PhyzJob: Fantasia on the Photoelectric Effect

Felix

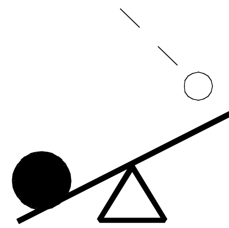
I. A Swarm of Baseballs Bears Down on a Field of Medicine Balls on See-Saws

1. Consider a swarm of baseballs moving with a range of speeds from 2.6 m/s to 7.4 m/s. If baseballs have a mass of 460 g, what is the range of kinetic energies of baseballs in the swarm?

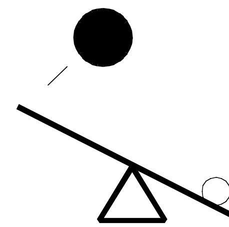
$KE = 1/2mv^2$

$KE = 1/2 \cdot 0.460\ kg \cdot (2.6\ m/s)^2 = 1.55\ J$

$KE = 1/2 \cdot 0.460\ kg \cdot (7.4\ m/s)^2 = 12.6\ J$



2. Some baseballs strike the high side of see-saws laden with medicine balls, as shown in the diagram to the right. When baseballs having 8.0 J of kinetic energy strike a see-saw, the medicine ball on the other side is catapulted into the air. It is observed to have a kinetic energy of 5.0 J. Baseballs with 9.0 J of kinetic energy launch medicine balls with 6.0 J of kinetic energy.



a. What is the frictional loss in the see-saws? (Express it in terms of energy and denote it with the Greek letter Φ.)

Φ = 3.0 J

b. A baseball with 2.0 J strikes a see-saw and fails to lift the medicine ball. What minimum kinetic energy must a baseball have to just lift the medicine ball (without giving it any excess kinetic energy)?

3.0 J

c. What minimum speed must a baseball have to lift a medicine ball? (This is called the threshold speed, denoted v_0.)

v_0 = 3.6 m/s

3. a. Write an expression for the kinetic energy of a medicine ball in terms of the mass and speed of the incident baseball and the frictional loss in the see-saw.

$KE = {}^{1}/{}_{2}mv^2 - \Phi$

b. Write an expression for the kinetic energy of a medicine ball in terms of the mass and speed of the incident baseball and the threshold speed for the see-saw.

$KE = {}^{1}/{}_{2}mv^2 - {}^{1}/{}_{2}mv_0{}^2 = m/2(v^2 - v_0{}^2)$

c. What is the kinetic energy of a medicine ball launched by a baseball moving at 8.7 m/s if the threshold speed for its see-saw is 4.2 m/s?

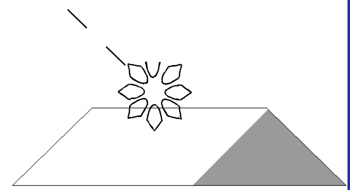
KE = 13.4 J

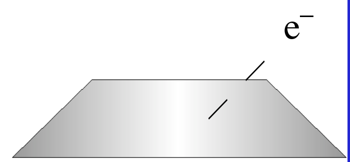
d. If the medicine ball has a mass of 2.0 kg, what is its speed?

v = 3.6 m/s

1. 1.55 J — 12.6 J 2.a. 3.0 J b. 3.0 J c. 3.6 m/s 3.c. 13.4 J d. 3.6 m/s

II. A Stream of Photons Bears Down on Electrons in a Metal Surface (The Photoelectric Effect)





1. Consider a stream of photons with a range of frequencies from 4.3E+14Hz to 3.1E+15Hz. What is the range of energies of the photons in the stream? (Express your answers in electron-volts.)

E = hf
E = 4.14E-15 eV·s · 4.3E+14 Hz = 1.78 eV
E = 4.14E-15 eV·s · 3.1E+15 Hz = 12.8 eV

2. The photons strike a metal surface, as shown in the diagram to the right. When photons having 8.0eV of energy strike the metal surface, electrons are liberated. They are observed to have a maximum kinetic energy of 5.0eV. Photons with 9.0eV of energy liberate electrons with a maximum of 6.0eV of kinetic energy.

a. What is the work function of this metal? (Express it in terms of energy and denote it with the Greek letter Φ.)

Φ = 3.0 eV

b. A photon with 2.0eV strikes the metal surface and fails to liberate any electrons. What minimum energy must a photon have to just barely liberate an electron from the surface (without giving it any excess kinetic energy)?

3.0 eV

c. What minimum frequency must a photon have to liberate an electron? (This is called the threshold frequency, denoted f_0.)

f_0 = 7.2E+14 Hz

3. a. Write an expression for the kinetic energy of a liberated electron (photoelectron) in terms of the frequency of the incident photon and the work function of the metal.

$KE = hf - \Phi$

b. Write an expression for the kinetic energy of a liberated electron in terms of the frequency of the incident photon and the threshold frequency of the metal.

$KE = hf - hf_0 = h(f - f_0)$

c. What is the maximum kinetic energy of a photoelectron liberated by an 8.7E+14 Hz photon from a metal whose threshold frequency is 4.2E+14 Hz?

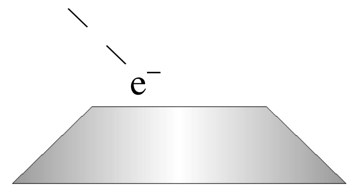
KE = 1.9 eV

d. And the speed of that photoelectron?

v = 8.1E+5 m/s

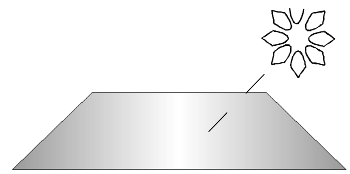
III. A Stream of Electrons Bears Down on Photons in a Metal Surface (Bremsstrahlung—"Braking Radiation," "Inverse Photoelectric Effect")

1. Consider a stream of electrons with a range of speeds from 2.0E+7 m/s to 3.0E+7 m/s. What is the range of energies of the electrons in the stream? (Express your answers in electron-volts.)



KE = 1/2 m v^2 = 1/2 · 9.11E-31 kg · (2E+7 m/s)^2 = 1.8E–16 J = 1100 eV
KE = 1/2 m v^2 = 1/2 · 9.11E-31 kg · (3E+7 m/s)^2 = 4.1E–16 J = 2600 eV

2. The electrons strike a metal surface, as shown in the diagram to the right. When electrons having 2100 eV of kinetic energy strike the metal surface, photons are liberated. The release of energy (in the form of a photon) allows the electron to slow down and become part of the metal body. Thus the photons given off are referred to as "braking radiation" (*bremsstrahlung* in German).



Since the work function of the metal is small compared to the energy of the incident electrons, the photons come off with about the same energy as the incident electrons.

a. What is the energy of the emerging photon (in this case)?

E = 2100 eV

b. What is the frequency of the emerging photon?

E = hf   f = E/h = 2100 eV / 4.14E-15 EV·s = 5.1E+17 Hz

c. To which part of the electromagnetic spectrum does this photon belong?

X-rays

3. Firing energetic electrons at a metal surface is a means by which radiation of this type can be generated. Are there any applications for this type of radiation?

X-ray imaging