1. **(20 points)** Assume you do the static equilibrium lab (three forces that add to zero). A mass of 500 g hangs below the knot and you measure the two other forces as:

\[ \vec{F}_1 = 2.0 \text{ N} @ 30^\circ \], \[ \vec{F}_2 = 9.5 \text{ N} @ 115^\circ \]

\[ \vec{F}_3 = 4.9 \text{ N} \]

Draw a VECTOR SUM of these three forces (NOT a free body diagram) and GRAPHICALLY find the net force.

\[ \vec{W} = 4.9 \text{ N} @ 270^\circ \]

\[ \text{IN} = 2 \text{ cm} \]

\[ \vec{F}_{\text{net}} = 10.25 \text{ N} \]

\[ = \frac{5.13 \text{ N}}{180 + 116} \]

\[ = 29.6^\circ \]
2. (15 points) In the energy in collisions lab, you rolled a spring loaded cart down a shallow ramp and measured how far back up the ramp it rolled after bouncing off a wall. Consider a cart (mass of 250 g) with an extra 500 g loaded (so total mass is 750 g) that is allowed to roll 35 cm down a ramp tilted at 2°. Suppose it bounces back up 20 cm. Set the zero level for potential energy at the point the cart just touches the wall.

A) Calculate the starting gravitational potential energy.

\[ U = mgd \sin \theta \]

\[ = (0.75 \text{ kg})(9.8 \text{ N/kg})(0.35 \text{ m}) \sin 2° \]

\[ = 0.0910 \text{ J} \]

B) Calculate the final gravitational potential energy.

\[ = (0.75 \text{ kg})(9.8 \text{ N/kg})(0.20 \text{ m}) \sin 2° \]

\[ = 0.051 \text{ J} \]
3. **(10 points)** For the rolling friction lab, we noted that there is a range of angles for which the cart would not roll, even if the ramp IS tilted. Using the model we developed (\( a = g \sin \theta - \mu g \)) and assuming that the friction coefficient is \( \mu = 0.017 \), find the maximum angle you can tilt the ramp and have the cart NOT roll.

\[
\text{Since the cart is not rolling,} \quad a = 0 = g \sin \theta - \mu g \\
\Rightarrow \sin \theta = \mu = 0.017 \\
\Rightarrow \theta = 0.017 \text{ radians} \approx 0.97 ^\circ
\]
4. **(20 points)** Use the following data (measurements of the distance in cm that a ruler fell before being caught) to construct a frequency histogram (like was done in the first lab).

<table>
<thead>
<tr>
<th>BIN</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 - 9.25</td>
<td>3</td>
</tr>
<tr>
<td>9.25 - 11.5</td>
<td>3</td>
</tr>
<tr>
<td>11.5 - 13.75</td>
<td>5</td>
</tr>
<tr>
<td>13.75 - 16</td>
<td>5</td>
</tr>
</tbody>
</table>

Minimum: 7, maximum: 16

Average: \( \frac{16 - 7}{4} = 2.25 \)

<table>
<thead>
<tr>
<th>BIN</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 - 9.25</td>
<td>3</td>
</tr>
<tr>
<td>9.25 - 11.5</td>
<td>3</td>
</tr>
<tr>
<td>11.5 - 13.75</td>
<td>5</td>
</tr>
<tr>
<td>13.75 - 16</td>
<td>5</td>
</tr>
</tbody>
</table>

To determine if 16 is included in the last bin, count the total frequency and see if it matches the last bin.

Total frequency: 15

Last bin frequency: 5

\[ Q = \frac{15}{5} = 3 \]

16 is included in the last bin if the ratio is 3 or more. Since it is 3, 16 is included.
5. **(15 points)** In the “free fall” lab, you had to calculate the error in the time you measured and then calculate the error in the SQUARED time. Use the same procedure to see how the tolerance in a measurement of the radius of a circle (maybe a hole drilled into a material) translates into the tolerance of the area of the circle (i.e., the hole). (Note that “tolerance” is just another word for error – in this case, it is the error you will allow, or “tolerate”).

Assume a hole of radius 10 mm has a tolerance of 0.3 mm (that is, \( R = (10.0 \pm 0.3) \text{ mm} \)). Calculate the tolerance of the area of that hole (recall that the area of a circle is \( A = \pi R^2 \) where \( R \) is the radius).

\[
\text{Quick and Dirty!} \\
A \pm \sigma_A = \pi \left( R \pm \sigma_R \right)^2 \\
A = \pi R^2 = 314 \text{ mm}^2
\]

\[
314 \text{ mm}^2 \pm \sigma_A = \pi \left( 10.0 \pm 0.3 \right)^2 \text{ mm}^2
\]

\[
+ \sigma_A = 333 \text{ mm}^2 - 314 \text{ mm}^2 = 19 \text{ mm}^2 \\
- \sigma_A = 295 \text{ mm}^2 - 314 \text{ mm}^2 = -18 \text{ mm}^2
\]

**Strictly Correct:**

\[
\frac{\sigma_A}{A} = 2 \cdot \frac{\sigma_R}{R}
\]

\[
\sigma_A = 2A \frac{\sigma_R}{R} = 19 \text{ mm}^2
\]
6. **(20 points)** Recall the projectile lab, for which we developed a model of:

\[ R = \sqrt{\frac{H \sin \theta}{4}} D^{0.5} \]

Suppose the following data is acquired:

<table>
<thead>
<tr>
<th>D [cm]</th>
<th>10</th>
<th>30</th>
<th>50</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>\sqrt{D} [cm^2]</td>
<td>3.16</td>
<td>5.5</td>
<td>7.1</td>
<td>8.9</td>
<td>9.5</td>
</tr>
<tr>
<td>R [cm]</td>
<td>4.5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

Show whether this data confirms the model shown above.

\[
\text{Plot } R \text{ vs } D^{0.5} (= \sqrt{D})
\]

Plot is linear.

Intercept is not zero, but small enough that this may be due to measurement error.