

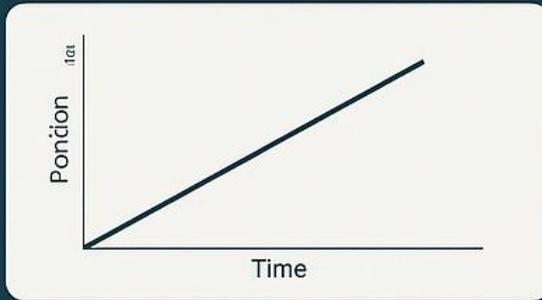
# SLOPE! WHAT?

**UNDERSTANDING THE  
MEANING OF SLOPE IN A  
200-LEVEL PHYSICS LAB**

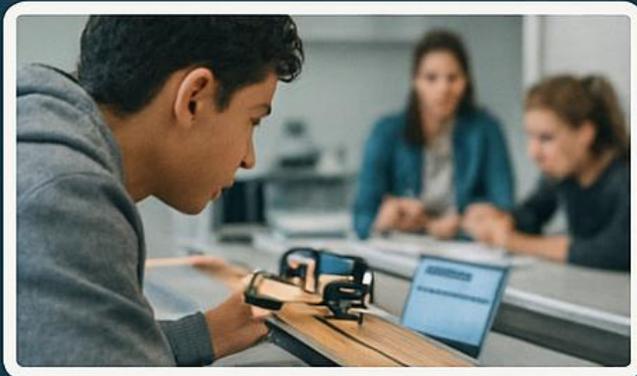
**SAMANTHI WICKRAMARACHCHI,  
VCU PHYSICS**

# Making Slope Meaningful in Physics

## THE SLOPE AS RATE OF CHANGE

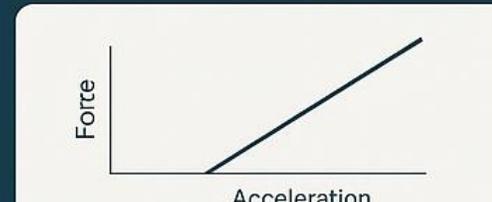


## INTERPRETING THE SLOPE



## LAB EXPERIMENTS AND DISCUSSIONS

## ENHANCING STUDENT UNDERSTANDING



# FUNDAMENTALS

- In physics, slope represents the rate of change between two quantities.
- It is commonly expressed as  $\Delta y/\Delta x$  – the change in the dependent variable over the independent variable.
- The physical meaning of the slope depends on the context of the experiment.

Exploring how slope connects math to physical meaning.

