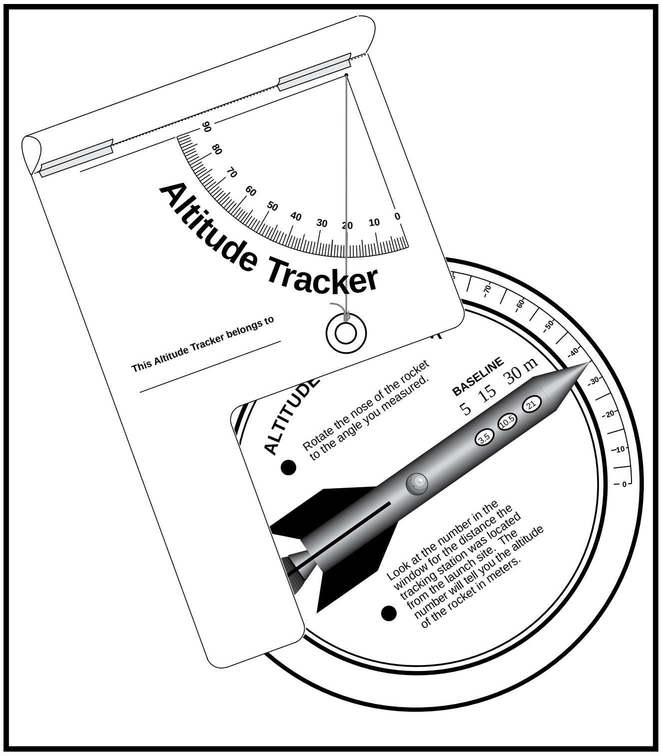


Teacher Information

Altitude Tracking

Objective:
To estimate the altitude a rocket achieves during flight.

Description:
In this activity, students construct simple altitude tracking devices for determining the altitude a rocket reaches in its flight.

Science Standards:
Physical Science - Position and motion of objects

Science Process Skills:
Measuring
Interpreting Data

Mathematics Standards:
Mathematics as Communication
Mathematics as Reasoning
Mathematical Connections
Estimation
Number Sense and Numeration
Geometry and Spatial Sense
Measurement
Trigonometry

Management:
Determining the altitude a rocket reaches in flight is a team activity. While one group of students prepares and launches a rocket, a second group measures the altitude the rocket reaches by estimating the angle of the rocket at its highest point from the tracking station. The angle is then input into the altitude tracker calculator and the altitude is read. Roles are reversed so that everyone gets to launch and to track. Depending upon the number of launches held and whether or not every student makes their own Altitude Trackers and Altitude Calculators, the activity should take about an hour or two. While waiting to launch rockets or track them, students can work on other projects.

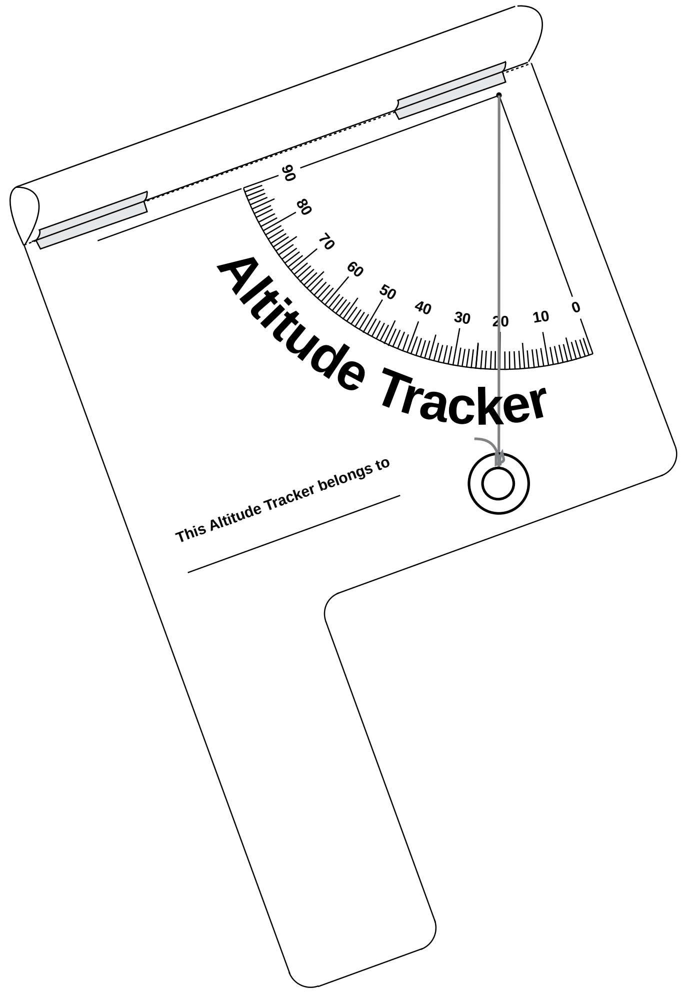
Altitude tracking, as used in this activity, can be used with the *Paper Rockets* (page 51), *3-2-1 Pop!* (page 43), and *Bottle Rockets* (page 81) activities and with commercial model rockets. The Altitude Calculator is calibrated for 5, 15, and 30 meter baselines. Use the 5-meter baseline for *Paper Rockets* and *3-2-1 Pop!* rockets. Use the 15-meter baseline for *Project X-35,* and use the 30-meter baseline for launching commercial model rockets.

