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Physics 416
Problem Set 3
Due Thursday, November 11, 2004

1) We wish to determine the index of refraction (n) of a medium by measuring how much light bends when it travels from one medium to another. The law relating angles and indexes of refraction is Snell's Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

Given the following measurements find n_2 and using propagation of errors the uncertainty (standard deviation) of n_2.

$n_1 = 1.0000$ $\theta_1 = 22.03 \pm 0.20$ degrees $\theta_2 = 14.45 \pm 0.20$ degrees

Hint: Convert degrees to radians before using the propagation of errors formula.

2) Taylor P3.22, page 83.

3) Taylor P3.24, page 83.

4) Taylor P3.46, page 90.

5) The following probability density function (*pdf*), $p(x)$, is commonly used in nuclear and high energy physics:

$$p(x) = \frac{A}{(x-\alpha)^2 + \beta^2}$$

In the above equation A, α, β are constants.

a) Find the value of A needed to normalize this *pdf*.
b) Find the mean of this *pdf*.
c) Find the variance of this *pdf*.
d) Does this *pdf* satisfy the conditions of the Central Limit Theorem?

6) A Central Limit Theorem problem. When a batch of a certain type of superconductor is produced the amount of an impurity in the material (considered to be a random variable) must be tightly controlled. The amount of the impurity in a single batch of superconductor has a mean of 4 micrograms and a standard deviation of 2 micrograms. If 100 independent batches of the superconductor material are produced and then combined what is the probability for the total amount of the impurity in the combined batch being more that 450 micrograms?

7) Describe the following physics processes in a few sentences:

a) Compton Scattering
b) Photo electric effect
c) Pair production

8) Do exercise #1 in appendix B of the handout "The Art of Experimental Physics".

9) The decay of an unstable particle is described by the following probability density function in terms of the decay time (t) and the particle's lifetime (λ).

$$p(t,\lambda) = \frac{e^{-\frac{t}{\lambda}}}{\lambda}$$

Three measurements of t ($t_1 = 7$ sec, $t_2 = 3$ sec, $t_3 = 4$ sec) are made.

a) Write down the likelihood function for this problem.
b) Use the Maximum Likelihood Method to calculate the value of λ for this data set.

10) Taylor P8.20, page 205 (hint: look at the example on page 190).