

August 15, 2015
Prelim Exam – Day 2

Begin each problem on a separate sheet of paper. Write your **Prelim ID #** in the top right-hand corner of each and every page you submit.

Problem 1:

Consider the operator

$$\hat{Q} = i \frac{d}{d\varphi},$$

where φ is the usual angular polar coordinate in two dimensions.

(a) Show that \hat{Q} is hermitian.

(b) Find its eigenfunctions and eigenvalues.

Problem 2:

An electron is in the spin state

$$\chi = A \begin{pmatrix} 3i \\ 4 \end{pmatrix}$$

- (a) Determine the normalization constant, A .
- (b) Find the expectation values of S_x , S_y , and S_z .

Problem 3:

Two events in reference frame S occur $10.0 \mu\text{s}$ apart at the same point in space. The distance between the two events is 2400 m in reference S' .

(a) What is the time interval between the events in reference frame S' ?

(b) What is the velocity of S' relative to S ?

Problem 4:

A lambda particle (Λ) decays into a proton and a pion, $\Lambda \rightarrow p + \pi$, and it is observed that the proton is left at rest. The masses involved are $m_\Lambda = 1116$, $m_p = 938$, and $m_\pi = 140$, all in MeV/c^2 .

- (a) What is the energy of the pion?

- (b) What was the energy of the original Λ ?

Problem 5:

In preparation for a bath, you mix 50 L of hot water ($T_H = 55^\circ\text{C}$) with 25 L of cold water ($T_C = 10^\circ\text{C}$). How much entropy have you created by mixing the water? (Solve symbolically first and then insert the numbers after finding a symbolic solution.) The mass density of water is 1 g cm^{-3} and the specific heat of water is $4.2 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$.