# THE STUDENT CHALLENGE

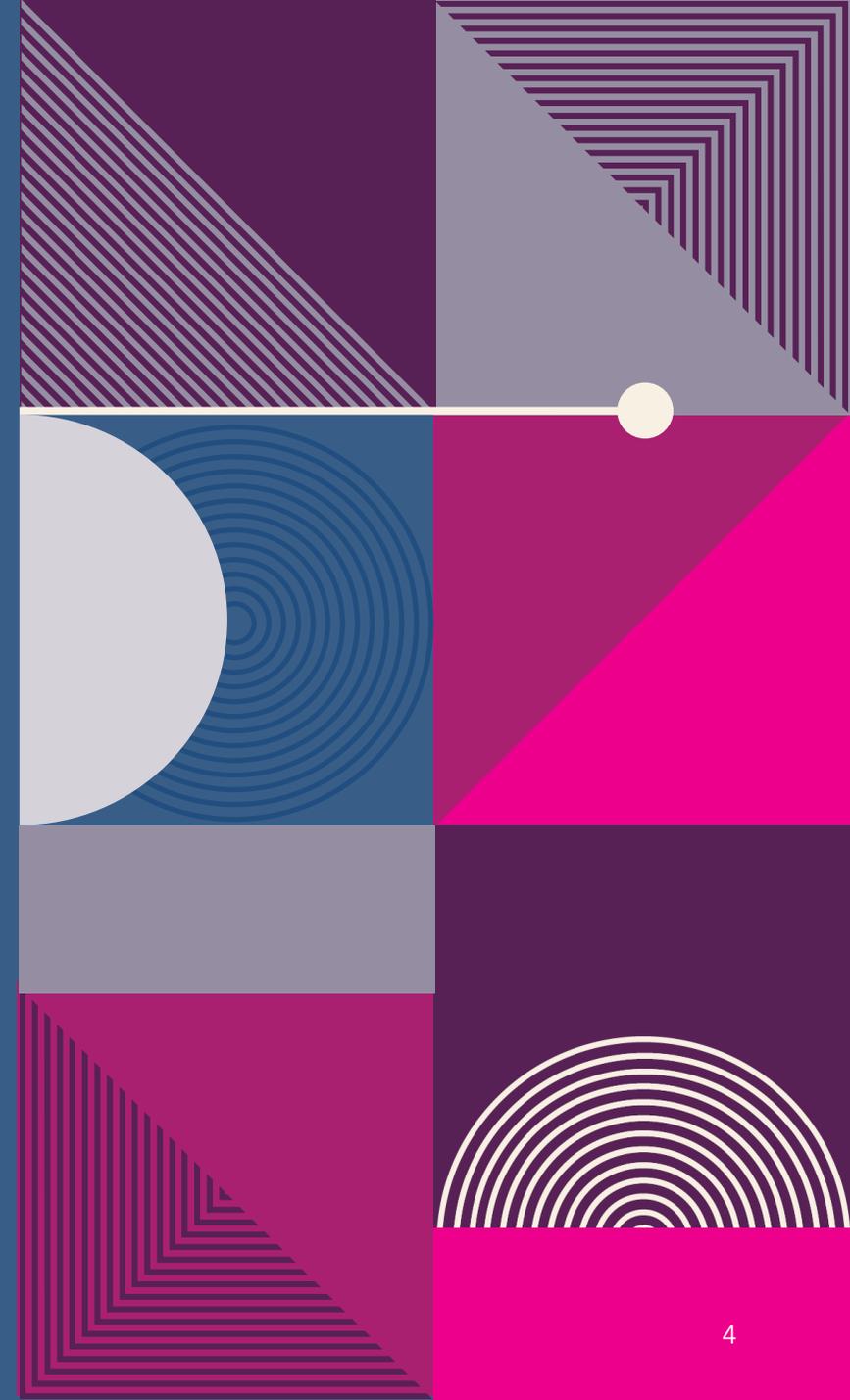
Students often see slope as just steepness.

Goal: connect graphs to real-world meaning.

## In-Lab Approaches

Hands-on experiments with motion sensors.

Real-time graphing and peer interpretation.



