Student #: ____________________________ Student Name: ___________________________________

TOPIC 16: MODERN PHYSICS

1. Two blocks of different sizes and masses float in a tray of water. Each block is half submerged, as shown in the figure. Water has a density of $1000\,\mathrm{kg/m^3}$. What can be concluded about the densities of the two blocks?

$n = 4$	———————	
$n = 3$	———————	-6.04 eV
$n = 2$	———————	-13.6 eV
$n = 2$	———————	-54.4 eV

Note: Energy levels not drawn to scale.

2. The diagram above shows the lowest four discrete energy levels of an atom. An electron in the $n = 4$ state makes a transition to the $n = 2$ state, emitting a photon of wavelength 121.9 nm.

   (a) Calculate the energy level of the $n = 4$ state.

   (b) Calculate the momentum of the photon.

   The photon is then incident on a silver surface in a photoelectric experiment, and the surface emits an electron with maximum possible kinetic energy. The work function of silver is 4.7 eV.

   (c) Calculate the kinetic energy, in eV, of the emitted electron.

   (d) Determine the stopping potential for the emitted electron.

3. The momentum of a particular proton is 5.5×10^{-20} kg · m/s. Relativistic effects can be ignored throughout this question.

   (a) Calculate the de Broglie wavelength of the proton.

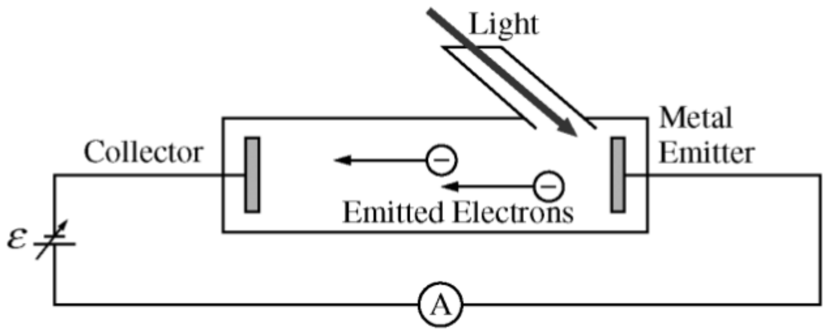
   (b) Calculate the kinetic energy of the proton.

   The proton is directed toward a very distant stationary uranium nucleus, $^{235}_{92}\text{U}$. The proton reaches a distance D from the center of the nucleus and then reverses direction. Assume that the nucleus is heavy enough to remain stationary during the interaction.

   (c) Calculate the value of D.

   (d) After the proton has moved away, the $^{235}_{92}\text{U}$ nucleus spontaneously fissions into $^{148}_{57}\text{La}$ and $^{84}_{35}\text{Br}$, along with three neutrons. As a result, 2.5×10^{-11} J of energy is released. Indicate whether the mass of the nucleus is greater or less than the mass of the fission products. Calculate the mass difference.

   ____ Greater   ____ Less



4. The apparatus shown above is used in determining the work function of a particular metal using the photoelectric effect. The experiment is set up with an ammeter A and a variable power supply. A light source that emits photons of frequency 7.5×10^{14} Hz is used. The emf e provided by the power supply is slowly increased from zero until the ammeter shows that the current between the collector and metal emitter is zero. The magnitude of the emf is 0.65 V when the current becomes zero.

   (a) Determine the wavelength of the incident photons.

   (b) Calculate the work function of the metal.

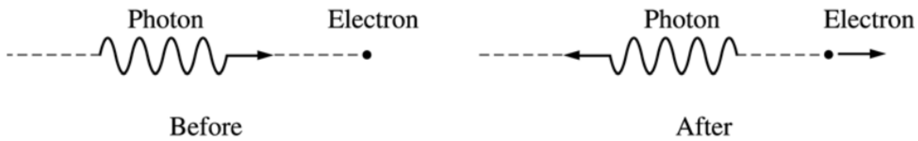
   (c) Calculate the minimum frequency of light at which electrons would be emitted.

   (d) If the power per unit area (intensity) of the incident light is increased and the wavelength stays the same, does the magnitude of the emf needed to stop the current increase, decrease, or remain the same? Justify your answer.

   ____Increases ____Decreases ____Remains the same

   (e) If the wavelength of light is decreased while the power per unit area (intensity) of the incident light stays the same, does the number of electrons emitted from the metal surface per unit time increase, decrease, or remain the same? (Assume that the light is initially above the threshold frequency.) Justify your answer.

   ____Increases ____Decreases ____Remains the same



5. A photon of wavelength 2.0×10^{-11} m strikes a free electron of mass m_e that is initially at rest, as shown above left. After the collision, the photon is shifted in wavelength by an amount $\Delta\lambda = 2h/m_e c$, and reversed in direction, as shown above right.

   (a) Determine the energy in joules of the incident photon.

   (b) Determine the magnitude of the momentum of the incident photon.

   (c) Indicate below whether the photon wavelength is increased or decreased by the interaction. Explain your reasoning.

   (d) Determine the magnitude of the momentum acquired by the electron.

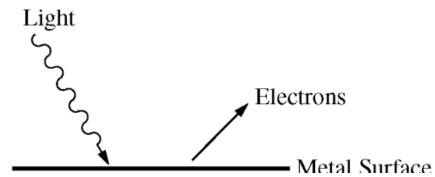
6. Energy-level diagrams for atoms that comprise a helium-neon laser are given above. As indicated on the left, the helium atom is excited by an electrical discharge and an electron jumps from energy level E_0 to energy level E_2. The helium atom (atomic mass 4) then collides inelastically with a neon atom (atomic mass 20), and the helium atom falls to the ground state, giving the neon atom enough energy to raise an electron from E_0' to E_2'. The laser emits light when an electron in the neon atom falls from energy level E_2' to energy level E_1'.

   (a) Calculate the minimum speed the helium atom must have in order to raise the neon electron from E_0' to E_2'.

   (b) Calculate the DeBroglie wavelength of the helium atom when it has the speed determined in (a).

   (c) The excited neon electron then falls from E_2' to E_1' and emits a photon of laser light. Calculate the wavelength of this light.

   (d) This laser light is now used to repair a detached retina in a patient's eye. The laser puts out pulses of length 20×10^{-3} s that average 0.50 W output per pulse. How many photons does each pulse contain?



7. Light of wavelength 400 nm is incident on a metal surface, as shown above. Electrons are ejected from the metal surface with a maximum kinetic energy of 1.1×10^{-19} J.
   (a) Calculate the frequency of the incoming light.
   (b) Calculate the work function of the metal surface.
   (c) Calculate the stopping potential for the emitted electrons.
   (d) Calculate the momentum of an electron with the maximum kinetic energy.