For practical reasons, the Altitude Calculator is designed for angles in increments of 5 degrees.

Materials and Tools:
- Altitude tracker pattern
- Altitude calculator pattern
- Thread or lightweight string
- Scrap cardboard or posterboard
- Glue
- Cellophane tape
- Small washer
- Brass paper fastener
- Scissors
- Razor blade knife and cutting surface
- Meter stick or metric
- Rocket and launcher

Younger children, may have difficulty in obtaining precise angle measurements with the Altitude Tracker. For simplicity's sake, round measurements off to the nearest 5 degree increment and read the altitude reached directly from the Altitude Calculator. If desired, you can determine altitudes for angles in between the increments by adding the altitudes above and below the angle and dividing by 2. A more precise method for determining altitudes appears later in the procedures.

A teacher aid or older student should cut out the three windows in in the Altitude Calculator. A sharp knife or razor and a cutting surface works best for cutting out windows. The altitude tracker is simple enough for everyone to make their own, but they can also be shared. ★Students should practice taking angle measurements and using the calculator on objects of known height such as a building or a flagpole before calculating rocket altitude.



Background Information:

This activity makes use of simple trigonometry to determine the altitude a rocket reaches in flight. The basic assumption of the activity is that the rocket travels straight up from the launch site. If the rocket flies away at an angle other than 90 degrees, the accuracy of the procedure diminishes. For example, if the rocket climbs over a tracking station, where the angle is measured, the altitude calculation will yield an answer higher than the actual altitude reached. On the other hand, if the rocket flies away from the station, the altitude measurement will be lower than the actual value. Tracking accuracy can be increased, by using more than one tracking station to measure the rocket's altitude. Position a second or third station in different directions from the first station. Averaging the altitude measurements will reduce individual error.

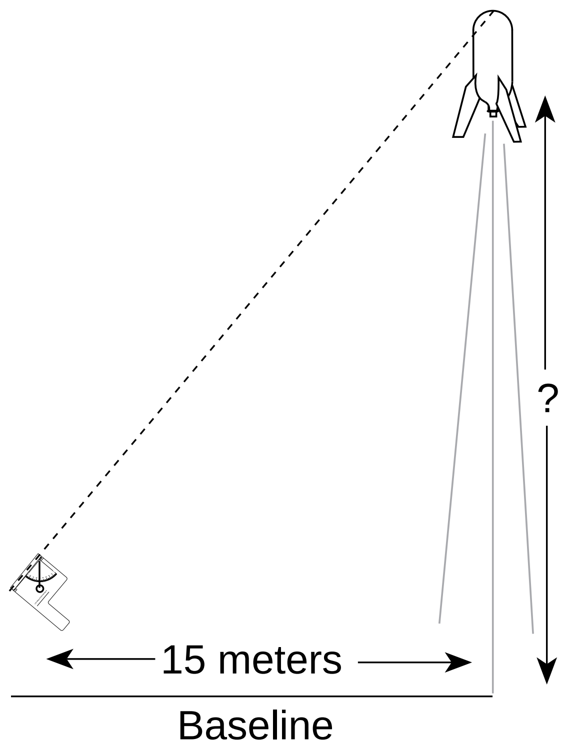
Procedure:
Constructing the Altitude Tracker Scope