# NOTE FROM STUDENTS:

## SLOPE IN CLASSICAL MECHANICS

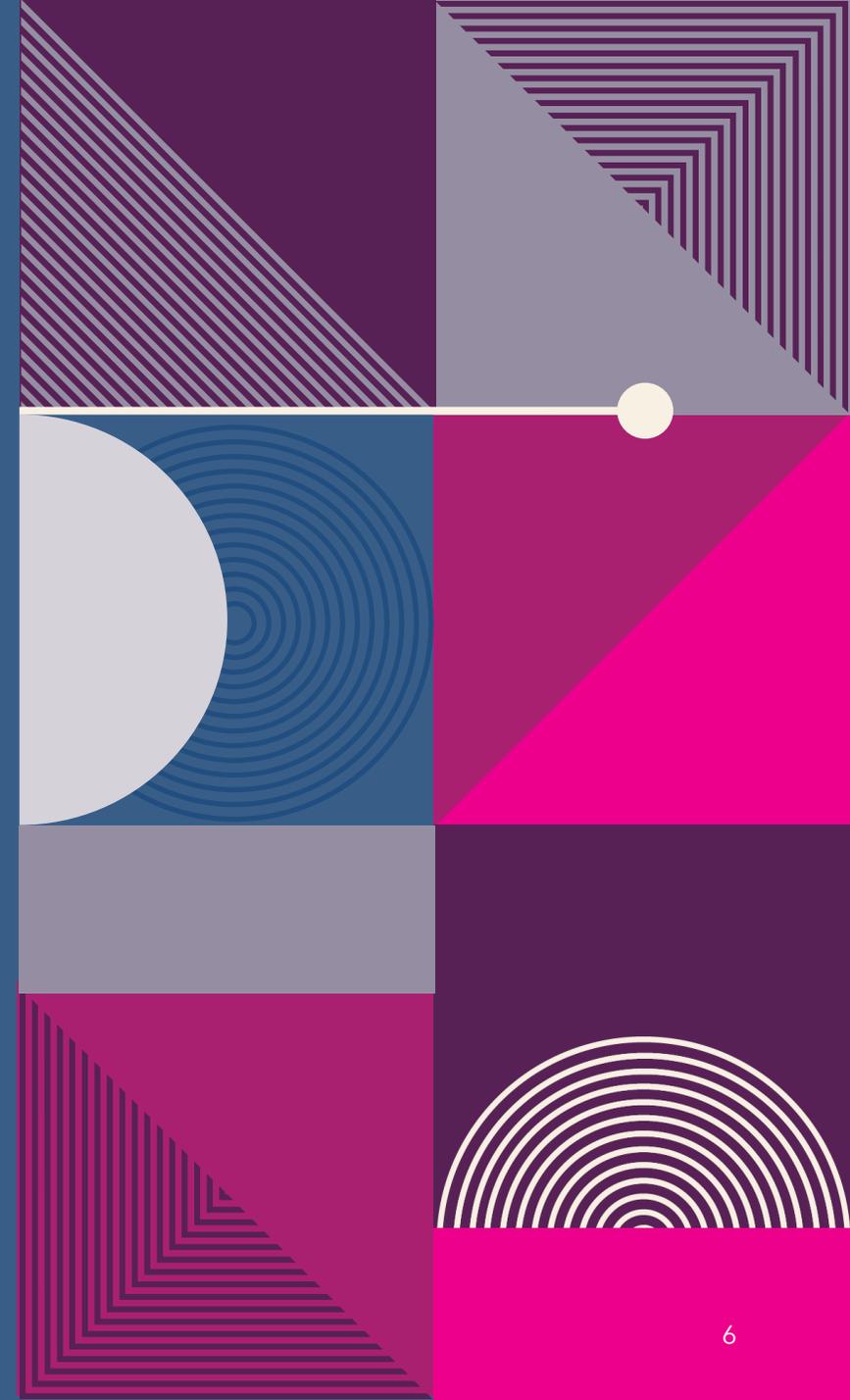
- ❖ **Velocity-Time Graph: Slope = Acceleration**  
(rate of change of velocity).
- ❖ **Displacement-Time Graph: Slope = Velocity**  
(rate of change of position).
- ❖ **Force-Extension Graph: Slope = Spring Constant (k)**  
in Hooke's Law.
- ❖ **Momentum-Time Graph: Slope = Net Force ( $F = dp/dt$ ).**

