Model and Remote Controlled Airplane Revised AeroLab Guidance
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Rio Rancho Falcon Civil Air Patrol Squadron, New Mexico, April 2014

AeroLab 1: Average Speed

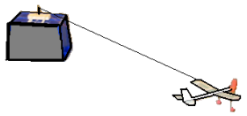
Team Members:
1)
2)
3)

Background: Average speed is the distance traveled divided by an elapsed time.
If you drive 100 miles in 2 hours, your average speed would be 50 miles/hour.
The formula for calculating average speed:

$$\textbf{Average Speed} = \frac{\textbf{Distance}}{\textbf{Time}}$$

Directions: Determine the average speed of a *JETSTREAM*.

1) Calculate the distance your plane will fly around the pylon in one revolution:
The **radius** from the pylon to the fuselage = _____ meters.

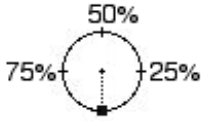


One lap = Circumference = $2\pi r$ = _____ meters.

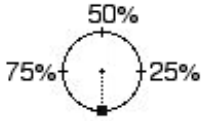
2) After winding 1000 times, release and note the exact point of takeoff.
Record the takeoff point on each circle below. (The release point is represented by the dot at the bottom of the circle.)
Time how many seconds the plane flies around the pylon while a third person counts the laps.
Stop timing and counting the instant the plane touches down.
Wind the rubber motor of the plane the same number of times for each trial.

3) Record your data in the table below:

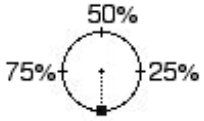
LAPS AND FLIGHT TIME OF THE JETSTREAM			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___ %



Takeoff = ___ %



Takeoff = ___ %

4) Calculate the average speed of your *JETSTREAM*.

$$\textbf{Average Speed} = \frac{\textbf{Distance}}{\textbf{Time}} = \frac{(\textbf{Average Laps} \times \textbf{Circumference})}{\textbf{Average Seconds}} = \_\_\_\_\_ \textbf{ m/sec}$$

Can you convert that to miles-per-hour?

Directions: Write the answer on the line that precedes each question.

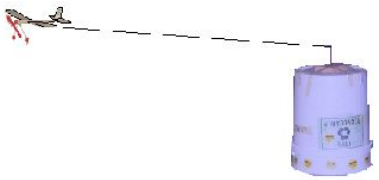
1. _____ Which of the following equations is true? (c = circumference, d = diameter, and r = radius)
   A) r = c
   B) c = 2πr
   C) r = 2dc
   D) c = πr

2. _____ The formula for speed is…
   A) time x distance
   B) distance / time
   C) speed / distance
   D) speed / time

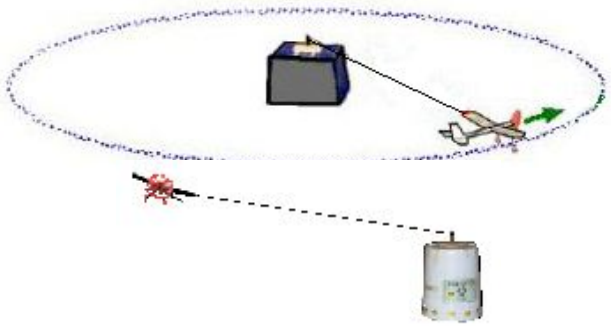
3. _____ The radius of the flight circle is measured from the nail on the pylon to…
   E) the end of the string
   T) the tip of the outer wing
   F) the fuselage

4. _____ If the radius were measured in inches instead of meters, the units for the average speed would be…
   A) Meters per inch
   B) Miles per hour
   C) Inches/second
   D) Feet per second

5. _____ How would you determine the average speed of a JETSTREAM?
   A) Divide the total distance flown by the time in the air.
   B) Multiply the number of laps by the time in the air.
   C) Multiply total distance flown by the time in the air
   D) Divide the number of laps by the time in the air.



