Week 8

PHYS 1C

PROBLEM SESSION

COURSE INSTRUCTOR: DR. FRANK WUERTHWEIN

We’ll start at 7:05

Check Your Grades Online

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Notice of Change:
Office hour next week
(Memorial Day)

May 26 (Mon)
5-8 PM
TUTORIAL CENTER

May 28 (Wed)
5-8 PM
TUTORIAL CENTER

Photoelectric Effect

- Stopping Potential $\Delta V_s$
- Maximum Kinetic Energy $K_{\text{max}}$
- Work function $\phi$
- Cutoff frequency / wavelength

\[
e \cdot \Delta V_s = K_{\text{max}} = hf - \phi
\]
\[
f_{\text{cutoff}} = \frac{\phi}{h} \quad \lambda_{\text{cutoff}} = \frac{hc}{\phi}
\]
Example 28.3

A sodium surface is illuminated with light having a wavelength of 300 nm. The work function for sodium metal is 2.46 eV.

1. Find the maximum kinetic energy of the ejected photoelectrons.
2. Find the cutoff wavelength for sodium.

- 1) 1.67 eV  2) 504 nm

Question 2

2. Which of the following phenomena most clearly demonstrates the particle nature of light? (a) diffraction (b) the photoelectric effect (c) polarization (d) interference (e) refraction

- (b)
**Compton Scattering**

- A photon is scattered at an angle $\theta$ by an electron.
- **Compton shift equation**
  \[ \Delta \lambda = \lambda' - \lambda_0 = \frac{h}{m_e c} (1 - \cos \theta) \]
- **Compton wavelength $\lambda_c$**
  \[ \lambda_c = \frac{h}{m_e c} = 0.00243 \text{ nm} \]

**Ch28 Example 28.4**

X-rays of wavelength $\lambda_0 = 0.200000 \text{ nm}$ are scattered from a block of material. The scattered x-rays are observed at an angle of $45.0^\circ$ to the incident beam. Calculate their wavelength.

- $0.200710 \text{ nm}$
Ch28

Question 3

3. In a Compton scattering experiment, a photon of energy $E$ is scattered from an electron at rest. After the scattering event occurs, which of the following statements is true? (a) The frequency of the photon is greater than $E/h$. (b) The energy of the photon is less than $E$. (c) The wavelength of the photon is less than $hc/E$. (d) The momentum of the photon increases. (e) None of those statements is true.

• (b)

Ch28

Question 12

12. An x-ray photon is scattered by an originally stationary electron. Relative to the frequency of the incident photon, is the frequency of the scattered photon (a) lower, (b) higher, or (c) unchanged?

• (a)
Blackbody Radiation

- Stefan’s law \[ P = \sigma \varepsilon A T^4 \]
- Peak wavelength \( \lambda_{\text{max}} \)
- Wien’s displacement law \[ \lambda_{\text{max}} \cdot T = \text{constant} = 2.898 \times 10^{-3} \]

Ch28

Example 28.1

Find the peak wavelength of the following objects:

1. Human body (skin temperature is 35°C)
2. The lightbulb (tungsten filament is 2000K)
3. The sun (surface of the sun is 5800K)

- 9.41x10^{-6}, 1.45x10^{-6}, 5x10^{-7} m
Example 28.1

4. Calculate the total power emitting by your skin, assuming it follows blackbody radiation.

5. Why your body doesn’t glow as brightly as a lightbulb?

Question 7

7. In a certain experiment, a filament in an evacuated light-bulb carries a current $I_1$ and you measure the spectrum of light emitted by the filament, which behaves as a black body at temperature $T_1$. The wavelength emitted with highest intensity (symbolized by $\lambda_{\text{max}}$) has the value $\lambda_1$. You then increase the potential difference across the filament by a factor of 8, and the current increases by a factor of 2. (i) After this change, what is the new value of the temperature of the filament? (a) $16T_1$ (b) $8T_1$ (c) $4T_1$ (d) $2T_1$ (e) still $T_1$

