***2.2** (Section 2.2). Rewrite the following answers in their clearest forms, with a suitable number of significant figures:

(a) measured height $= 5.03 \pm .04329$ meters;
(b) measured time $= 19.5432 \pm 1$ sec;
(c) measured charge $= -3.21 \times 10^{-19} \pm 2.67 \times 10^{-20}$ coulombs;
(d) measured wavelength $= 0.000{,}000{,}563 \pm 0.000{,}000{,}07$ meters;
(e) measured momentum $= 3.267 \times 10^{3} \pm 42$ gm·cm/sec.

***2.3** (Section 2.3).

(a) A student measures the density of a liquid five times and gets the results (all in gm/cm^3), 1.8, 2.0, 2.0, 1.9, 1.8. What would you suggest as the best estimate and uncertainty based on his measurements?
(b) He is told that the accepted value is 1.85 gm/cm^3. What is the discrepancy (between his best estimate and the accepted value)? Do you think it significant?

***2.12** (Section 2.7). In order to calculate the acceleration of a cart, a student measures its initial and final velocities, v_i and v_f, and computes the difference $(v_f - v_i)$. His data in two separate trials (all in cm/sec) are shown in Table 2.8. All four measurements have 1 percent uncertainty.

Table 2.8. Initial and final speeds.

	v_i	v_f
First run	14.0	18.0
Second run	19.0	19.6

(a) Calculate the absolute uncertainties in all four measurements; find the change $(v_f - v_i)$ and its uncertainty in each run.
(b) Compute the percentage uncertainty for each of the two values of $(v_f - v_i)$. (Your answers here, particularly for the second run, illustrate the disastrous results of measuring a small number by taking the difference of two much larger numbers.)

***3.6** (Section 3.2). A visitor to a medieval castle decides to measure the depth of a well by dropping a stone and timing its fall. He finds that the time to fall is $t = 3.0 \pm 0.5$ sec. What does he conclude about the depth of the well?

***3.11** (Section 3.5).

(a) An angle θ is measured as 125 ± 2 degrees, and this value is used to compute $\sin\theta$. Using the rule in (3.23), calculate $\sin\theta$ and its uncertainty.

(b) If a is measured as $a_{\text{best}} \pm \delta a$, and this value used to compute $f(a) = e^a$, what are f_{best} and δf? If $a = 3.0 \pm 0.1$, what is e^a and its uncertainty?

(c) Repeat the whole of part (b) for the function $f(a) = \ln a$.

***3.19** (Section 3.9). If we measure three independent quantities x, y, z, and then calculate a function like $q = (x + y)/(x + z)$, then, as was discussed at the beginning of Section 3.9, a step-by-step calculation of the uncertainty in q may overestimate the uncertainty δq.

(a) Consider the measured values $x = 20 \pm 1$, $y = 2$, $z = 0$; and, for simplicity, suppose that δy and δz are negligible. Calculate the uncertainty δq correctly, using the general rule in (3.47), and compare the result with what you would get if you were to calculate δq in steps.

(b) Do the same for the values $x = 20 \pm 1$, $y = -40$, $z = 0$. Explain any differences between parts (a) and (b).

*4.7 (Section 4.3).

(a) Calculate the mean $\bar{t}$ and standard deviation σ_t of the following 30 measurements of a time t (all in sec). You will need a calculator, but

8.16, 8.14, 8.12, 8.16, 8.18, 8.10, 8.18, 8.18, 8.18, 8.24,
8.16, 8.14, 8.17, 8.18, 8.21, 8.12, 8.12, 8.17, 8.06, 8.10,
8.12, 8.10, 8.14, 8.09, 8.16, 8.16, 8.21, 8.14, 8.16, 8.13.

(b) We have seen that after many measurements we can expect about 70 percent of all values to be within σ_t of $\bar{t}$ (i.e., inside the range $\bar{t} \pm \sigma_t$). In Chapter 5 we will show that we can also expect about 95 percent of all values to be within $2\sigma_t$ of $\bar{t}$ (i.e., inside the range $\bar{t} \pm 2\sigma_t$). For the measurements of part (a), about how many would you expect to lie *outside* the range $\bar{t} \pm \sigma_t$? How many do? Answer the same questions for the number outside $\bar{t} \pm 2\sigma_t$.