Final: Info

- Tuesday, May 3, 1:30 – 4:00 PM, HERE !
- Format of exam:
  - Multiple choice (~ 90% of pts)
  - Long answer questions (~ 10% of pts)
  - Info sheet included (mainly constants)
- Bring:
  - Pencil and calculator
  - Three 3 x 5 note cards, both sides, handwritten notes
- Info on course website, Sample problems on D2L
- Review sessions: Today and Friday in class

  Today 5-6 pm in helproom area

  Thurs 4-6 pm in helproom area

We frequently think of light as an electromagnetic wave and represent it by a sinusoidal curve.

What does this curve tell you?

(A) The direction and strength of the electric field along the center line of the curve

(B) The actual path that the light takes

(C) Both of these

(D) None of these

Midterm 1

Electromagnetic wave: sources of electromagnetic radiation; the relation between oscillating electric and magnetic fields; the relation between wavelength, frequency and speed of light; propagation direction; interference phenomena; power; intensity etc.

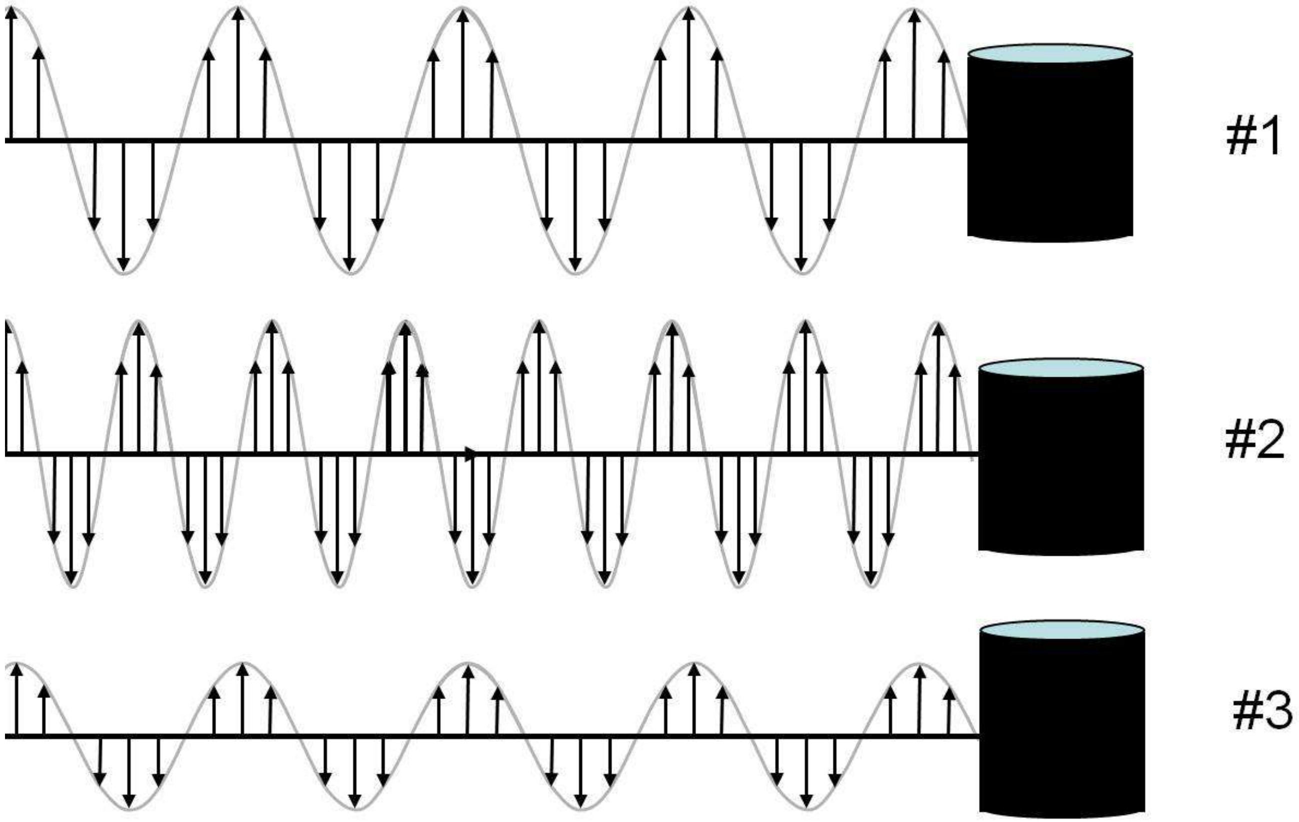
Photoelectric effect: basic concepts of electric field, force on a charged particle, work done by the field on the particle, and voltage etc.; set-up of the photoelectric effect experiment; change in kinetic and potential energy of the electron between the plates; variation of frequency, intensity and voltage in the experiment; the concept of stopping voltage; the definition of eV as energy unit etc.
Main observations; failures of light as classical EM wave; the success of photon view (energy quanta); Dependence of the current, the maximum kinetic energy etc. on the intensity or frequency of the light.