**STUDENTS OFTEN MEMORIZE FORMULAS WITHOUT UNDERSTANDING PHYSICAL MEANING.**

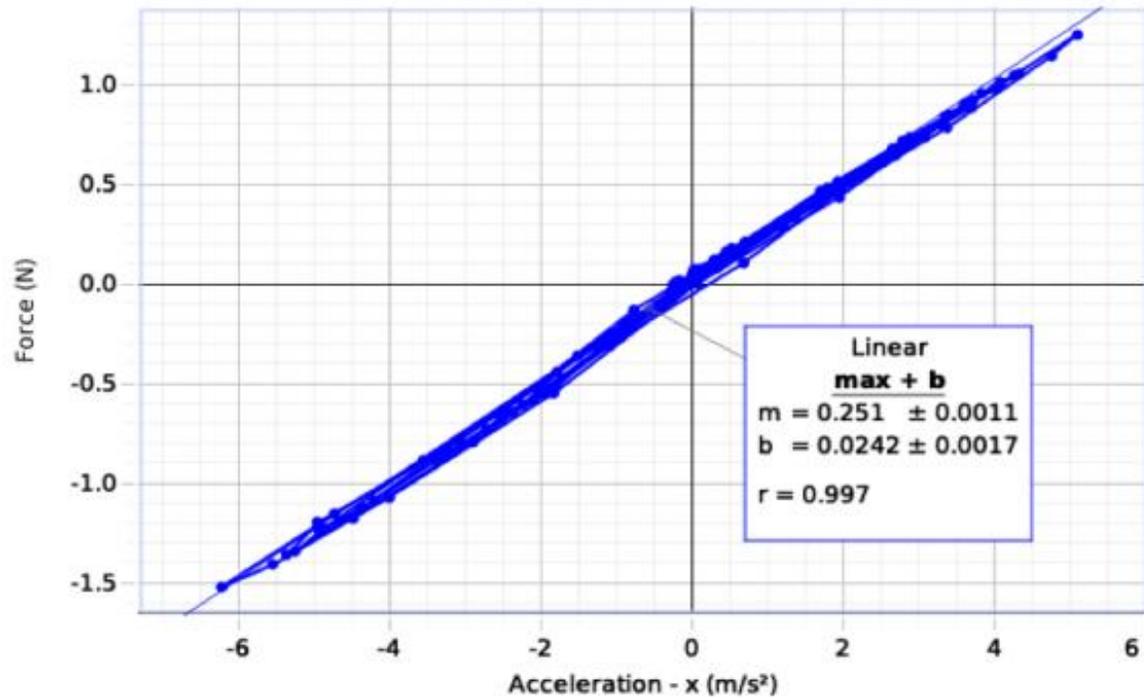
**CONFUSION ARISES WHEN SLOPE UNITS CHANGE BETWEEN TOPICS.**

**GRAPH INTERPRETATION SKILLS ARE OFTEN WEAK.**

**STUDENTS STRUGGLE TO CONNECT MATHEMATICAL SLOPE WITH EXPERIMENTAL DATA TRENDS.**



# EXAMPLE



Newton's Second Law - Smart Cart

2. Write the equation for your linear trend line of force vs. acceleration using meaningful variables and units. What does the slope represent? [5 pts]

Referring to the information given in the introduction to the experiment, find the total theoretical mass  $M_{theory}$  of the system and record in Data Table 2.

- (a) Write the linear fit equation for the trend line provided by the graph fitting. [3 pts]

- (b) What are the Physical variables plotted on the y-axis and x-axis on this graph? [5 pts]

x-axis variable =

y axis Variable =

- (c) By comparing the linear fit equation (answer for question 10(a)) with Newton's second law equation and the variables listed in answer to 10(b), Write the linear fit for your graph using meaningful variables and units. What does the slope of this graph represent? [5 pts]

- (d) Based on the concept previously outlined in questions 10(a) to 10(c), determine the mass of the system experimentally ( $M_{exp}$ ). Also record  $M_{Exp}$  in Data Table 2. [2 pts]

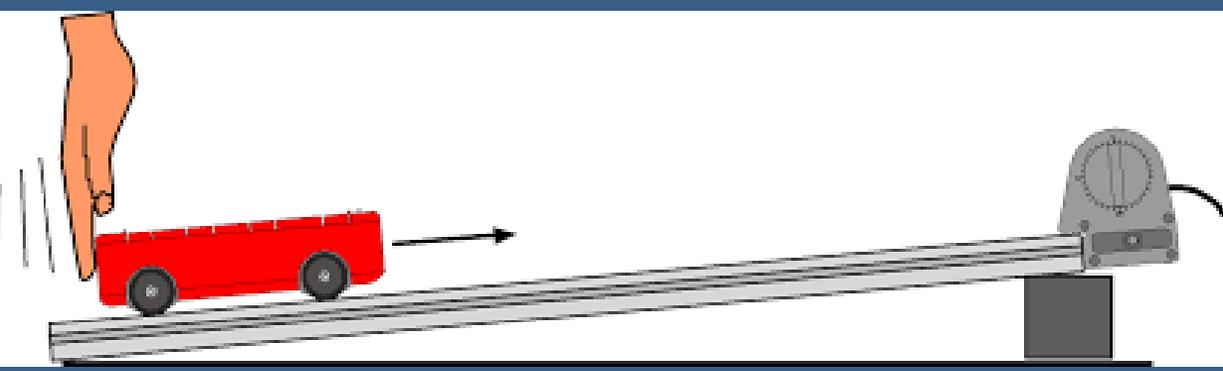


Table 2.2: [10 pts] Fitting parameters for the  $s(m)$ ,  $v(m/s)$ , and  $a(m/s^2)$  vs.  $t(s)$  graphs for a differential height of about 10 cm.

Parameter	$s(m)$ vs. $t(s)$	$v(m/s)$ vs. $t(s)$	$a(m/s^2)$ vs. $t(s)$
	$At^2 + Bt + C$	$mt + b$	$mt + b$
A		NA	NA
B		NA	NA
C		NA	NA
m	NA		
b	NA		

