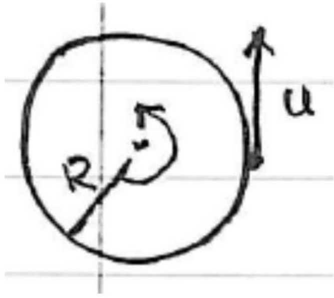
Classical Mechanics TFY 4345 – Exercise 11

1. Binding energy of a deuteron. [This one is a short one.]

Deuteron can be split by gamma rays in a nuclear experiment $\gamma + {}^2H \rightarrow p + n$. Calculate the energy required for the gamma rays.

2. Frequency shift on rotating disk. [Short one as well.]

A radioactive ^{57}Co element is situated on the periphery of a rotating disk. The peripheral velocity is u. The radiation is received by an observer located in the center of the disk. Let ν_0 be the eigenfrequency of the radiation in the inertial system where the element is momentarily at rest. Find the frequency ν of the observed radiation.



3. Fast moving particle in two inertial frames. [Exam Dec. 2019]

We shall consider a particle with rest mass m seen from two different inertial reference systems. In the reference system S the particle has a velocity

$$\boldsymbol{u} = (u_x, u_y, u_z).$$

The reference system S' is moving along the z-axis with a constant velocity v relative to the reference system S. The velocity of the particle is

$$\boldsymbol{u'} = (u'_x, u'_y, u'_z)$$

in the reference system S'. Find the explicit interrelationship between $\boldsymbol{u'}$ and $\boldsymbol{u}$, i.e. derive the transformation that gives $\boldsymbol{u'}$ from the components of $\boldsymbol{u}$ based on the Special Theory of Relativity.

4. Lorentz transformation of energy and momentum.

We shall consider a particle with rest mass m seen from two different inertial reference systems. In the reference system S the particle has a velocity $\mathbf{u} = (u_x, u_y, u_z)$. The reference system S' is moving along the z-axis with a constant velocity v relative to the reference system S. The velocity of the particle $\mathbf{u'} = (u'_x, u'_y, u'_z)$ in the reference system S' is then given by Einstein's velocities addition formula.

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a) Use Einstein velocity addition formulas and show that :

$$\frac{1}{\sqrt{1-u'^2/c^2}} = \gamma \frac{1-\frac{vu_z}{c^2}}{\sqrt{1-u^2/c^2}} \tag{1}$$

where $\gamma = \frac{1}{\sqrt{1-v^2/c^2}}$, $u^2 = |\mathbf{u}|^2 = u_x^2 + u_y^2 + u_z^2$ and likewise $u'^2 = |\mathbf{u}'|^2$

b) The energy E and momentum $\mathbf{p}$ of the particle in reference system S is:

$$E = \frac{mc^2}{\sqrt{1-u^2/c^2}} \tag{2}$$

$$\mathbf{p} = \frac{m\mathbf{u}}{\sqrt{1-u^2/c^2}} \tag{3}$$

and in the reference system S':

$$E' = \frac{mc^2}{\sqrt{1-u'^2/c^2}} \tag{4}$$

$$\mathbf{p}' = \frac{m\mathbf{u}'}{\sqrt{1-u'^2/c^2}} \tag{5}$$

Make use of Equation (1) and find the Lorentz transformation for energy and momentum, i.e. express E' and $\mathbf{p}'$ as a function of E and $\mathbf{p}$.