1. We can choose to measure time and distance in the same units, either m or s. Try in all cases to find an appropriate prefix like kilo, milli, etc.
   (a) This class lasts 50 min. Express this in meters.
   (b) As of July 2007, Voyager I, the most distant man-made object, is 103 astronomical units (AU) away. What is this distance in hours?
   (c) The distance to Proxima Centauri is quoted as 4.3 light-years. What is this distance in m?
   (d) The half-life of $^{137}\text{I}$ is 24.5 s. Express in m.
   (e) The diameter of a hydrogen atom is $1.06 \times 10^{-10}$ m.

2. (a) A car travels at 60 mph. How far does it travel in 35 ms? (ms = milliseconds)
   (b) A sprinter can complete 100 m in 9 sec. How far does she travel in 35 ms, assuming constant speed?
   (c) In a 100 m dash the winner finishes the race 1.00 foot ahead of his competitor, winning by 0.020 seconds. What is the speed of the winner in m/s?
   (d) How far does a pulse of light travel in 35 ms?
   (e) Find the speed of light in units of ft/ns. (ns = nanosecond = $1 \times 10^{-9}$ s)

3. A rocket is 150 m long. Barbara rides at the front of the rocket, and Betsy rides at the rear. Andrew and his friend Albert stand on the ground and see the rocket move to the right at 200 m/s. At this speed no noticeable relativistic effects occur.
   (a) Andrew and Albert make careful measurements that show they are 100 m apart, with Andrew to the right of Albert. Explain clearly how they made this measurement.
   (b) Andrew and Albert synchronize their watches. Clearly explain the method they use.
      Event 1 is defined as Barbara at the same location as Albert.
Event 2 is defined as Barbara at the same location as Andrew.
Event 3 is defined as Betsy at the same location as Albert.
Event 4 is defined as Betsy at the same location as Andrew.

(c) Draw an event diagram as seen by Andrew for the 4 events clearly showing the locations of each person. Remember that time increases as you move up.

(d) Draw an event diagram as seen by Barbara for the 4 events clearly showing the locations of each person.

(e) Compute the entries for the following table. Note that you are showing results as measured by Andrew in one pair of columns, and Barbara in the other pair. Show me how you get your answers, don’t just give the answer.

<table>
<thead>
<tr>
<th>Interval</th>
<th>Andrew’s Measurements</th>
<th>Barbara’s Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time interval (s)</td>
<td>Distance (m)</td>
</tr>
<tr>
<td>Event 1 to Event 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event 1 to Event 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event 1 to Event 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event 2 to Event 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event 2 to Event 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event 3 to Event 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Approximations are an integral part of doing physics. Consider the Binomial Approximation, \((1 + x)^n\) for small values of \(x << 1\).

\[
(1 + x)^n \approx 1 + nx + \frac{n(n-1)}{2}x^2 + \cdots
\]

If we use terms up to and including \(x^2\) we are making a second order approximation. If we only use terms up to and including \(x\) we are making a first order approximation. If we keep only the constant term (1) we are making a zeroth approximation.

(a) In the next chapter we will use dimensionless speeds, \(\beta = v/c\) and a dilation factor \(\gamma = (1 - \beta^2)^{-1/2}\). Expand \(\gamma\) to second order.

(b) Complete the following table evaluating \(\gamma\) exactly, to second order, and to first order.
(c) For the last two values, very small $\beta$, all three results will look very close. It makes more sense to look at the difference between the $\gamma$ (exact or approximated) and 1, that is at $\gamma - 1$. Compute these for the last two values. In the last line the approximation is better than the values that most calculators can evaluate.

<table>
<thead>
<tr>
<th>$\beta$</th>
<th>$\gamma - 1$ (Exact)</th>
<th>$\gamma - 1$ (Second Order)</th>
<th>$\gamma - 1$ (First Order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$2 \times 10^{-8}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(d) Voyager I is receding from Earth at 3.6 AU/year. Convert this to m/s and then find $\beta$. Finally determine the quantity $\gamma - 1$.

(e) In practice, when making approximations, I want to get a result that is within some tolerance of the correct answer. Define $Error = (Exact - Approx)/Exact$. For what range of $\beta$ will the first order approximation be correct to 1%? Answer based on values you computed in the table.

(f) For what range of $\beta$ will the second order approximation be correct to 1%? Answer based on values you computed in the table.