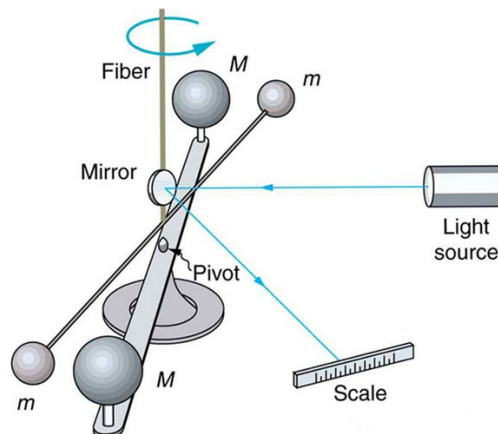# FINDING THE GRAVITATIONAL CONSTANT TEACHER GUIDE

1) Use the "I Notice / I Wonder" table to reflect on the two videos about how Henry Cavendish applied Newton's Law of Gravitation to measure the gravitational constant using a torsional balance in 1798.

Video 1: https://www.youtube.com/watch?v=4wt0135G8kM&t=38s

Video 2: https://www.fourmilab.ch/gravitation/foobar/videos/foobar1.webm

I Notice	I Wonder
Answers will vary.	*Answers will vary.*

2) Use the data table and Newton's Universal Law of Gravity to decide what should be graphed on the x and y axis to make a linear graph and show how the slope of that graph can be used to help you calculate the Gravitational constant, G.

$$F_g = \frac{Gm_1 m_2}{r^2}$$

M_{Person} (kg)	50	50	50	50	50
M_{Earth} (kg)	5.97×10^{24}	5.97×10^{24}	5.97×10^{24}	5.97×10^{24}	5.97×10^{24}
$r_{Person\ to\ Earth}$ (m)	6.38×10^6	1.29×10^7	1.92×10^7	2.50×10^7	3.21×10^7
$F_{g\ Person}$ (N)	489	124	52.3	32.1	19.4
x: $\frac{1}{r^2}\left(\frac{1}{m^2}\right)$	*2.457×10^{-14}*	*6.01×10^{-15}*	*2.713×10^{-15}*	*1.60×10^{-15}*	*9.705×10^{-16}*
y: $F_{g\ Person}$ (N)	*489*	*124*	*52.3*	*32.1*	*19.4*

Answers will vary.

$$F_g = \frac{Gm_1m_2}{r^2} \rightarrow G = \frac{F_g \cdot r^2}{m_1m_2}$$

Decide to graph F_g vs $\frac{1}{r^2}$ to create a linear graph.

Calculate these variables in the table. Want F_g on the y axis and $\frac{1}{r^2}$ on the x axis.

Graph F_g vs $\frac{1}{r^2}$, and solve for the slope of graph (slope $= \frac{F_g}{\frac{1}{r^2}}$).

Relate Newton's Law of Gravitation back to slope. $G = \frac{F_g \cdot r^2}{m_1m_2} = \frac{slope}{m_1m_2}$

3) Notes from pairing up with another person to discuss the combined answer to the same question.

Answers will vary and build on answer to question 2.

4) Notes from class discussion over the same question.

Answers will vary and build on answer to question 3.

5) With a partner, follow the steps described above to create a graph and use its slope to calculate the gravitational constant.

a) Complete the table above with what will be on the x and y axis.

See table above.

b) Clearly label the variable and unit for each axis on the graph.

See graph below.

c) Include a clearly marked scale for each axis and clearly mark the plotted points.

See graph below.

d) Draw a best fit line for the graph.

See graph below.

e) Show the work to calculate the slope of the graph.

slope $= \frac{rise}{rnn} = \frac{}{} =$

f) Using the slope show the steps to find the gravitational constant.

g) Find the percent error of the calculated value of gravitational constant, if the actual value of the gravitational constant, G, is 6.67 x 10⁻¹¹ Nm² / kg².