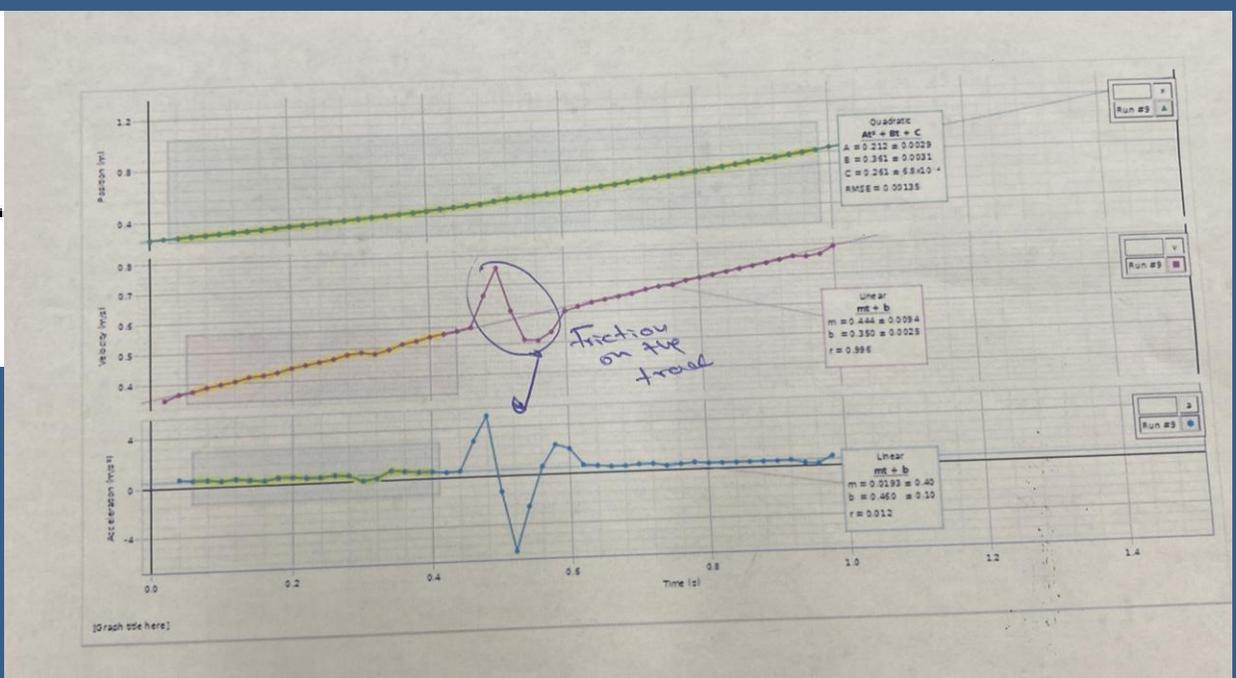


Table 2.2: [10 pts] Fitting parameters for the  $s(m)$ ,  $v(m/s)$ , and  $a(m/s^2)$  vs.  $t(s)$  graphs for a differential height of about 10 cm.

Parameter	$s(m)$ vs. $t(s)$	$v(m/s)$ vs. $t(s)$	$a(m/s^2)$ vs. $t(s)$
	$At^2 + Bt + C$	$mt + b$	$mt + b$
A	0.212	NA	NA
B	0.351	NA	NA
C	0.261	NA	NA
m	NA	0.444	0.0193
b	NA	0.350	0.460

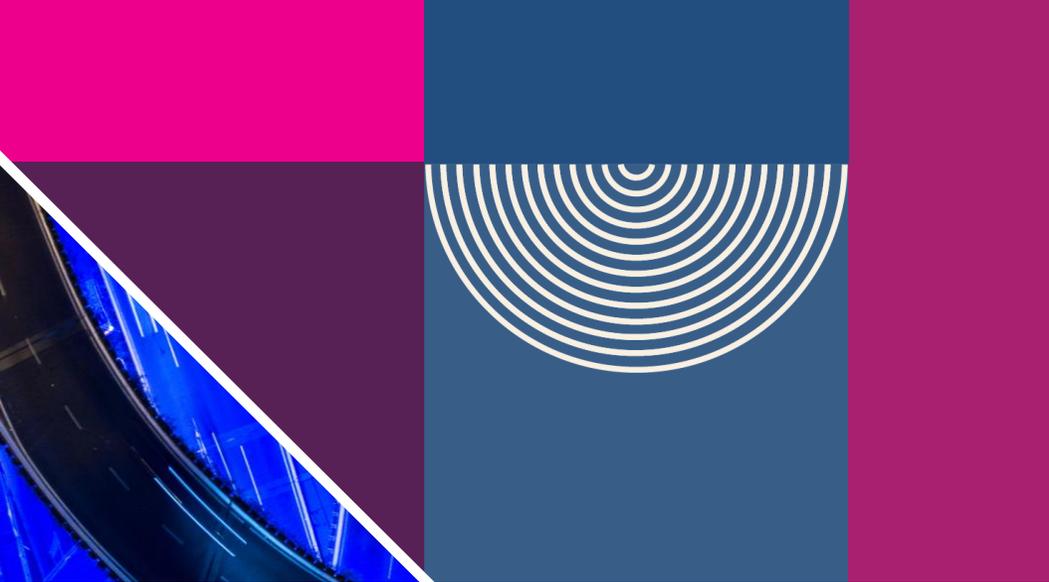
Table 2.3: [10 pts] Explanation of fitting parameters for the  $a(\text{m/s}^2)$  vs.  $t(\text{s})$  graphs for a differential height of