6. _____ Both Sally's plane and Tyrone's plane flew a total of 5 laps on the same pylon. The total time for Sally's plane was 10 seconds and the total time for Tyrone's plane was 13 seconds. Which plane was faster?
   A) Sally's plane
   B) Can't tell
   C) Same speed
   D) Tyrone's plane



7. _____ The distance flown is equal to…
   A) # of laps x Circumference
   B) # of laps x Circumference / time
   C) Radius x Circumference
   D) # of laps x Radius

10. _____ Which value for π is NOT appropriate to use?
   A) 3.14159
   B) 3
   C) 3.14
   D) 22/7

11. _____ What would be the average laps, if the three trials were 6.8 laps, 7.9 laps and 6.3 laps?
   A) 6.8
   B) 7.0
   C) 10.5
   D) 2

AEROLAB 2: Examining Variables

Background: When conducting experiments, one needs to deal with *variables*, those factors or elements that are likely to vary or change. A typical study has an *independent variable* and a *dependent variable*.

The independent (or manipulated) variable is something that the experimenter purposely changes or varies over the course of the investigation. For example, you might change the position of the wing to see how it affects the average speed of a model plane.

The dependent (or responding) variable is the one that is observed and likely changes in response to the independent variable. In the example above, the average speed of the plane is the dependent variable because it is expected to change as a result of moving the position of the wing.

When conducting an experiment, all other variables must be kept the same throughout the investigation; they should be *controlled*. The variables that are not changed are called *controlled variables*.

Directions: You will be designing an experiment to see **what affects the average speed** of a *JETSTREAM*. Work with your partners and answer the questions below:

1) What factors may increase or decrease the average speed of your *JETSTREAM*? List a few ideas:

2) We plan to investigate/change the following variable:

3) We plan to keep the following variables the same throughout our investigation:

4) Calculate the distance your plane will fly around the pylon:

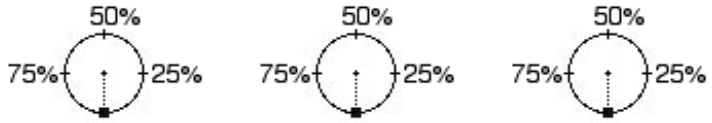
The radius from the pylon to the fuselage = _____ meters

One revolution = Circumference = $2\pi r$ = _____ meters

5) After winding your plane 1000 times, release it and note the exact point of takeoff. Record the takeoff point on each circle below. (The release point of the plane is represented by the dot at the bottom of the circle.) Time how many seconds the plane flies in the air around the pylon and count the laps in the air. Stop timing and counting laps the instant the plane touches down. Wind the rubber motor of the plane the same number of times for each trial.

6) Record your data in the table below:

LAPS AND FLIGHT TIME OF THE JETSTREAM			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___ % Takeoff = ___ % Takeoff = ___ %

7) Calculate the average speed of your JETSTREAM.

Average Speed = $\frac{\textbf{Distance}}{\textbf{Time}}$ = ($\frac{\textbf{Average Laps x Circumference}}{\textbf{Average Seconds}}$) = _____ **m/sec**

8) We investigated/changed the following variable:

9) What was the result?

10) Was the average speed of this experiment different from your initial unmodified flights? Why or why not?

AEROLAB 3: Potential Energy

Background: When you wind the rubber motor of a model plane, you are storing **potential energy**. This energy is transformed into **kinetic energy** when you launch the plane. According to Newton's 2nd law, F=MA, planes with more turns on the rubber motor will generate more thrust and accelerate faster than planes with less thrust. As thrust accelerates the plane forward, the wings of the plane generate lift. Drag, the resistance to forward motion, is a by-product of the plane's passage through the air. As the plane accelerates, **drag increases until the drag equals thrust**, causing the plane to fly at constant speed. **At this point lift also equals weight**. Planes with more potential energy will generate more thrust and will fly farther and faster.

Directions: You will study how increasing the turns in a rubber motor will affect a plane's average speed and flight distance. Work with your team and choose one plane to study.