Einstein's postulates: Relation between energy and frequency; Concept of photons as energy quanta; Interaction of photons with material (absorbed at once, entirely); Relation between intensity, energy and number of photons.

Early atom models: Discoveries of electron and nucleus.

Discharge lamps / Energy spectra: Experiments with discharge lamps and insights on electron energy levels from the spectra (discrete levels, spacing determines color of light, …); the mechanism of energy transfer to electrons in atoms difference between absorption of photons and collision with electrons

Consider different beams of laser light hitting a barrel of water. The drawing shows a snapshot of the electric field component of the electromagnetic wave in each case (the amplitude for #1 and #2 are the same, the amplitude for #3 is half of the other two).

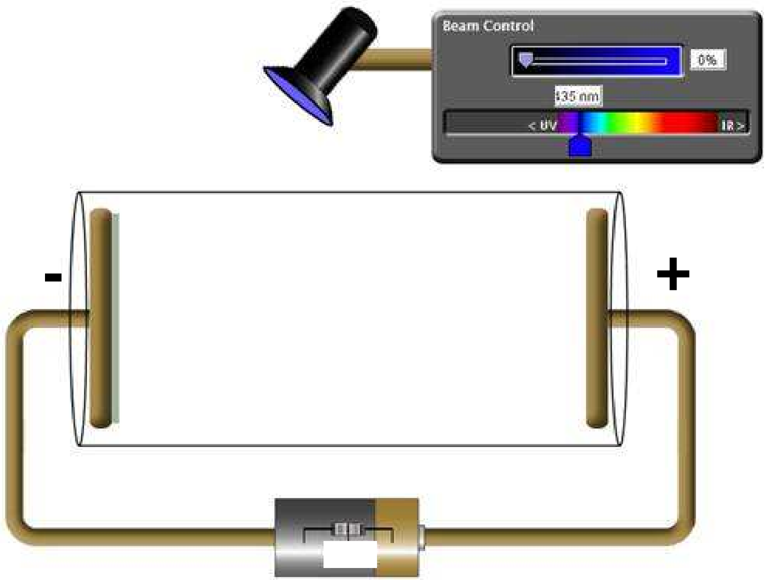


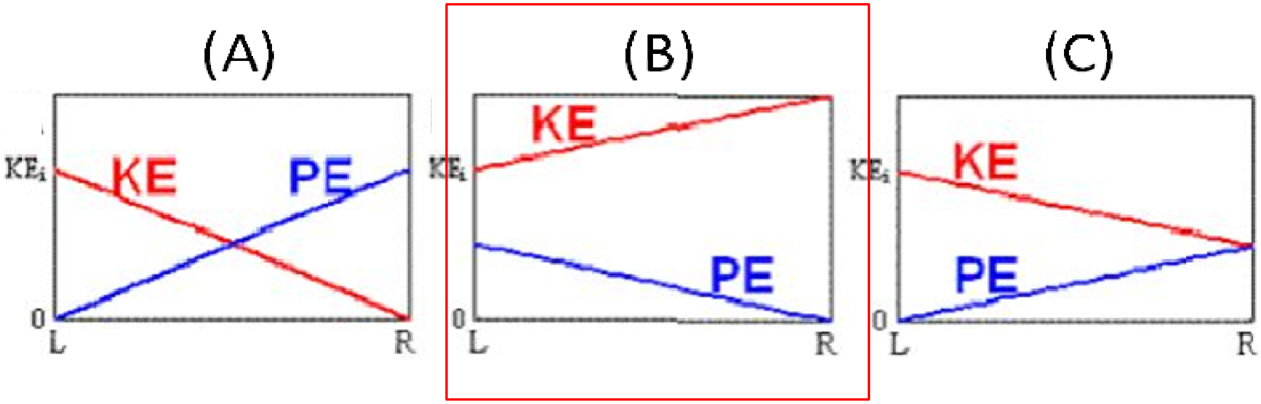
Rank the number of photons hitting the barrels in one minute.

