

Modern Physics

Review Session

Special Relativity and Pre-Quantum Mechanics

LUMS School of Science and Engineering

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1 Time Dilation

When he returns his Hertz rent-a-rocket after one week's cruising in the galaxy, Spock is shocked to be billed for the three week's rental. Assuming that he travelled straight out and then straight back, always at the same speed, how fast was he moving.

2 Lorentz Transformation

Consider two events that occur simultaneously at $t=0$ in frame S , both on the x -axis at $x=0$ and $x=a$.

a) Find the times of the two events as measured in a frame S' travelling in the positive direction along the x -axis with speed V .

b) Do the same for the second frame S'' travelling at speed V but in the negative direction along the x -axis.

c) Comment on the time-ordering of the two events as seen in the three different frames.

3 Addition of Velocities

A rocket is travelling at speed V along the x -axis of frame S . It emits a signal (for example, a pulse of light) that travels with speed c along the y' axis of the rocket's rest frame S' . What is the speed of the signal as measured in S ?

4 Threshold Energies

A gamma ray (a high energy photon) can produce an electron (e^-) and a positronium (e^+) of equal mass when it enters the electric field of a heavy nucleus: $\gamma \rightarrow e^+ + e^-$. What minimum gamma-ray energy is required to accomplish this task?

5 Energy-Momentum Conservation

A pion at rest ($m_\pi = 273m_e$) decays to a muon ($m_\mu = 207m_e$) and an antineutrino ($m_\nu = 0$). This reaction is written as $\pi^- \rightarrow \mu^- + \bar{\nu}$. Find:

- the kinetic energy of the muon
- the energy of the antineutrino in electron volts.

6 Decay of Particles

An unstable particle at rest spontaneously breaks into two fragments of unequal mass. The mass of the first fragment is 2.50×10^{-28} kg, and that of the other is 1.67×10^{-27} kg. If the lighter fragment has a speed of $0.893c$ after the breakup, what is the speed of the heavier fragment?

7 The Photoelectrons in a Magnetic Field

Photons of wavelength 450 nm are incident on a metal. The most energetic electrons are ejected from the metal and bent into a circular arc of radius 20 cm by a magnetic field whose strength is equal to 2.0×10^{-5} T. What is the work function of the metal?

8 Compton Effect

A photon undergoing Compton scattering has an energy after scattering of 80 keV, and the electron recoils with an energy of 25 keV. Find

- the wavelength of the incident photon.
- the angle at which the photon is scattered.
- the angle at which the electron recoils.

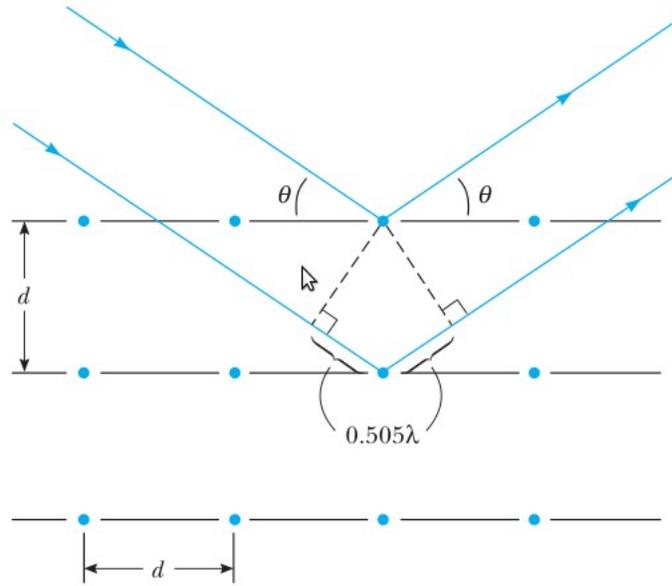


Figure 1: The Davisson-Germer Experiment

9 Compton Effect 2

If the maximum energy given to an electron during Compton scattering is 30 keV, what is the wavelength of the incident photon?

10 The Davisson-Germer Experiment

Figure 1 below shows the top three planes of a crystal with planar spacing d . If $2d\sin\theta = 1.01\lambda$ for the two waves shown, and high energy electrons of wavelength λ penetrates many planes deep into the crystal, which atomic plane produces a wave that cancels the surface reflection?