1) Finish this hypothesis: If thrust increases, then…

List three variables you should keep the same every time you test the plane.
2)
3)
4)

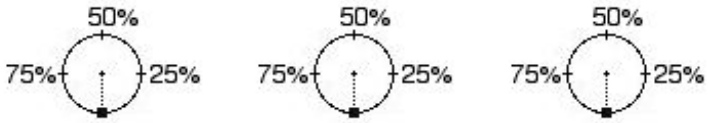
5) The radius from the pylon to the fuselage = _____ meters

6) One revolution = Circumference = $2\pi r$ = _____ meters

7) Flying your *JETSTSREAM* with 600 turns on the rubber motor:

- Move the wing to balance the plane. Mark the wing position. Put 600 turns on your rubber motor.
- Execute and record three trials:

JETSTREAM WITH 600 TURNS ON THE RUBBER MOTOR			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___% Takeoff = ___% Takeoff = ___%

8) **Distance Plane Flew with 600 Turns = Average Laps x Circumference = _____ m**

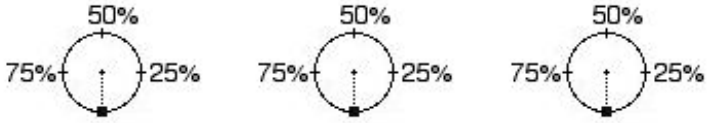
9) Calculate the average speed of your *JETSTREAM* with **600 turns**:

Average Speed = **Distance** = **Distance Plane Flew** = **_____ m/sec**
Time Average Seconds

10) Flying your *JETSTSREAM* with 800 turns on the rubber motor:

- Move the wing to balance tht plane. Mark the wing position. Put 800 turns on your rubber motor.
- Execute and record three trials:

JETSTREAM WITH 800 TURNS ON THE RUBBER MOTOR			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___% Takeoff = ___% Takeoff = ___%

11) **Distance Plane Flew with 800 Turns = Average Laps x Circumference = _____ m**

12) Calculate the average speed of your *JETSTREAM* with 800 turns:

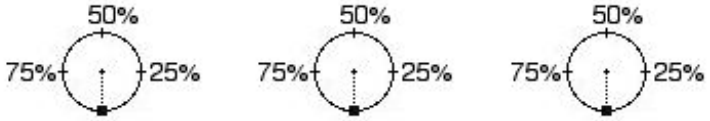
Average Speed = **Distance** = **Distance Plane Flew** = **_____ m/sec**
Time Average Seconds

13) Flying your *JETSTSREAM* with 1000 turns on the rubber motor:

- Move the wing to balance the plane. Mark the wing position. Put 1000 turns on your rubber motor.

- Execute and record three trials:

JETSTREAM WITH 1000 TURNS ON THE RUBBER MOTOR			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___% Takeoff = ___% Takeoff = ___%

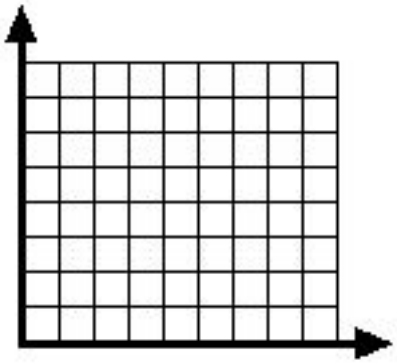
14) **Distance Plane Flew with 1000 Turns = Average Laps x Circumference = _____ m**

15) Calculate the average speed of your *JETSTREAM* with 1000 turns:

Average Speed = $\frac{\text{Distance}}{\text{Time}} = \frac{\text{Distance Plane Flew}}{\text{Average Seconds}} =$ **_____ m/sec**

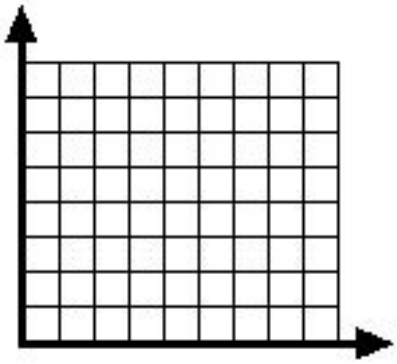
16) Graph your data:

Average Distance JETSTREAM Flew in the Air (meters)



Number of Turns on Rubber Motor

Average Speed (m/s) JETSTREAM Flew in the Air



Number of Turns on Rubber Motor

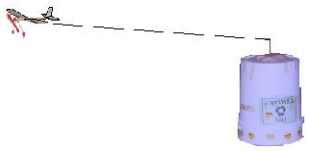
17) How did changing the number of turns on the rubber motor affect the takeoff distance?