(A) 1 = 2 = 3 (B) 2 > 1 = 3 (C) 1 = 2 > 3 (D) 1 = 3 > 2 (E) 3 > 1 = 2

Correct answer is:
1 > 3 > 2

Consider an electron traveling between two plates that are at some potential V. Which of the following plots describes the kinetic and potential energy as a function of position?





(D) None of these

(E) More than one of these are possible.

Suppose in the photoelectric effect you shine light of 253 nm on an aluminum plate. Electrons are ejected from the plate with a maximum KE of 0.82 eV. Initially, there is some voltage (potential) difference between the plates applied such that the electrons are *accelerated* toward the other plate and a current is measured.

How can you increase the **(initial) maximum kinetic energy of the electrons ejected from the plate** in the experiment?

(A) Increase the voltage (potential) difference between the plates

(B) Increase the wavelength of the light

(C) Increase the intensity of the light

(D) None of these

(E) More than one of these

Suppose in the photoelectric effect you shine light of 253 nm on an aluminum plate. Electrons are ejected from the plate with a maximum KE of 0.82 eV. Initially, there is some voltage (potential) difference between the plates applied such that the electrons are *accelerated* toward the other plate and a current is measured.

How can you increase **the amount of current** measured in the experiment?

(A) Increase the voltage (potential) difference between the plates

(B) Increase the wavelength of the light

(C) Increase the intensity of the light

(D) None of these

(E) More than one of these

Directly after a collision with a free electron an atom with the energy levels shown is in the n=5 state. Which of the following is the most complete set of photon energies (of those shown) that can be emitted by the atom?

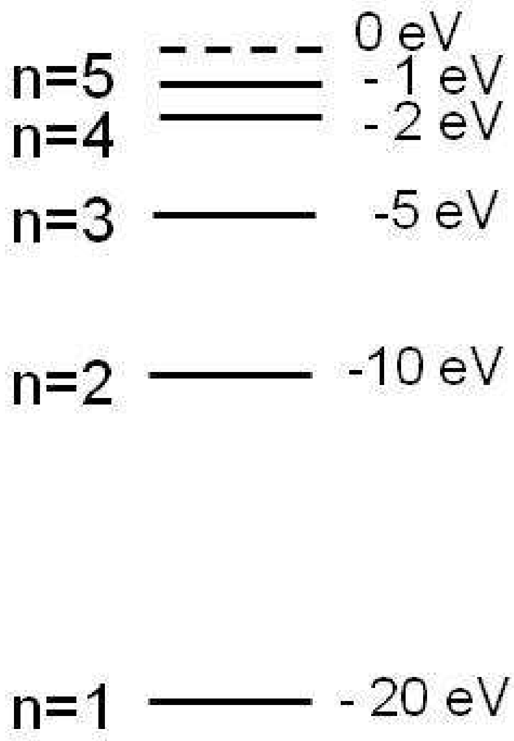
(A) 1 eV

(B) 1 eV, 4 eV, 9 eV, 19 eV

(C) 1 eV, 3 eV, 4 eV, 9 eV, 19 eV

(D) 1 eV, 3 eV, 4 eV, 5 eV, 10 eV, 19 eV

(E) 1 eV, 2 eV, 3 eV, 4 eV, 5 eV, 10 eV, 19 eV, 20 eV



An atom with the energy levels shown is initially in the ground (n=1) state. Which of the following is the most complete set of photon energies that can be absorbed by the atom?