1. Glue the altitude tracker pattern on to a piece of cardboard. Do not glue the dotted portion of the tracker above the dashed line.
2. Cut out the pattern and cardboard along the outside edges.
3. Roll the part of the pattern not glued to the cardboard into a tube and tape it as shown in the illustration.
4. Punch a tiny hole in the apex of the protractor quadrant.
5. Slip a thread or lightweight string through the hole. Knot the thread or string on the back side.
6. Complete the tracker by hanging a small washer from the other end of the thread as shown in the diagram above.

Procedure:
Using the Altitude Tracker

1. Set up a tracking station location a short distance away from the rocket launch site. Depending upon the expected altitude of the rocket, the tracking station should be 5, 15, or 30 meters away. (Generally, a 5-meter distance is sufficient for paper rockets and antacid-power rockets. A 15-meter distance is sufficient for bottle rockets, and a 30-meter distance is sufficient for model rockets.

2. As a rocket launches, the person doing the tracking will follow the flight with the sighting tube on the tracker. The tracker should be held like a pistol and kept at the same level as the rocket when it is launched. Continue to



aim the tracker at the highest point the rocket reached in the sky. Have a second student read the angle the thread or string makes with the quadrant protractor. Record the angle.

Procedure:
Constructing the Altitude Calculator

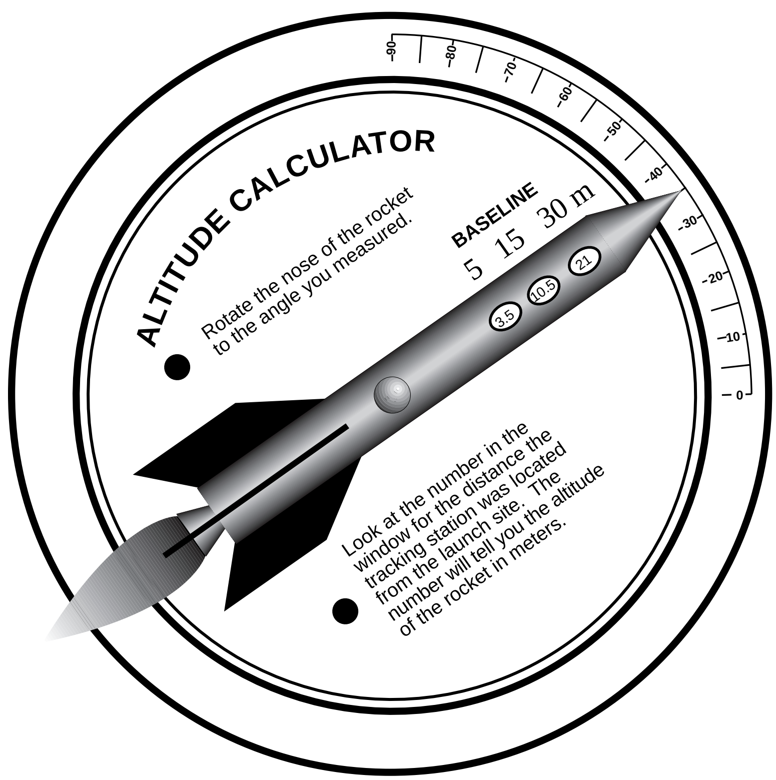
1. Copy the two patterns for the altitude calculator onto heavy weight paper or glue the patterns on to light weight posterboard. Cut out the patterns.
2. Place the top pattern on a cutting surface and cut out the three windows.
3. Join the two patterns together where the center marks are located. Use a brass paper fastener to hold the pieces together. The pieces should rotate smoothly.