18) How did changing the number of turns on the rubber motor affect the average distance flown?

19) How did changing the number of turns on the rubber motor affect the average speed of the plane?

AEROLAB 4: Weight and Balance

Background: When you wind up the rubber motor of a model plane, you are **storing potential energy**. This **energy is transformed into kinetic energy** when you launch the plane. As thrust accelerates the plane forward, the wings of the plane generate lift. As a plane goes faster, lift increases.



According to Newton's 2nd Law, F=MA, if mass is added to a plane and thrust remains the same, the plane will accelerate more slowly, thereby delaying take off. Lift is equal to weight when a plane flies level and at constant speed. For example, a 15-gram plane generates 15 grams of lift. A *JETSTREAM* with added mass will have greater kinetic energy (but less potential energy) than a lighter *JETSTREAM*.

Directions: Add pennies to the plane to study how added weight affects flight

2) Finish this hypothesis: If weight increases, then…

3) List at least three variables you should keep the same every time you test your plane.

4) In addition to weight, what variable is also affected when you add pennies to your plane?

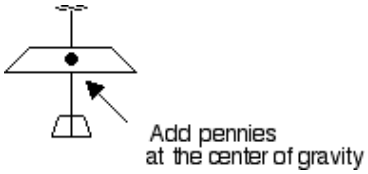
4) Calculate the distance your plane will fly around the pylon:

The radius from the pylon to the fuselage = _____ meters

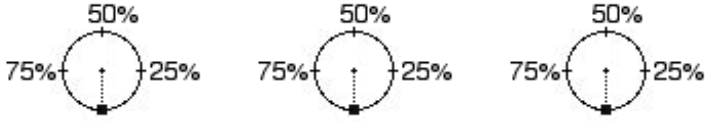
One revolution = Circumference = $2\pi r$ = _____ meters

7) Fly your *JETSTREAM* with added weight

- Add 1 penny to the exact center of gravity (about 1/4 of the way back from the front of the wing) and collect data. Adjust your wing so that it is back at the marked location. Collect data using the same procedure as before.



JETSTREAM WITH ADDED MASS			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___ % Takeoff = ___ % Takeoff = ___ %

8) Calculate the average speed of your *JETSTREAM* with added weight.

Average Speed = **Distance** = (**Average Laps x Circumference**) = _____ **m/sec**
Time **Average Seconds**

9) How did the addition of weight affect the takeoff distance?

10) Why did the heavier plane fly the way it did? Discuss the relationship between its greater weight, kinetic energy and potential energy

11) How did the addition of weight affect the flight time?

AEROLAB 5: Effect of Drag

Background: When you wind up the rubber motor you are **storing potential energy**. This **energy is transformed into kinetic energy** when you launch the plane. Drag, the resistance to forward motion, is a by-product of the plane's passage through the air, and it slows the plane down. Adding yarn to a plane increases drag. If yarn is added to a plane (but thrust remains the same) the plane will accelerate more slowly, thereby delaying takeoff according to Newton's 2nd Law, F=MA. As thrust accelerates the plane forward, the wings of the plane generate lift. Both lift and drag are proportional to speed *squared*. Drag increases until it equals thrust, causing the plane to fly at a constant speed. When the plane flies level and at constant speed, weight equals lift and drag equals thrust. Drag limits the speed of a plane. In general, planes with more drag need more thrust to fly.

Directions: Add yarn to your plane to study how the increased drag affects flight.

1) Finish this hypothesis: If drag increases, then _____

List at least three variables you should keep the same every time you test your plane.
2)
3)
4)

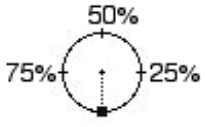
5) The radius from the pylon to the fuselage = _____ meters

6) One revolution = Circumference = $2\pi r$ = _____ meters

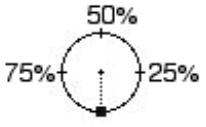
7) Fly your *JETSTREAM* with added drag.