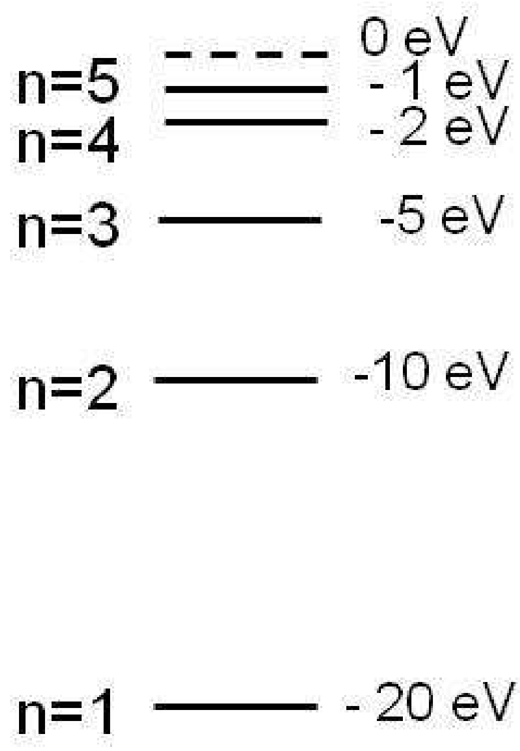
(A) 1 eV

(B) 1 eV, 4 eV, 9 eV, 19 eV

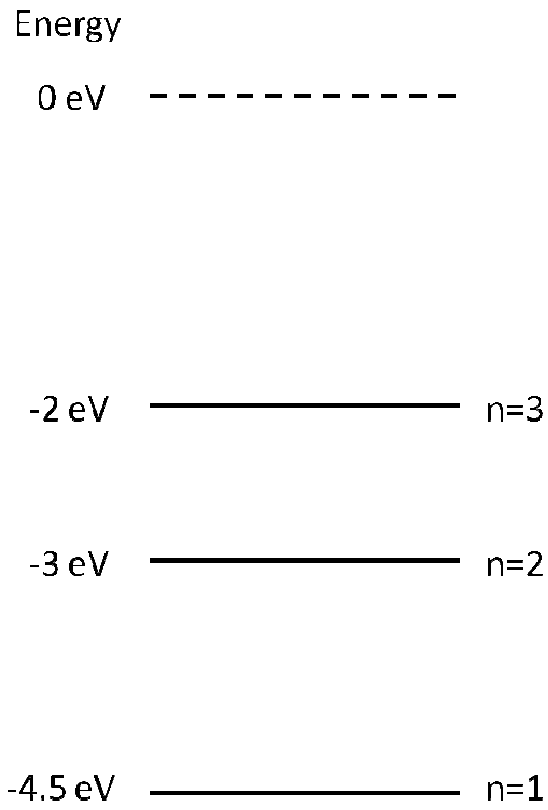
(C) 2 eV, 5 eV,10 eV, 20 eV

(D) 10 eV, 15 eV, 18 eV

(E) 10 eV, 15 eV, 18 eV, 25 eV



A fictitious element X has just three energy levels.
All atoms of element X are in the ground (n=1) state.
Suppose we increase the voltage (potential) difference in the discharge lamp, such that the kinetic energy of the electron increases from 3 eV to 10 eV. What happens?



(A) We will observe more discrete color lines.
(B) We will observe less discrete color lines.
(C) We will observe the same number of discrete color lines.
(D) We will observe a continuous spectrum of light.
(E) We will observe no light at all.

Midterm 2

Bohr model: Postulates; principles of classical physics are fulfilled and which are violated in the model; relation between kinetic, potential and total energy for hydrogen (and hydrogen like ions, e.g. He+ etc.); quantization of energy and radius (incl. formulas); the number of of possible states etc.

de Broglie wavelength: Concept and formula; calculate wavelength for a given particle (mass, energy) or photon (energy); concept of standing waves and relation to a quantization of the orbital angular momentum.

Double slit experiment: Results and interpretation for electrons and other massive particles; particle, wave and probabilistic features; the concept of matter wavefunction and the probability density

Wave function: Concept and physical meaning of probability density and probability based on the wavefunction (incl. calculation); superposition and normalization.

Schrodinger equation (time-dependent and time-independent): separation of variables; solutions for a free particle

Heisenberg uncertainity relation: difference between plane wave and wave packet; uncertainty in position and momentum for plane waves and wave packets; complementary variables; consequences for measurements

Stern-Gerlach experiment: results and interpretation; concept of spin of electrons and atoms; analysis with one and more than one Spin-Gerlach analyzers (in different directions).

Consider the energy E_n of the n-th orbital of the Bohr model for the hydrogen atom. Which of the following statements is correct?

(A) The difference between E_{n+1} and E_n of two successive orbitals decreases as n increases and the maximum energy (for $n \rightarrow \infty$) is ∞.

(B) The difference between E_{n+1} and E_n of two successive orbitals decreases as n increases and the maximum energy (for $n \rightarrow \infty$) is smaller than ∞.

(C) The difference between E_{n+1} and E_n of two successive orbitals increases as n increases and the maximum energy (for $n \rightarrow \infty$) is ∞.

(D) The difference between E_{n+1} and E_n of two successive orbitals increases as n increases and the maximum energy (for $n \rightarrow \infty$) is smaller than ∞.

(E) The difference between E_{n+1} and E_n of two successive orbitals remains the same as n increases.