Procedure:
Determining the Altitude

1. Use the Altitude Calculator to determine the height the rocket reached. To do so, rotate the inner wheel of the calculator so that the nose of the rocket pointer is aimed at the angle measured in step 2 of the previous procedure.
2. Read the altitude of the rocket by looking in the window. If you use a 5-meter baseline, the altitude the rocket reached will be in the window beneath the 5. To achieve a more accurate measure, add the height of the person holding the tracker to calculate altitude. If the angle falls between two degree marks, average the altitude numbers above and below the marks.

Advanced Altitude Tracking:

1. A more advanced altitude tracking scope can be constructed by replacing the rolled sighting tube with a fat milkshake straw. Use white glue to attach the straw along the 90 degree line of the protractor.



2. Once you determine the angle of the rocket, use the following equation to calculate altitude of the rocket:

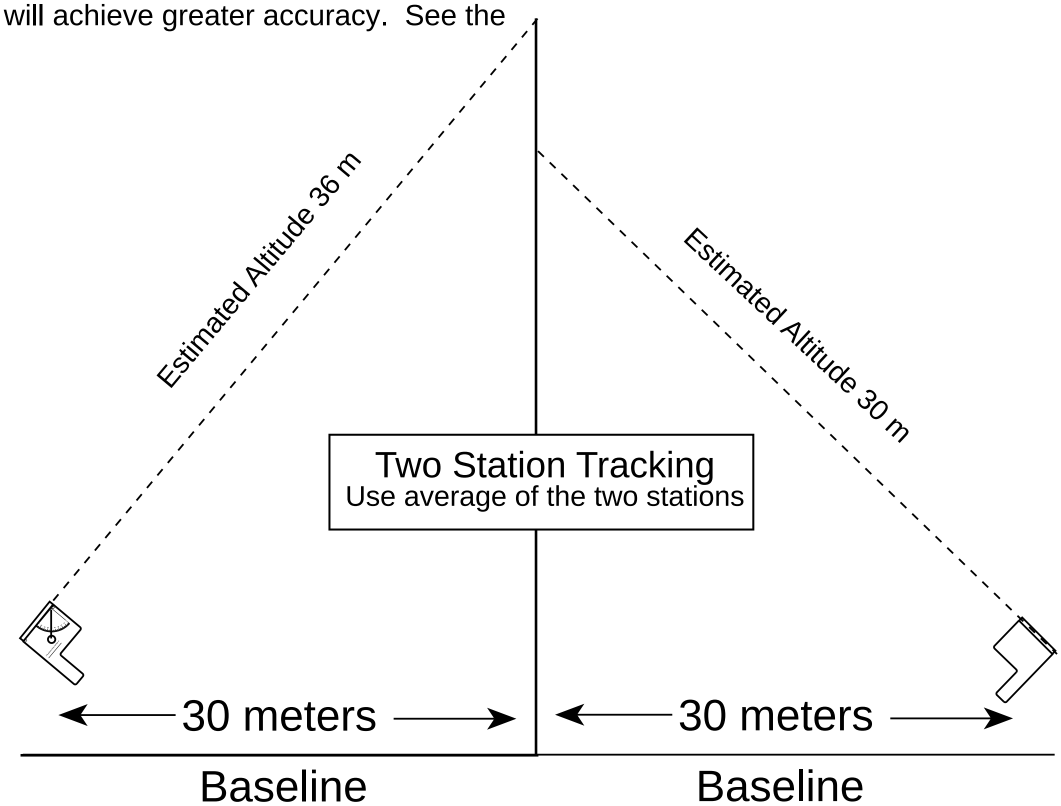
$$Altitude = \tan\angle \times baseline$$

Use a calculator with trigonometry functions to solve the problem or refer to the tangent table on page 86. For example, if the measured angle is 28 degrees and the baseline is 15 meters, the altitude is 7.97 meters.

$$Altitude = \tan 28^{o} \times 15m$$

$$Altitude = 0.5317 \times 15m = 7.97m$$

3. An additional improvement in accuracy can be obtained by using two tracking stations. Averaging the calculated altitude from the two stations will achieve greater accuracy. See the figure below.



