Prediction vs Observation – the behaviour of masses under acceleration

Aristotle stated that different objects accelerated downwards at rates that depended on their masses – thus if stone A was twice as massive as stone B it would accelerate at twice the rate of stone B.

For two thousand years Aristotle's opinion was unquestioned. Now it is the end of the 16^{th} century. Your name is Galileo Galilei, and you want to see if Aristotle was correct.

It is difficult to observe dropped objects closely since they move so quickly. So your idea is to slow their accelerations by allowing them to roll down a slope instead. By some unknown miracle you have a digital stopwatch (as opposed to bucket of water, a spigot and a graduated cylinder). Maybe the battery has run down, so you're using the timer on your mobile phone. That's okay, it'll do, and you're not expecting any calls.

You have been provided with the following equipment:

1. ball bearings x 5
2. metre-stick
3. tape measure
4. plastic pipe
5. timer / stopwatch
6. retort stands x 2
7. electronic balance
8. vernier callipers

Your challenge is to prove Aristotle right or wrong, just be careful of the Inquisition.

You will roll each of the ball bearings down the pipe at different slopes, all the time collecting data to see what effect mass has on acceleration. You will measure all the physical properties of the ball bearings that might influence their accelerations. Complete the measurements and fill in the values in *Table 1*. Let **A** be the smallest ball bearing and **E** be the largest.

Table 1

Ball Bearing	**Mass g**	**Diameter cm**	**Radius cm**	**Surface Area cm^2**	**Volume cm^3**	**Density $g.cm^{-3}$**
A						
B						
C						
D						
E						

$$Surface\ Area,\ SA = 4\pi r^2;\ Volume,\ V = \frac{4}{3}\pi r^3;\ density,\ \rho = \frac{m}{V}$$

Now, you must make your predictions, based on your experience of the world around you.

Which ball bearing will have the greatest acceleration? In other words, which one will reach the end of the pipe in the shortest time when released from rest at the top?

- ☐ Largest
- ☐ Smallest
- ☐ Other

Will the angle of the pipe change this result?

- ☐ Yes
- ☐ No

If you answered "yes", how will increasing the pipe's angle of incline affect the outcome?

- ☐ It will increase the time gaps between the bearings
- ☐ It will decrease the time gaps between the bearings

Your contemporary, Johannes Kepler, has sent you a video camera by fast mule. So, now you can film the freefall of two dropped masses and view them in slow motion on your laptop. (Don't forget to post the video on your webpage!)

Which one do you think will hit the ground first?

- ☐ The larger one
- ☐ The smaller one

Time to collect data and see if you are as good an observer as you think you are . . .

<u>Method</u> – Record all data in *Table 2*

1. Use the tape measure to accurately obtain a value for the length of the pipe, ***L*** ;
2. Use the retort stands and clamps to hold the pipe up at one end; allow the other end to rest on the ground – the pipe should lie at a shallow angle;
3. At the raised end, measure the height above the ground of the inside lower edge of the pipe, **h**;
4. Ready the stopwatch to record the time it takes for the ball bearing to travel down the pipe;
5. Release the ball bearing and start the stopwatch;
6. Stop the stopwatch when the ball emerges from the far end of the pipe;
7. Repeat steps 4 – 7 to obtain five values for the time;
8. Find the average time for the ball bearing to travel the length of the pipe;
9. Use the retort stand to vary the height of the raised end of the pipe;
10. Collect data at five different heights for each size ball bearing.

Table 2

Pipe Length, L/cm	Height, h/cm	Slope	Ball Bearing	T_1 /s	T_2 /s	T_3 /s	T_4 /s	T_5 /s	T_{AVG}
300	4		**A**						
			B						
			C						
			D						
			E						
	8		**A**						
			B						
			C						
			D						
			E						
	12		**A**						
			B						
			C						
			D						
			E						
	16		**A**						
			B						
			C						
			D						
			E						
	20		**A**						
			B						
			C						
			D						
			E						

Formula to calculate slope:

$$\tan\left(\frac{h}{\sqrt{L^2-h^2}}\right)$$

Tasks – use a spreadsheet package to create your graphs

1. Plot a graph of time (vertical axis) against mass (horizontal axis) for each slope.
2. Plot a graph of time (vertical axis) against height of release (horizontal axis) for each mass.
3. Study your graphs to see if there is any correlation between time and mass or between height of release and mass.
4. Note your conclusions and compare them to your original predictions.

Conclusions

And the winner is (circle one):

Α Ρ Ι Σ Τ Ω Τ Λ or *Galileo*