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de Broglie wavelength

Consider the following particles:

- electron A with kinetic energy of 1 eV
- electron B with kinetic energy of 1 keV
- proton C with kinetic energy of 1 eV

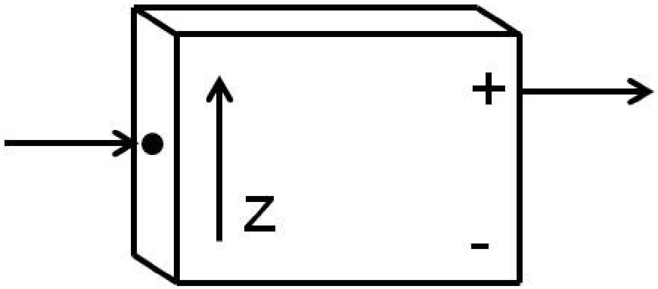
Order the (de Broglie) wavelengths of these particles?

(A)A = C > B   (B) A > B = C

(C) A > B > C   (D) A = B = C

(E) Some other order

Consider a Stern-Gerlach analyzer, as shown below, and ensemble of atoms with …. spin is injected on the left hand side:



What is the probability to leave the plus-channel of the Stern-Gerlach analyzer (oriented in z-direction):

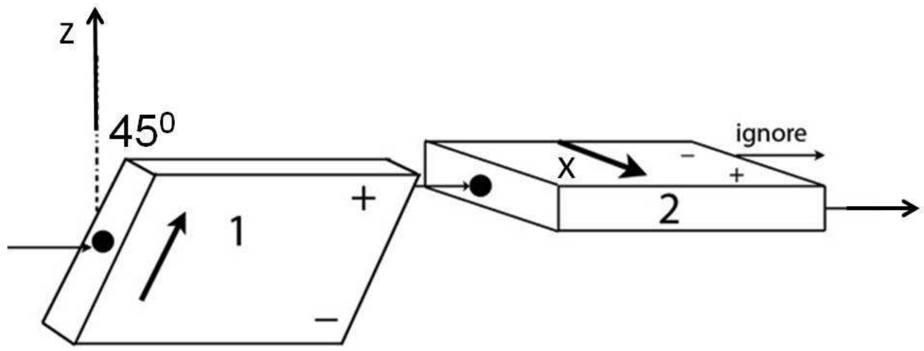
(A) 0% (with spin-down in z-direction)

(B) 25% (with orientation of spin at 120 deg angle to +z)

(C) 50% (with spin oriented along x/y or randomly oriented)

(D) 100% (with spin-up in z-direction)

Analyzer 1 points along an axis at angle of 45^0 with respect to the z-axis, while analyzer 2 points along the x-axis.



Atoms with spin orientation in +z-direction enter the first analyzer on the left. What is the probability that the atoms leave the plus-channel of analyzer 1?

(A) 1

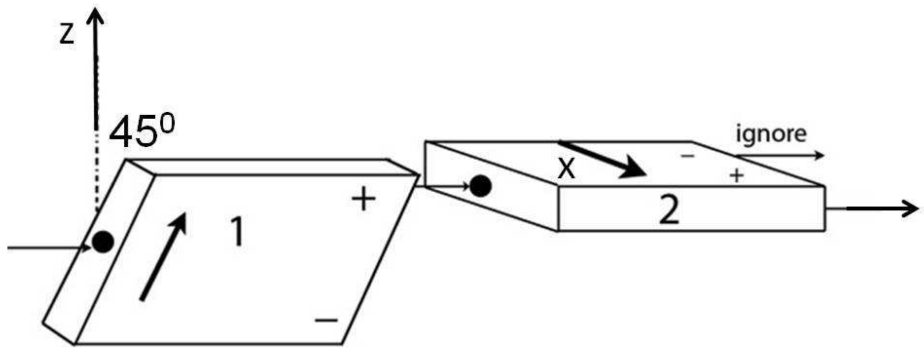
(B) 0.85

(C) 0.5

(D) 0.15

(E) 0

Analyzer 1 points along an axis at angle of 45^0 with respect to the z-axis, while analyzer 2 points along the x-axis.



Atoms with random spin orientation enter the first analyzer on the left. Which of the following best describes the state of an atom leaving the plus-channel of analyzer 2?

(A) (0.85 $|\uparrow_z>$) $|\uparrow_x>$

(B) (0.5 $|\uparrow_z>$) $|\uparrow_x>$

(C) $|\uparrow_z>$ $|\uparrow_x>$

(D) $|\uparrow_x>$

(E) $|\uparrow_z>$