(ii) What is the new value of the wavelength emitted with highest intensity? (a) $4\lambda_1$ (b) $2\lambda_1$ (c) $\lambda_1$ (d) $\frac{1}{2}\lambda_1$ (e) $\frac{1}{4}\lambda_1$

- (i) d (ii) d
Blackbody Radiation
Quantum Oscillator

- Review: period of SHM / a oscillator
- Energy is quantized

\[ E_n = nhf \]

Ch28
Lecture Example

A pendulum has a length of 1.50m. Treating it as a quantum system:

(a) calculate its frequency in the presence of Earth’s gravitational field.
(b) calculate the energy carried away in a change of energy levels from n=1 to n=3.

- (a) 0.407Hz (b) 5.39x10^{-34}J
Example 28.2

A 2-kg block is attached to a massless spring that has a force constant $k = 25 \text{ N/m}$. The spring is stretched 0.4m from its equilibrium position and released from rest.

1. Find the total energy of the system and the frequency of oscillation according to classical calculation.
2. Assuming the energy of the oscillator is quantized, find the quantum number $n$ for the system oscillating with this amplitude.

- (1) $2 \text{ J}$, $0.563 \text{ Hz}$, (2) $5.36 \times 10^{33}$

**Matter Wave**

- **Momentum** $p = mv$
- **de Broglie wavelength** $\lambda = \frac{h}{p}$
- $E = hf$
Example 28.5

1. Calculate the de Broglie wavelength for an electron \((m_e = 9.11 \times 10^{-31} \text{ kg})\) moving at \(1.00 \times 10^7 \text{ m/s}\).

2. A rock of mass 50g is thrown with a speed of 40 m/s. What is its de Broglie wavelength?

- \((1) \ 7.27 \times 10^{-11} \text{ m}, (2) \ 3.3 \times 10^{-34} \text{ m}\)

Question 5

5. A proton, an electron, and a helium nucleus all move at speed \(v\). Rank their de Broglie wavelengths from largest to smallest.

- Electron > proton > helium nucleus
8. What is the de Broglie wavelength of an electron accelerated from rest through a potential difference of 50.0 V?
(a) 0.100 nm (b) 0.139 nm (c) 0.174 nm (d) 0.834 nm (e) none of those answers

- (C)

17. Rank the wavelengths of the following quantum particles from the largest to the smallest. If any have equal wavelengths, display the equality in your ranking. (a) a photon with energy 3 eV (b) an electron with kinetic energy 3 eV (c) a proton with kinetic energy 3 eV (d) a photon with energy 0.3 eV (e) an electron with momentum 3 eV/c

- (d) > (e) > (a) > (b) > (c)
The Uncertainty Principle

\[ \Delta x \cdot \Delta p \geq \frac{h}{4\pi} \]

\[ \Delta E \cdot \Delta t \geq \frac{h}{4\pi} \]

Ch28

Example 28.7

The speed of an electron is measured to be \( 5.00 \times 10^3 \) m/s to an accuracy of 0.00300%. Find the minimum uncertainty in determining the position of this electron.

- 0.386 mm
Question 16

16. Which of the following statements are true according to the uncertainty principle? More than one statement may be correct. (a) It is impossible to simultaneously determine both the position and the momentum of a particle along the same axis with arbitrary accuracy. (b) It is impossible to simultaneously determine both the energy and momentum of a particle with arbitrary accuracy. (c) It is impossible to determine a particle’s energy with arbitrary accuracy in a finite amount of time. (d) It is impossible to measure the position of a particle with arbitrary accuracy in a finite amount of time. (e) It is impossible to simultaneously measure both the energy and position of a particle with arbitrary accuracy.

• (a) (c)

Question 18

18. Both an electron and a proton are accelerated to the same speed, and the experimental uncertainty in the speed is the same for the two particles. The positions of the two particles are also measured. Is the minimum possible uncertainty in the electron’s position (a) less than the minimum possible uncertainty in the proton’s position, (b) the same as that for the proton, (c) more than that for the proton, or (d) impossible to tell from the given information?

• (C)
See you next week