Appendix D
Answers to Exercises

Answers to Exercises in § 5.6

1 a) 43.2 m ± 0.0023
b) 2.0613×10^{-6} kg ± 0.00053
c) -5.639 s ± 0.0055

2 a) $2063. \pm 89.$ N
b) $(6.0721 \pm 0.0019) \times 10^{-15}$ J
c) $-19.3 \pm 2.3°$ C

3 a) 17.30 ± 0.02 m
b) 6.154 ± 0.034 s
c) 57.3 ± 2.9 K
d) 20.000 ± 0.006 N

4 a) $F = 1.185 \pm .040$ N $= 1.185$ N $\pm 0.034 = 1.185$ N $\pm 3.4\%$
b) $v = 1.498 \pm 0.032$ m s^{-1} $= 1.498$ m s^{-1} $\pm\ 0.021 = 1.498$ m s^{-1} $\pm\ 2.1\%$
c) $W = 4.04 \pm 0.21$ J $= 4.04$ J $\pm 0.052 = 4.04$ J $\pm 5.2\%$

5 disagree, agree, agree, disagree

Answers to Exercises in § 6.3

1. (See Graph 1). Notice the vertical axis does not start at $t = 0$ s. It is rarely necessary for a graph to include the zero, though it often will when convenient.

   If one is looking for a gentle curve in the data, the datum at $S = 0.6$ looks suspect. On the other hand, we cannot tell *a priori* that the data are not supposed to be linear with one slope for $S < 0.6$, and linear again with a gentler slope for $S > 0.6$, which these data seem to indicate. Thus, at this point we are not really justified in "throwing out" the datum at $S = 0.6$.

Typically, experimental trends can be resolved with more than one data point if they are, in fact, real. If we did suspect this bilinear relationship, we would do this experiment again with many more data points, say at $\Delta S = 0.1$ or even 0.05, and see if this suspicion holds up.

As plotted, the data do not lie on a single straight line.

2. (See Graph 2). To generate this graph, we first need to compute all values of t^2 along with their uncertainties. These are tabulated along with the original data below. Notice that even though the absolute uncertainties in t are all the same, the absolute uncertainties for t^2 are *not*.

S (m)	t (± 0.01 s)	t^2 (s^2)
0.2	0.48	0.230 ± 0.010
0.4	0.69	0.476 ± 0.014
0.6	0.88	0.774 ± 0.018
0.8	0.97	0.941 ± 0.019
1.0	1.08	1.166 ± 0.022
1.2	1.19	1.416 ± 0.024
1.4	1.27	1.613 ± 0.025

Notice this time the datum at $S = 0.6$ rather stands out; it is the only datum that does not seem to follow the straight line. At this point, we may wish to go back to the lab and remeasure this datum; perhaps we wrote down the wrong number by mistake.

For the purpose of this exercise, slopes are drawn on the graph without including the datum at $S = 0.6$. Two lines are drawn through the data. One has the minimum slope allowed by the data (labelled m_{min}), the other has the maximum slope allowed by the data (labelled m_{max}).

To measure m_{min}, measure (directly from the graph) the rise and run of the line labelled "m_{min}" between points A and B on Graph 2, carefully interpolating between finest divisions where possible:

$$\begin{aligned}\text{rise (in } t^2) &= 1.580 - 0.245 = 1.335 \text{ s}^2, \\ \text{run (in } S) &= 1.4 - 0.2 = 1.2 \text{ m},\end{aligned}$$

and thus

$$m_{\text{min}} = \frac{1.335}{1.2} = 1.113 \text{ s}^2\,\text{m}^{-1}.$$

To measure m_{max}, measure (directly from the graph) the rise and run of the line labelled "m_{max}" between points C and D on Graph 2, carefully interpolating between finest divisions where possible:

$$\begin{aligned}\text{rise (in } t^2) &= 1.678 - 0.213 = 1.465 \text{ s}^2, \\ \text{run (in } S) &= 1.4 - 0.2 = 1.2 \text{ m},\end{aligned}$$

and thus

$$m_{\max} = \frac{1.465}{1.2} = 1.221 \text{ s}^2\,\text{m}^{-1}.$$

Thus, the slope we report for this graph is given by equation I.11:

$$m = \frac{m_{\max} + m_{\min}}{2} \pm \frac{m_{\max} - m_{\min}}{2} = 1.167 \pm 0.054 \text{ s}^2\,\text{m}^{-1}.$$