Graph	Explanation	A
$s(\text{m})$ vs. $t(\text{s})$		
$v(\text{m/s})$ vs. $t(\text{s})$		
$a(\text{m/s}^2)$ vs. $t(\text{s})$		

Table 2.3: [10 pts] Explanation of fitting parameters for the  $s(\text{m})$ ,  $v(\text{m/s})$ , and  $a(\text{m/s}^2)$  vs.  $t(\text{s})$  graphs for a differential height of about 10 cm.

Graph	Explanation	Acceleration
$s(\text{m})$ vs. $t(\text{s})$	$\Delta x = v_x t + \frac{1}{2} a_x t^2$ compare with $x_m vs t$ $A t^2 + B t + C$ where $A = \frac{1}{2} a_x = \text{half of the acceleration}$ $B = v_x = \text{velocity}$	$2(0.212)$ $= 0.424 \text{ m/s}^2$
$v(\text{m/s})$ vs. $t(\text{s})$	$v_i + at$ compare $v vs t$ $mt + B$ $m = \text{acceleration}$ $b = v \text{ average}$	$0.444 \text{ m/s}^2$
$a(\text{m/s}^2)$ vs. $t(\text{s})$	$a vs t$ fitting $mt + b$ $m = 0$ (no change in $a$ ) $b = \text{Acceleration}$	$0.460 \text{ m/s}^2$

2.3. [5 pts] Which graph is the most accurate to calculate acceleration? Why? Record this acceleration as  $a_{\text{exp}}$  in Table 2.7



6. Write the equation of the trend line for your  $T^2$  vs. length graph using meaningful variables and units. [5 pts]

7. Square both sides of the equation given in the introduction - how does the result relate to the slope of your equation above? From your result, obtain an experimental determination of the acceleration due to gravity  $g$  and record this value as  $g_{expt}$  in Data Table 3. [10 pts]

7. (a) What type of relationship does Hooke's Law predict for the force and displacement (See question 5)? [5 pts]

(b) Does your graph show this relationship? [5 pts]

the slope of your graph? Given this, how does your slope constant  $k$ ? [5 pts]

slope (from your trend line) for each data set in Data Table previous question (8.c) to complete the Spring constant  $k$  [5 pts]

spring constant for the series combination in Data Table 2

Table 2: Spring Constants [5 pts]

	Slope	$k$ (N/m)
Spring B:		
Springs in series:		



# EXAM QUESTION

35. In one of the physics labs, you have investigated circular motion by measuring the **centripetal force** acting on an object moving in a circle at various speeds. They plot a graph of **centripetal force (N)** on the y-axis versus **tangential velocity squared ( $v^2$ )** on the x-axis. The relationship is given by:

$$F_{Cent} = \frac{mv^2}{r}$$

Using **linear fitting**, what does the **slope** of this graph represent?

- The radius of the circular path
- The quantity  $\frac{r}{m}$
- The mass of the object
- The quantity  $\frac{m}{r}$
- The angular velocity

Q35

Response	Frequency	Percent	
A	2	4.76	
B	1	2.38	
C	2	4.76	
D	12	28.57	
*E	25	59.52	

Q35

Response	Frequency	Percent	
A	5	12.50	
B	3	7.50	
C	1	2.50	
*D	19	47.50	
E	12	30.00	

Only 38 % of students answered it correctly

# Conclusion

Slope tells the story of change.  
Meaningful slope teaching  
builds strong physics thinkers.

The background features a complex geometric composition. A diagonal line runs from the top-left to the bottom-right. The area to the left of this line is divided into several sections: a dark purple triangle at the top-left containing a white dot; a blue square with concentric circles; a light grey semi-circle; a pink triangle with diagonal lines; a pink square with a white corner pattern of lines; a blue square; a light grey triangle; a dark purple triangle; and a pink triangle. The area to the right of the diagonal line is a solid blue background.

**THANK YOU**