Modern Physics

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Exercise 4

§ Special Relativity & Wave-Particle Dualism §

Problem 1: Simultaneity and relativity

A spaceship of length L_0 moves along space with a velocity of $v = 0.3\,c$. An observer at rest (first reference system) sees two light flashes hitting the spaceship (second reference system) simultaneously, one at the very front and one at the very end.

(1) Assume that both flashes occur simultaneously in the reference system of the observer. What is the position of the observer relative to the spaceship when the two flashes appear, and what is the position of the observer relative to the spaceship when he notices/discovers the two flashes?

(2) Write down the Lorentz transformations.

(3) At which times do the two flashes occur in the reference system of the spaceship?

(4) Where is the pilot of the spaceship if he also notices both flashes at the same time?

Problem 2: Thermal radiation

A black body is an idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. Using this idealization:

(1) Calculate the wavelength λ at which the radiation from a human body with 33^oC surface temperature is at its maximum.

(2) Find the surface temperature of the sun if the solar constant is $E_0 = 1.361$ kW m^{-}2. The solar constant refers to the solar irradiance per unit area that would be incident on a plane perpendicular to the rays at a distance of one astronomical unit (AU) from the sun (roughly the mean distance from sun to earth). At which wavelength λ does the emission of the sun have a maximum?

{helpful constants: radius sun $r_S = 6.96 \times 108$ m, distance sun-earth $r_{SE} = 1.5 \times 1011$ m.}

Problem 3: Photoelectric effect

Monochromatic light with a wavelength of $\lambda = 500$ nm is incident on a small piece of metal. The emitted electrons have a maximum velocity of $v = 2.6 \times 10^5\,\mathrm{m\,s^{-1}}$.

(1) Calculate the work function of the metal.

(2) What is the maximum wavelength λ_{max} at which electron emission is still possible?

Problem 4: Spontaneous and stimulated radiation

The ratio between the spontaneous and stimulated emission rates can be expressed by the following equation:

$$\frac{\dot{n}_{spon}}{\dot{n}_{stim}} = \exp\left(\frac{h\nu}{k_B T}\right) - 1$$

Calculate this ratio for a system that is in thermal equilibrium at room temperature ($T = 300$ K) and assume that the electromagnetic radiation is in the ...:

(1) ... visible part of the spectrum.

(2) ... microwave part of the spectrum.