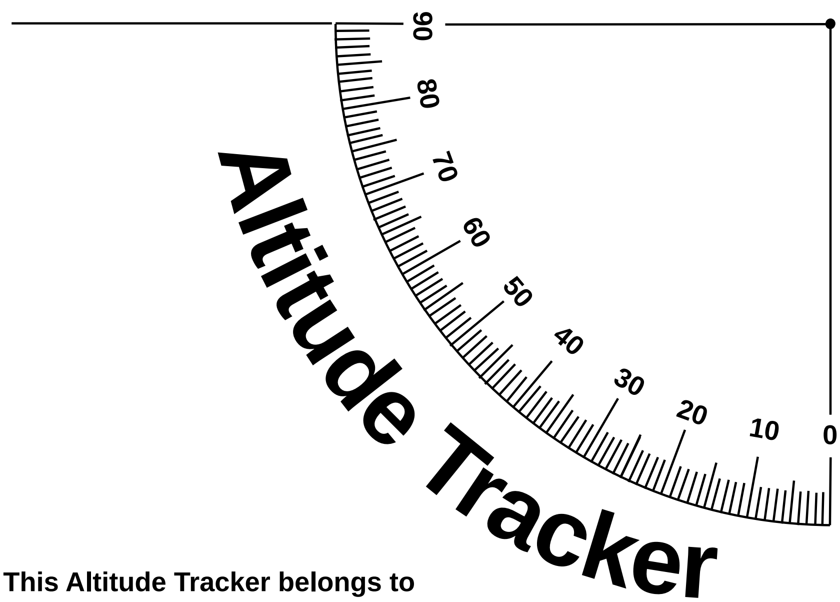
Assessment:

Have students demonstrate their proficiency with altitude tracking by sighting on a fixed object of known height and comparing their results. If employing two tracking stations, compare measurements from both stations.

Extensions:

- Why should the height of the person holding the tracker be added to the measurement of the rocket's altitude?
- Curriculum guides for model rocketry (available from model rocket supply companies) provide instructions for more sophisticated rocket trcking measurements. These activities involve two-station tracking with altitude and compass direction measurement and trigonometric functions.

Roll this section over and tape the upper edge to the dashed line. Shape the section into a sighting tube.