$$\text{Percent Error} = \frac{[Actual - Predicted]}{Actual} \times 100$$
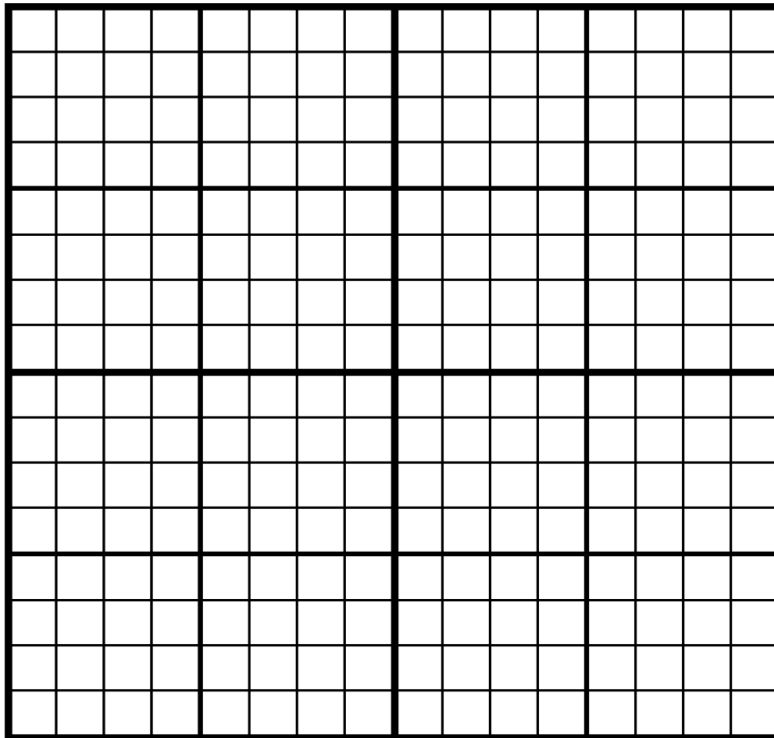
e) $slope = \dfrac{rise}{run}$

$slope = \dfrac{440 - 280}{2.2 \times 10^{-14} - 1.64 \times 10^{-14}}$

$slope = 2 \times 10^{16} \ N \cdot m^2 = \dfrac{F_g}{\frac{1}{r^2}} = F_g r^2$

f) $F_g = \dfrac{G m_1 m_2}{r^2}$

$G = \dfrac{F_g \cdot r^2}{m_1 m_2} = \dfrac{slope}{m_1 m_2}$

$G = \dfrac{2 \times 10^{16} \ N \cdot m^2}{50 kg \ (5.97 \times 10^{24} kg)}$

$\boxed{G = 6.7 \times 10^{-11} \ N \cdot m^2 / kg^2}$
Predicted Value

$F_g (N)$

640

480

320

160
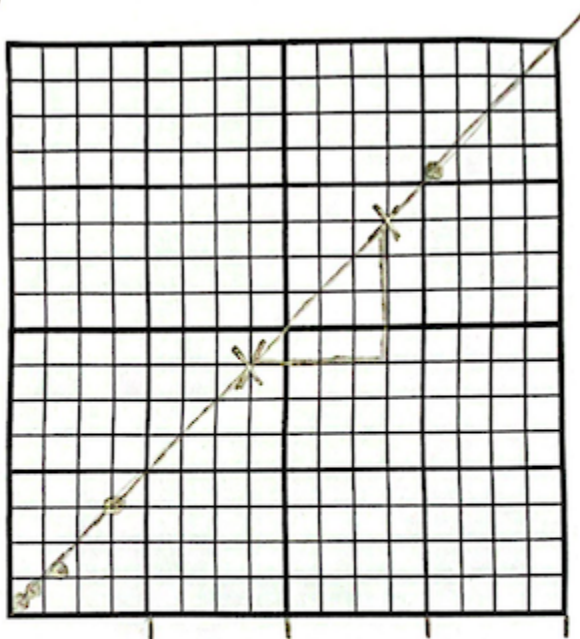
$8 \times 10^{-15} \quad 1.6 \times 10^{-14} \quad 2.4 \times 10^{-14} \quad 3.2 \times 10^{-14}$

$\dfrac{1}{r^2} \left(\dfrac{1}{m^2} \right)$

g) $\% \ error = \dfrac{|Actual - Predicted|}{Actual} \times 100 = \dfrac{|6.67 \times 10^{-11} - 6.7 \times 10^{-11}|}{6.67 \times 10^{-11}} \times 100 = \boxed{.45 = \% \ error}$