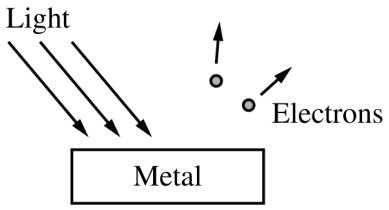
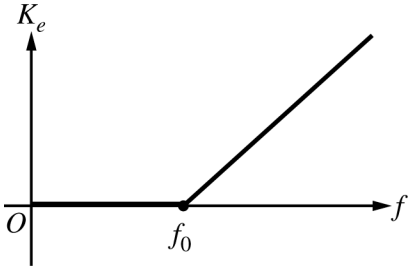


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

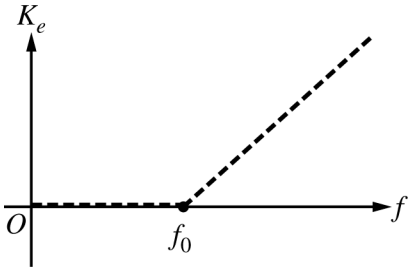
(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.

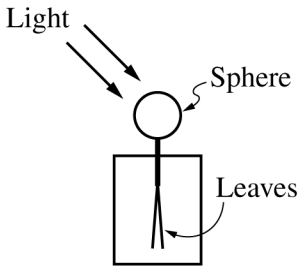


ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

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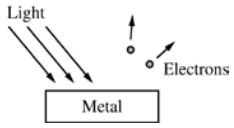
Question 3

12 points total **Distribution of points**

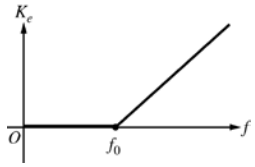


Monochromatic light of frequency *f* shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. LO 5.B.4.2, SP 1.4, 2.1, 2.2; LO 6.F.3.1, SP 6.4
3 points

Based on conservation of energy, the relationship between K_e and *f* is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where *A* and *B* are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to *A* and *B*. Also, explain the physical meaning of *A*, *B*, and f_0.



For indicating that *A* represents the slope or the rate of change of K_e as a function of *f* and equals Planck's constant		1 point
For indicating that *-B* is the intercept with the K_e axis and equals the minimum energy needed to release an electron from the metal (the work function)		1 point
For indicating that f_0 is the minimum frequency that will release an electron from the metal (the cutoff or threshold frequency)		1 point

ii. LO 6.F.3.1, SP 6.4
1 point

Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

For indicating that the horizontal portion of the graph represents frequencies of light whose energy is insufficient to eject an electron		1 point

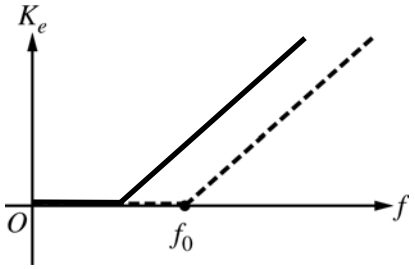
Question 3 (continued)

Distribution of points

(a) (continued)

iii. LO 6.F.3.1, SP 6.4
3 points

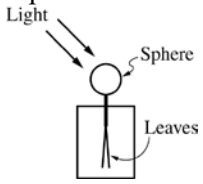
A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



For drawing a line that is parallel to the given line		1 point
For drawing the horizontal intercept on either side of f_0 with the line ending at the horizontal axis (The horizontal segment does not have to be drawn.)		1 point
For indicating that the K_e or f intercept changes because the work function or the frequency at which electrons can be emitted is different		1 point

(b)

The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. LO 1.B.1.2, SP 6.4, 7.2, LO 4.E.3.3, SP 6.4; LO 6.F.3.1, SP 6.4
2 points

Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

For indicating that the UV light causes electrons to be ejected from the electroscope		1 point
For indicating that the electroscope becomes less negatively charged, causing the leaves to move closer together		1 point

Question 3 (continued)

Distribution of points

(b) (continued)

ii. LO 6.F.1.1, SP 6.4, 7.2, LO 6.F.3.1, SP 6.4
1 point

Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

For indicating that the green light frequency or energy per photon is too low to eject electrons		1 point

(c) LO 6.F.3.1, SP 6.4
2 points

The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

For indicating that the increase in brightness causes an increase in the number of photons in the beam or increases the amplitude of the wave		1 point
For indicating that the leaves would not separate because the energy per photon or frequency of the light remains the same		1 point
The particle nature of light (photons) must be discussed to receive full credit.		

Learning Objectives (LO)

LO 1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. [See Science Practices 6.4, 7.2]
LO 4.E.3.3: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors. [See Science Practices 1.1, 1.4, 6.4]
LO 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. [See Science Practices 1.4, 2.1, 2.2]
LO 6.F.1.1: The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation. [See Science Practices 6.4, 7.2]
LO 6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect. [See Science Practice 6.4]