Explain how this leads to the Particle Model of Light. ☐

The table below shows predictions for the Photoelectric Effect based on the Wave Model vs. Actual Experimental Results. Explain how the Actual Experimental Results contributes to the Particle Model of Light

Classical Wave Model Prediction	Actual Experimental Result Supporting Particle Model
Increasing intensity of light means increasing amplitude of the "light waves". This means that higher intensity light should give us the same number of more energetic electrons.  Low Intensity High Intensity Stopping voltage should be proportional to light intensity.	Increasing intensity increases the number of electrons produced per second – the current increases and is proportional to intensity.  Low Intensity High Intensity
Changing the frequency of the "light wave" means increasing the number of waves that arrive per second. This means that we should get more electrons ejected every second.  Low Freq. High Freq. Number of electrons (current) should be proportional to the frequency of light hitting the plate.	Changing frequencies effects whether or not the plate produces electrons at all – some frequencies work, others do not.  Low Freq. High Freq.

The results of the photoelectric effect indicate the particle nature of light because using photons as a model for light rather than the wave model accounts for the results of the experiment

6.1.1B – Define the term "photon" and use equation to calculate: photon energy; frequency; or wavelength. Determine photon "types" using the EM Spectrum. ☐

What is the energy of a photon that is traveling through space with a wavelength of 2.5×10^{-10} meter?

7.96×10^{-16} J

What is the frequency of a photon with 6.5×10^{-25} joules of energy? What type of photon is this?

9.8×10^{8} Hz - radio

Energy/Mass Duality

6.1.1C – Use equation to determine the amount of energy contained in a given quantitiy of mass. ☐

How much energy (in joules) is contained in 3.0 kilograms of matter?

2.7×10^{17} J

What is the mass equivalent of 2 mega-joules of energy?

2.2×10^{-11} kg

6.1.1D – Convert from universal mass units to MeV. ☐

A proton has a mass of 1.67×10^{-27} kilograms. Determine the amount of energy (in joules) that this mass represents. Convert this energy to electron-volts.

1.50×10^{-10} J = 9.39×10^{8} eV

Confirm that the proton's equivalent mass is close to one universal mass unit (u), given the conversion factor: 1 u = 9.31×10^{2} MeV.

9.39×10^{8} eV = 9.39×10^{2} MeV
the 'missing' energy is binding energy

Atomic Energy Levels

6.1.2A – Determine ionization energies and kinetic energies of liberated electrons. ☐

What energy is needed to liberate an electron from the C-level of a mercury atom?

5.52 eV

A hydrogen atom with an electron in the n=3 level is hit with a photon with an energy of 2.5 electron-volts. What kinetic energy will the electron have as it leaves the atom?

0.99 eV

6.1.2B – Use equation to determine either: the energy needed to move an electron to a higher energy level; or the energy emitted when an electron drops to a lower energy level. Perform conversions from eV to joules and joules to eV. Use photon equation to determine photon types. ☐

A photon strikes an electron in the ground state of a hydrogen atom, moving it to the n=4 energy level. What energy must this photon have had? What was this photon's frequency? What type of photon must this have been?

12.75 eV → 3.08 x 10^{15} Hz → UV

An electron in the n=3 level of a hydrogen atom drops to the n=2 level and emits a photon in the process. What energy will this photon have? What type of photon will be emitted?

1.89 eV → 4.56 x 10^{14} Hz → visible light (red)

6.1.2C – Determine possible numbers of photons produced during transitions between levels. ☐

An electron in the n=4 level of hydrogen moves to the n=2 level. How many different photons could be emitted by the atom during this transition?

3

An electron in the D-level of a mercury atom drops to the atom's ground-state. Determine the number of potential photons that the atom could emit during this transition.

6

6.1.2D – Explain the existence of bright line and absorption spectrums. ☐

Explain how the particle model of light and the quantized model of the atom give rise to the bright-line spectrum phenomenon.

The hot gas has lots of electrons dropping to lower energies – when they do so the atoms emit VERY specific energies and thus photons with VERY specific frequencies. Each element only produces a certain set of frequencies.

Explain how the particle model of light and the quantized model of the atom give rise to the absorption spectrum phenomenon.

The atoms in the cold gas absorb ONLY photons with VERY specific energies and thus photons with VERY specific frequencies. Each element only absorbs a certain set of frequencies.

Explain why the bright-line and absorption spectrums are similar to photographic negatives of one another.

The transition energies are the same for emission and absorption – it just depends on what the atoms is doing more of.

Standard Model

6.1.3A – Describe the classification of matter into hadrons (baryons and mesons) and leptons.

Classify the following as either: lepton, anti-lepton, baryon, anti-baryon, or meson. If there is not enough information to tell, state "unable to determine".

(1) A particle made up of three qua
(2) A particle with no charge
(3) An electron
(4) A neutron
(5) A particle composed of an up q
(6) A particle composed of three ar
(7) A muon-neutrino.
(8) A particle with a charge of +1.
(9) An anti-electron

(1) baryon
(2) unable to determine
(3) lepton
(4) baryon
(5) meson
(6) anti-baryon
(7) lepton
(8) unable to determine
(9) anti-lepton

6.1.3B –Determine the charge on hadrons.

A particle is composed of one up quark and two down quarks. What is the charge on this particle?

0e (it's actually a neutron)

What is the charge on a particle that is composed of a down quark and an anti-up quark?

-1

6.1.3C – Explain the relationship between matter and anti-matter

A hydrogen atom consists of a proton and an electron. An anti-hydrogen atom consists of an anti-proton and an anti-electron (positron). Explain the differences and similarities between hydrogen and anti-hydrogen in terms of mass and charge.

They would have the same mass, but opposite charge

A proton is constructed using the quark configuration *uud*. Confirm that this produces a charge of +1. An anti-proton is built using the quark configuration $\overline{uud}$. Confirm that this configuration has the opposite charge of the proton.

uud → 2/3 + 2/3 + -1/3 = +1

$\overline{uud}$ → -2/3 + -2/3 + 1/3 = -1

6.1.3D – Describe the fundamental forces of nature.

What is the function of the strong nuclear force?

Holds nuclei together

What fundamental force is involved in the phenomenon of beta decay?

Weak Nuclear Force

Which fundamental force is still unexplained by the current Standard Model?

Gravity

Which fundamental force is involved in keeping electrons and protons together in their atomic structures?

Electromagnetism

6.1.3E – Explain the phenomenon of beta-decay.

During beta decay, a neutron is turned into a proton. Explain why the Law of Conservation of Charge requires that an equivalent negative charge (in the form of an electron) be created at the same time.

Neutron has zero charge

During beta decay, a neutron is turned into a proton as its quark configuration is altered from udd to uud. Explain how this change in quarks produces the change in charge from 0 to +1.

udd = 0 udd = +1

During beta decay, a neutron is turned into a proton and an electron. However, the combined mass of the electron and proton is less than that of the neutron. What conclusions can be drawn from this?

Neutrons are slightly more massive than protons.