This Altitude Tracker belongs to

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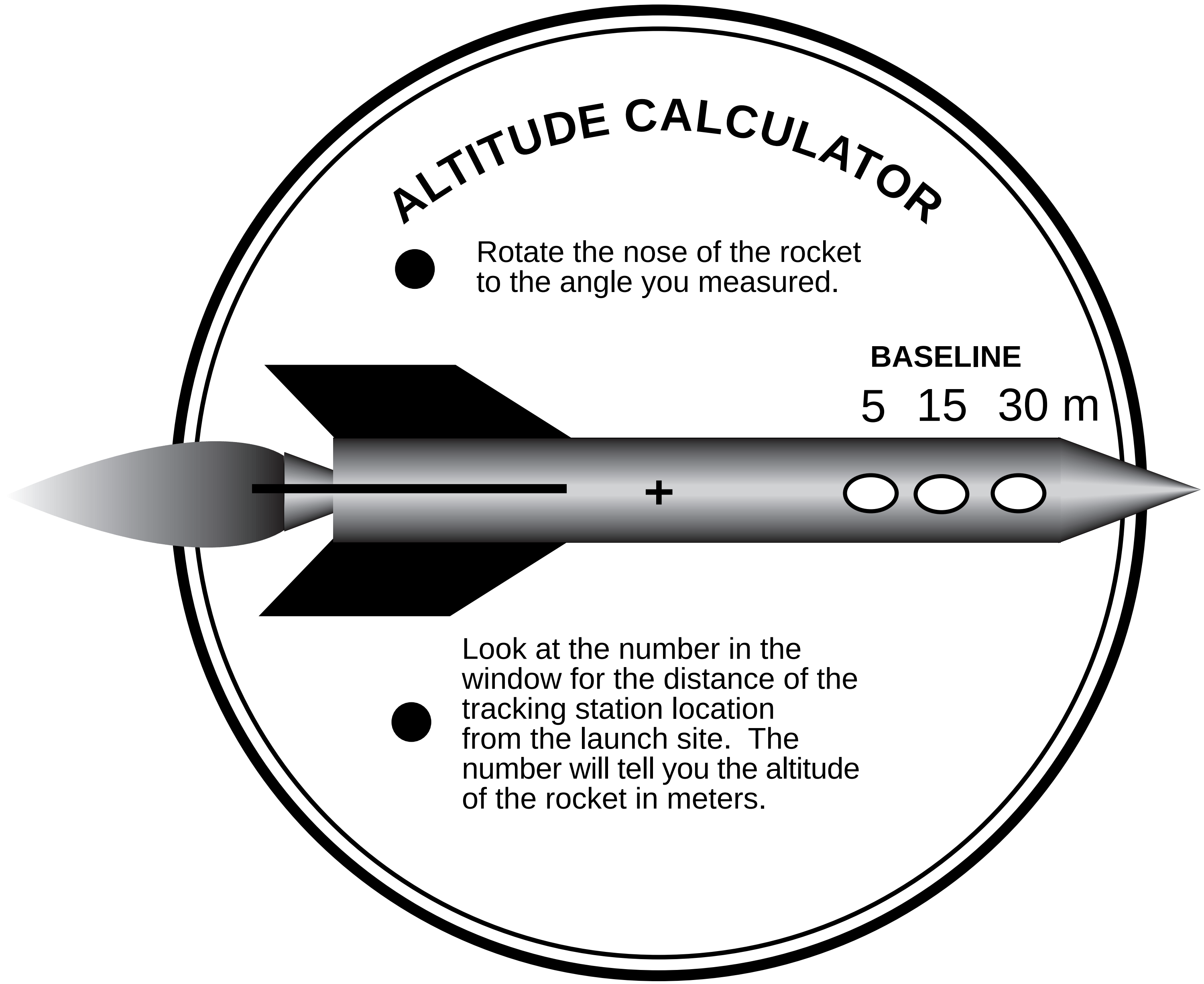
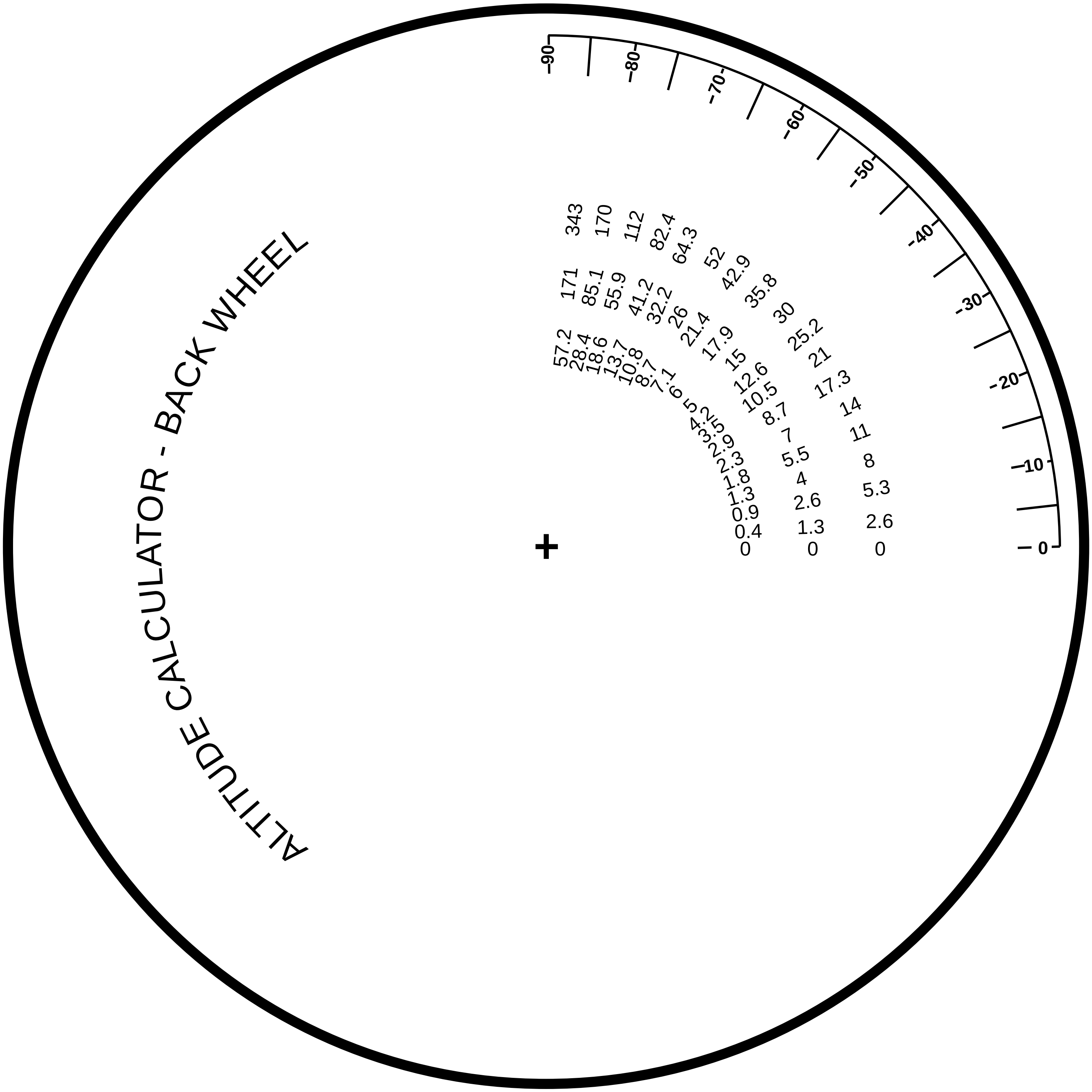

