Suggested Reading

Scheck Section 1.25, 1.26, Goldstein Sections 4-10, Landau Chapter 4 Section 39.

Problems

Problem 7.1 (20 pts)

Consider a beam of particles hitting a stationary target made of atoms with number density $n \, [m^{-3}]$. An incoming particle is fully absorbed and stopped if it collides with an atom. The absorption cross section is $\sigma \, [m^2]$. Find the beam intensity as a function of depth $I(x)$ in the material if the initial intensity was $I_0 \, [m^{-2}s^{-1}]$.

Problem 7.2 (20 pts)

Consider two beams of colliding particles. Find the frequency of reactions occurring in the volume $dV$ at the intersection of the two beams. The number density of the two beams are $n_1$ and $n_2$ respectively and their velocities are $\vec{v}_1$ and $\vec{v}_2$. The total reaction cross section is $\sigma$.

Problem 7.3 (20 pts)

Determine differential cross section $\sigma(\theta)$ for scattering of small particles on a surface formed by rotating the curve $\rho(z) = b \sin(z/a)$ about $z$-axis ($a, b > 0$). Before the scattering the particles travel with velocities parallel to the $z$-axis. Consider two cases:

a. The collision is elastic, the energy of emerging particle is the same as before collision.

b. The surface is smooth but non-elastic. The component of the velocity perpendicular to the surface becomes zero after the collision.

Problem 7.4 (20 pts)

Consider a tower of height $h$ on Earth located at the northern latitude $\lambda$. A stone is dropped with zero initial velocity. Calculate the displacement from vertical in East-West and North-South directions of the stone when it hits the ground. In your calculation assume that $h << R$ where $R$ is Earth’s radius and $R\Omega^2 << g$ where $\Omega$ is Earth’s angular velocity.
Problem 7.5 (20 pts)

In a bizarre attempt to make a space station, NASA made a hollow sphere of radius $R$ which rotates with angular velocity $\omega$ around the pole, $\vec{\omega} = \omega \cdot \hat{z}$.

The idea is that the crew lives on the inside of the sphere and that the centrifugal force from the rotation of the sphere creates an artificial gravity. In all the questions below refer to an observer in the rotating frame, i.e. one standing inside the sphere and rotating with it.

a. Give the effective gravitational force as a function of $\theta$ and $\phi$ on the inside of the sphere.

b. Find the potential corresponding to the force in part a).

c. At $t = 0$ the sphere is at rest. A particle is located at $\theta = \pi/2, \phi = 0$ and is free to move without friction on the inside of the sphere. At $t = 0$, the sphere begins to rotate, $\omega(t) = \alpha t$. Give the position of the particle at $t = t_0 > 0$.

d. After $t_0$, the sphere rotates with constant angular velocity $\omega$. A particle, free to move frictionlessly, initially located at $\theta = \pi/2, \phi = 0$ is displaced by a small angle $\theta_0$ from $\theta = \pi/2$ and released from rest at $t = t_0$. Find the subsequent motion of the particle.