- Attach 50 – 80 cm of yarn to the tip of each wing. Adjust your wing so that it is back at the marked location. Collect data using the same procedure as before.

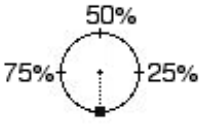
JETSTREAM WITH ADDED YARN			
Trial 1	**Trial 2**	**Trial 3**	**Averages**
Laps =	Laps =	Laps =	Average Laps =
Seconds =	Seconds =	Seconds =	Average Seconds =



Takeoff = ___ %



Takeoff = ___ %



Takeoff = ___ %

8) Calculate the average speed of your *JETSTREAM* with added drag.

Average Speed = $\frac{\textbf{Distance}}{\textbf{Time}} = \frac{\textbf{(Average Laps x Circumference)}}{\textbf{Average Seconds}} =$ **_____ m/sec**

9) What does the data show? **Summarize.**

10) _____ Which plane seemed to fly at a slower speed?
A) The plane **without yarn** was slower.
B) B) The plane **with yarn** was slower

11) _____ Which plane seemed to climb to a higher altitude?
A) The plane **without yarn** climbed to a higher altitude.
B) The plane **with yarn** climbed to a higher altitude.

12) _____ In addition to increasing drag, what other variable is changed when yarn is added to the plane?

13) _____You may have "flown" your hand out of a car window at fast and slow speeds. Use your experience to answer this question: What happens to ***lift*** when the car (or an airplane) slows down?

I) Lift **Increases** as the car (or plane) slows down
D) Lift **Decreases** as the car (or plane) slows down

14) How did the addition of yarn affect the takeoff distance?

15) Was the *potential energy* of your plane changed when yarn was added to it? Why or why not?

16) Why did the plane with yarn behave the way it did?

17) Discuss the relationship between the plane's drag and speed.

18) Discuss what happens to the lift when yarn is added.

AEROLAB 6: Center of Gravity

Background: The center of gravity of the plane is the point at which it could be balanced

Directions: Determine how changing the center of gravity affects the flight of a *JETSTREAM*.

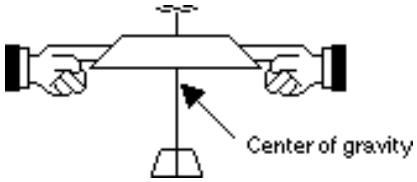
1) Calculate the distance your plane will fly around the pylon in one revolution:

The **radius** from the pylon to the fuselage = _____ meters

One revolution = Circumference = $2\pi r$ = _____ meters

2) Move your wings forward in the slot, toward the nose of the plane.

3) Use your fingers to support your plane at the end of each wing. Please note that the center of gravity is behind the center of lift of the wings.



4) How does your plane balance when you hold it by its wings? Check one:

_____ Its nose is pointed up.

_____ The plane is level and balanced.

_____ Its nose is pointed down.

5) Make sure that your wing is still all the way forward. Wind the rubber motor with a winder and attach your plane to a pylon. Wind your rubber motor the same number of times for each trial. Release your plane and watch it fly. Repeat this procedure two more times and record your data in the table on side two of this sheet.

6) Record your data in this table:

Wing Placement (cm)	Number of Revolutions in the Air around Pylon:			Average Number of Revolutions in the Air	Average Distance Flown (m)
	Trial 1	Trial 2	Trial 3		
Forward in the slot (0 cm back)					
1 cm back					
2 cm back					

7) Calculate the Average Distance your *JETSTREAM* flew:

Average Distance = Distance in one Revolution x Average Number of Revolutions in the Air

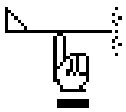
8) How did your plane behave during its flights when the wings were near the nose? Draw and explain.

9) How did your plane behave during its flights when the wing was toward the tail? Draw and explain.

10) What wing placement resulted in the greatest average distance flown?