Since the slope is given by $2/g \sin\theta$, we can evaluate g. If we have $\sin\theta = 0.174 \pm 0.003$ (absolute, corresponding to $\theta = 10.0 \pm 0^\circ\!.2$),

$$\begin{aligned} g &= \frac{2}{m \sin\theta} = \frac{2 \;\; \text{m}\,\text{s}^{-2}}{(1.167 \pm 0.054)(0.174 \pm 0.003)} = \frac{2 \;\; \text{m}\,\text{s}^{-2}}{(1.167 \pm 4.6\%)(0.174 \pm 1.8\%)} \\ &= 9.85 \text{ m}\,\text{s}^{-2} \pm 6.4\% = 9.85 \pm 0.63 \text{ m}\,\text{s}^{-2}. \end{aligned}$$

Answers to Exercises in § C.1

a) 0.170 ± 0.005 cm

b) 1.760 ± 0.005 mm

c) 1.920 ± 0.005 cm

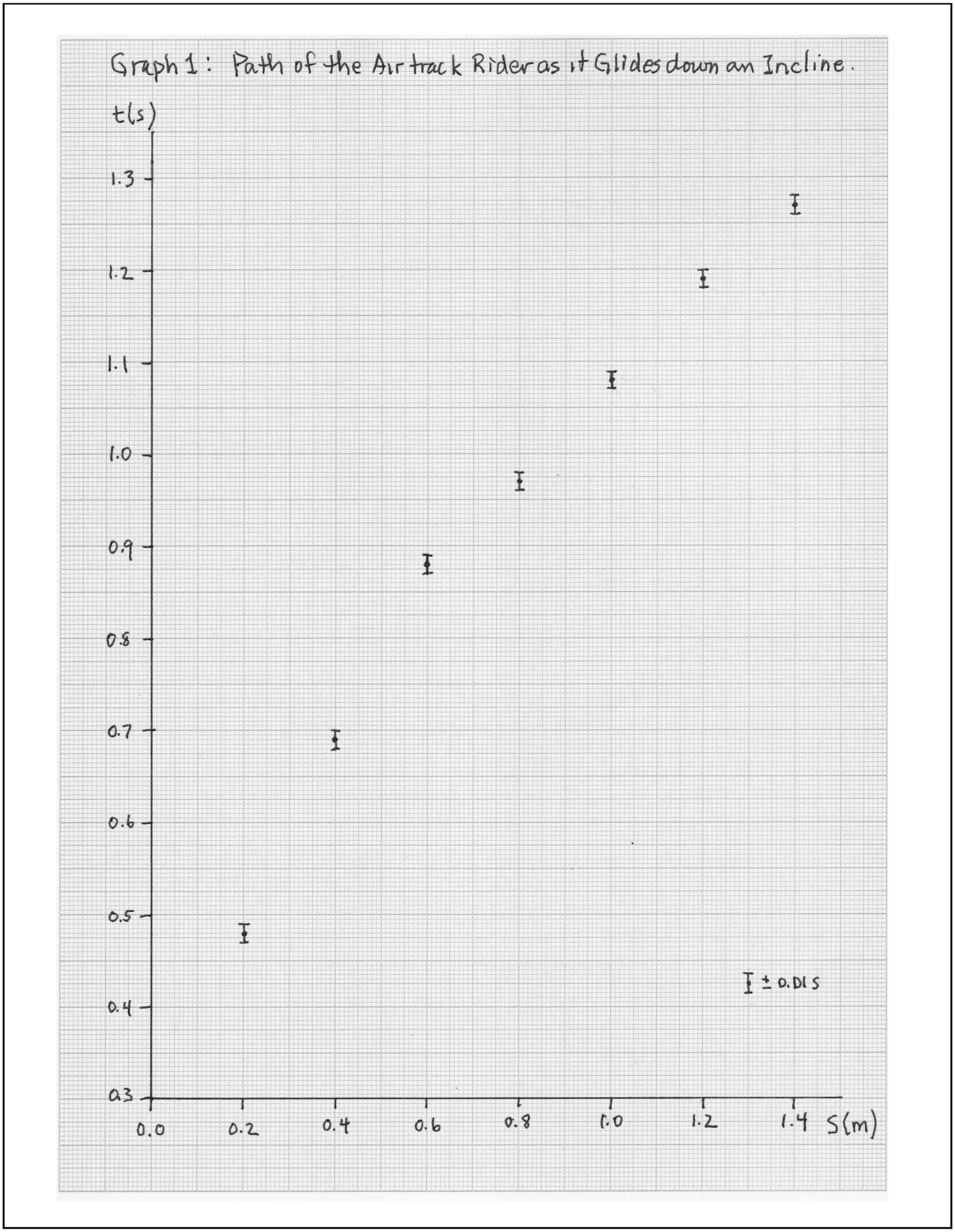
d) 3.335 ± 0.005 cm

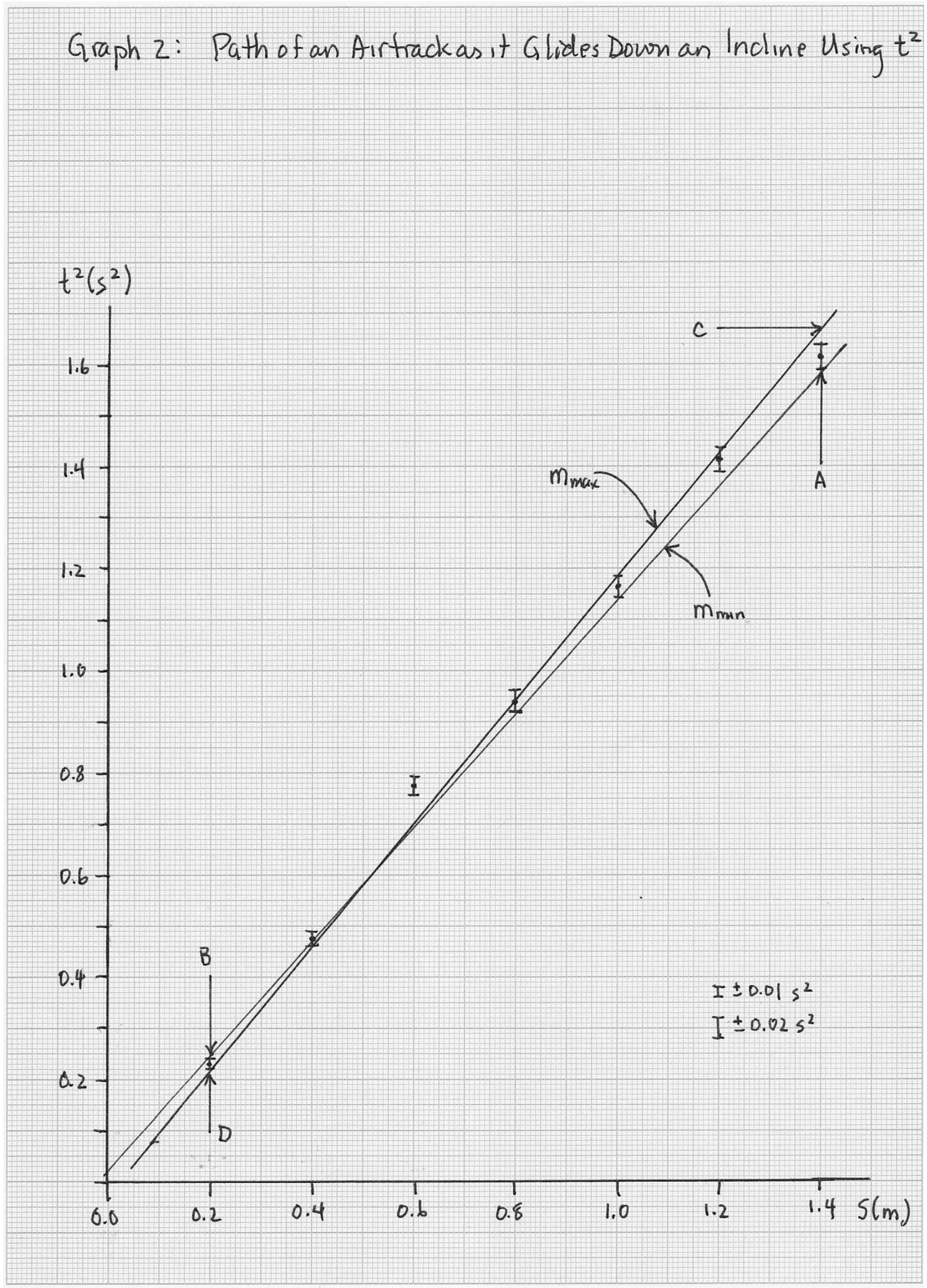
e) 2.990 ± 0.005 cm

f) 3.945 ± 0.005 mm

In parts a, b, c, and e, there is one tick mark on the Vernier scale that clearly lines up best with a tick mark on the main scale above. These cases resemble Fig. C.2a, and the first example in § C.1.

In parts d and f, no tick mark on the Vernier scale lines up perfectly with a tick mark on the main scale, though two are *very* close. These cases resemble Fig. C.2b and the second example in § C.1.


Graph 1: Path of the Air track Rider as it Glides down an Incline.
t(s)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
S(m)
± 0.01 s


Graph 2: Path of an Airtrack as it Glides Down an Incline Using t^2
$t^2(s^2)$
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
$S(m)$
C
A
B
D
m_{max}
m_{min}
I ± 0.01 s^2
I ± 0.02 s^2