ALTITUDE CALCULATOR
Rotate the nose of the rocket to the angle you measured.
BASELINE
5 15 30 m
+
Look at the number in the window for the distance of the tracking station location from the launch site. The number will tell you the altitude of the rocket in meters.


ALTITUDE CALCULATOR - BACK WHEEL
90
80
70
60
50
40
30
20
10
0
343 170 112 82.4 64.3 52 42.9 35.8 30 25.2 21 17.3 14 11 8 5.3 2.6 0
171 85.1 55.9 41.2 32.2 26 21.4 17.9 15 12.6 10.5 8.7 7 5.5 4 2.6 1.3 0
57.2 28.4 18.6 13.7 10.8 8.7 7.1 6 5.2 4.3 3.5 2.9 2.3 1.8 1.3 0.9 0.4 0

Tangent Table

Degree	Tan	Degree	Tan	Degree	Tan
0	0.0000				
1	0.0174	31	0.6008	61	1.8040
2	0.0349	32	0.6248	62	1.8807
3	0.0524	33	0.6494	63	1.9626
4	0.0699	34	0.6745	64	2.0603
5	0.0874	35	0.7002	65	2.1445
6	0.1051	36	0.7265	66	2.2460
7	0.1227	37	0.7535	67	2.3558
8	0.1405	38	0.7812	68	2.4750
9	0.1583	39	0.8097	69	2.6050
10	0.1763	40	0.8390	70	2.7474
11	0.1943	41	0.8692	71	2.9042
12	0.2125	42	0.9004	72	3.0776
13	0.2308	43	0.9325	73	3.2708
14	0.2493	44	0.9656	74	3.4874
15	0.2679	45	1.0000	75	3.7320
16	0.2867	46	1.0355	76	4.0107
17	0.3057	47	1.0723	77	4.3314
18	0.3249	48	1.1106	78	4.7046
19	0.3443	49	1.1503	79	5.1445
20	0.3639	50	1.1917	80	5.6712
21	0.3838	51	1.2348	81	6.3137
22	0.4040	52	1.2799	82	7.1153
23	0.4244	53	1.3270	83	8.1443
24	0.4452	54	1.3763	84	9.5143
25	0.4663	55	1.4281	85	11.4300
26	0.4877	56	1.4825	86	14.3006
27	0.5095	57	1.5398	87	19.0811
28	0.5317	58	1.6003	88	28.6362
29	0.5543	59	1.6642	89	57.2899
30	0.5773	60	1.7320	90	------------