11) How would you position the wings to ensure a long flight? Check one:

____ The wing should be closer to the nose (in front of the center of gravity).



____ The wing should be positioned near the center of gravity.

____ The wing should be positioned near the tail (behind the center of gravity).

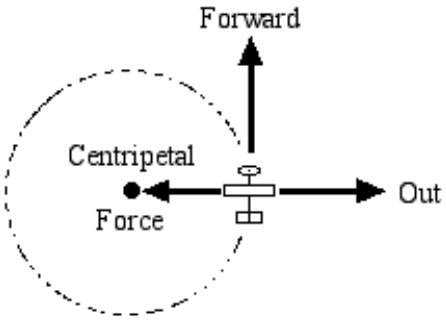
AEROLAB 7: Centripetal & Centrifugal Force

Background Information about Inertia and Centripetal Force: According to Newton's 1st law, inertia, a plane at rest will remain at rest until a force acts on it. A plane with 1000 turns on the rubber motor will create the thrust necessary to accelerate it forward. Once the plane is in motion, it will stay in motion in a straight line until a force (like drag, gravity or the string) acts on it. If the pylon string breaks, the inertia of the plane would cause it to fly forward.

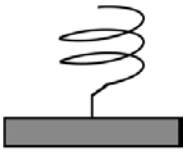
Centripetal force pulls the plane toward the center of the curved path. The pylon string applies the centripetal force and counteracts the inertia and velocity of the plane. The centripetal force causes the plane to change direction and fly in a circular path.

Directions: In this activity, you will work with a *JETSTREAM* and a pylon helix. You will predict the direction the plane will fly once centripetal force no longer acts on it.

1) In what direction will the plane fly once centripetal force no longer acts? Circle your answer.



Centrifugal Force



2) Wind the rubber motor of your *JETSTREAM* 1000 times.

3) Hook one end of the pylon string to the wing. Hook the other end of the string to the pylon helix.

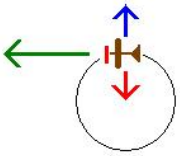
4) In what direction did your plane fly once centripetal force stopped acting on the plane?

5) Rotate the pylon helix so that its end points in a new direction before the next flight.

6) Repeat the procedure.

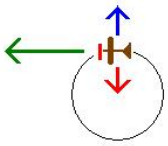
Note: The string attached to the wing may cause the plane to turn and the plane may not fly perfectly straight.

7. _____ A plane is flying around its pylon. In what direction is centripetal force acting?
   I) Inward
   O) Outward
   S) Straight



8. _____ A plane is flying around its pylon when its string breaks. In what direction will the plane fly according to Newton's law of inertia?

O) Outward
S) Straight
I) Inward



9. _____ A plane is flying in a circular path at constant speed. In what direction is centripetal force acting on the plane?

S) Straight - in the direction of its motion
O) Outward - away from the center of the curve
I) Inward - toward the center of the curve.

Centripetal force is a force that makes a body follow a curved path: its direction is always orthogonal to the velocity of the body, toward the fixed point of the instantaneous center of curvature of the path. Centripetal force is generally the cause of circular motion.

In simple terms, centripetal force is defined as a force which keeps a body moving with a uniform speed along a circular path and is directed along the radius towards the centre.

Centrifugal force is the apparent force that draws a rotating body away from the center of rotation. It is caused by the inertia of the body as the body's path is continually redirected. The term *centrifugal force* is used to refer to one of two distinct concepts: an inertial and a reaction force corresponding to a centripetal force.

These different forces are equal in magnitude, but centrifugal and reactive centrifugal forces are opposite in direction to the centripetal force.

AeroLab 8: Free Flight

Flying the models without landing gear.

Assemble and read the instructions that come with each model.

Note that you should only wind these no more than 100 turns.

1. Does the airplane tend to turn in the same direction while in flight?
2. If so, why might this be happening?
3. Could you devise a way to counter this turning tendency?

AeroLab 9: Determining Thrust

Classroom

Working as a team, devise a means of measuring the relative trust of the “motor”.

Can you engineer a way of tracking the “decay” (lowering) of the thrust as the rubber band unwinds?

Each washer weighs .022 ounces. Can you determine some method of using them to measure the thrust?

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