Graphing Data

The data collected in a physics experiment are often represented in graphical form. A graph makes it easier to determine whether there is a trend or pattern in the data.

Making a Graph

By convention, the **independent variable,** the one the experimenter changes, is graphed on the x- or horizontal axis. The **dependent variable,** the one that changes as a result of the changes made by the experimenter, is graphed on the y- or vertical axis. The axes are labeled with the quantities and their units are given in parenthesis. An appropriate, linear scale that accommodates the range of data is determined for each axis. It is not necessary to label every grid line. The graph should be titled as the dependent variable versus the independent variable. After the data points are plotted, a smooth line of best fit is drawn. The **line of best fit** is a straight or curved line which approximates the relationship among a set of data points. This line usually does not pass through all measured points. Sometimes the line of best fit is extrapolated. **Extrapolation** means extending the line beyond the region in which data was taken. This is important because the point where the extended line intersects the horizontal or vertical axis has physical significance.

The **slope,** or inclination of a graphed line, often has a physical meaning. On an x-y coordinate system, the slope of a line is defined as the ratio $\frac{\Delta y}{\Delta x}$ for any two points on the line. See Figure 1-9.

$$\text{slope} = \frac{\Delta y}{\Delta x} = \frac{\text{vertical change}}{\text{horizontal change}}$$

$$\text{slope} = \frac{\text{change in dependent variable}}{\text{change in independent variable}}$$

Figure 1-9. Slope defined

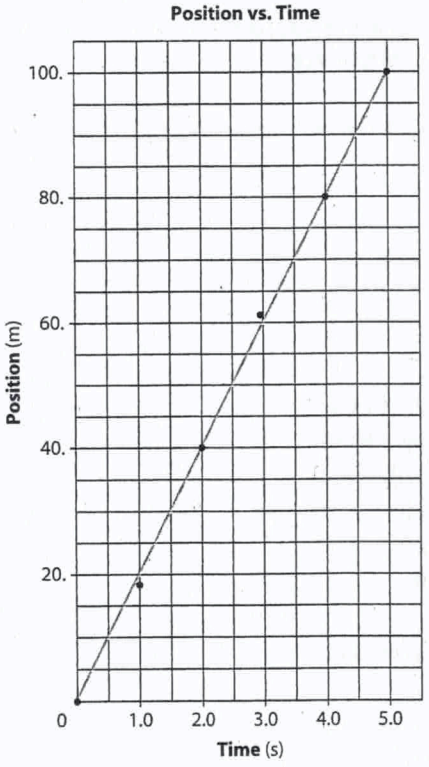
SAMPLE PROBLEM

The position of a moving car was measured at one-second intervals and recorded in the table.

Plot the data on the grid provided and draw the line of best fit. Calculate the slope of the line of best fit.

Time (s)	Position (m)
0.0	0
1.0	18
2.0	40.
3.0	62
4.0	80.
5.0	100.

SOLUTION: Using the information in the table, plot the data and draw the line of best fit.



Calculate the slope of the line.

$$\text{slope} = \frac{\text{change in position}}{\text{change in time}}$$

$$\text{slope} = \frac{100.\text{ m} - 40.\text{ m}}{5.0\text{ s} - 2.0\text{ s}}$$

$$\text{slope} = 20.\text{ m/s}$$

In determining the slope of a graphed line, points directly from the data table can only be used if those points lie on the line of best fit. (**Note to student:** Although the formula for slope does not appear on the *Reference Tables for Physical Setting/ Physics*, calculating slope is testable.)

A horizontal line has a slope of zero. If a line is nearly horizontal, its slope has a small absolute value. If a line slants steeply, its slope has a large absolute value. A line that slopes downward to the right has a negative slope. Figure 1-10 illustrates some slopes of straight and curved lines.

Mathematical Relationships

Some of the common relationships that exist between quantities measured in physics are revealed by the shapes of graphs.

- Two quantities are **directly proportional** if an increase in one causes an increase in the other. The quotient of the quantities is a non-zero constant. The direct proportion $y = 2x$ or $\frac{y}{x} = 2$ is illustrated in Figure 1-11A.
- Two quantities are **inversely proportional** if an increase in one causes a decrease in the other. The product of the quantities is a non-zero constant. The equation $y = \frac{12}{x}$ or $xy = 12$ expresses the inverse proportion shown in Figure 1-11B.
- Two quantities have a **constant proportion** if an increase in one causes no change in the other. The equation $y = 6$, illustrated in Figure 1-11C, is a constant proportion.
- Two quantities have a **direct squared proportion** if an increase in one causes a squared increase in the other. The direct squared proportion $y = x^2$ is shown in Figure 1-11D.
- Two quantities have an **indirect squared proportion** if an increase in one causes a squared decrease in the other. The equation $y = \frac{12}{x^2}$ expresses the indirect squared proportion illustrated in Figure 1-11E.
- Figure 1-11F represents the equation $y = \sqrt{x}$.

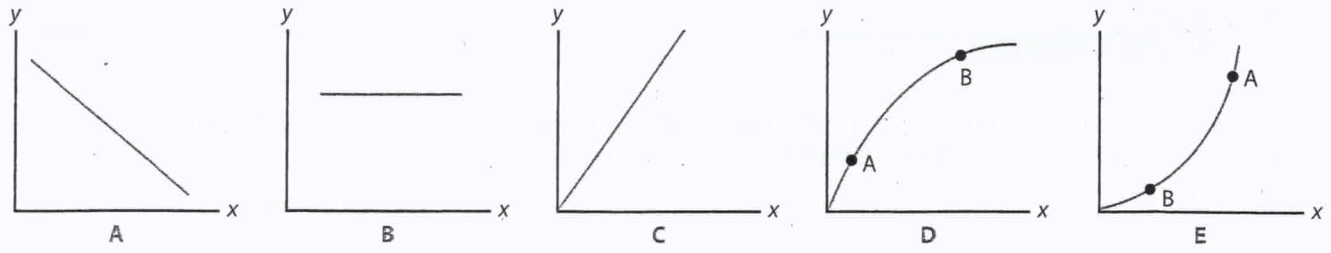


Figure 1-10. Slopes of common curves: The line in graph A has a negative slope. The line in graph B has a slope of zero. The line in graph C has a positive slope. In graphs D and E, the slope at point A is greater than at point B.

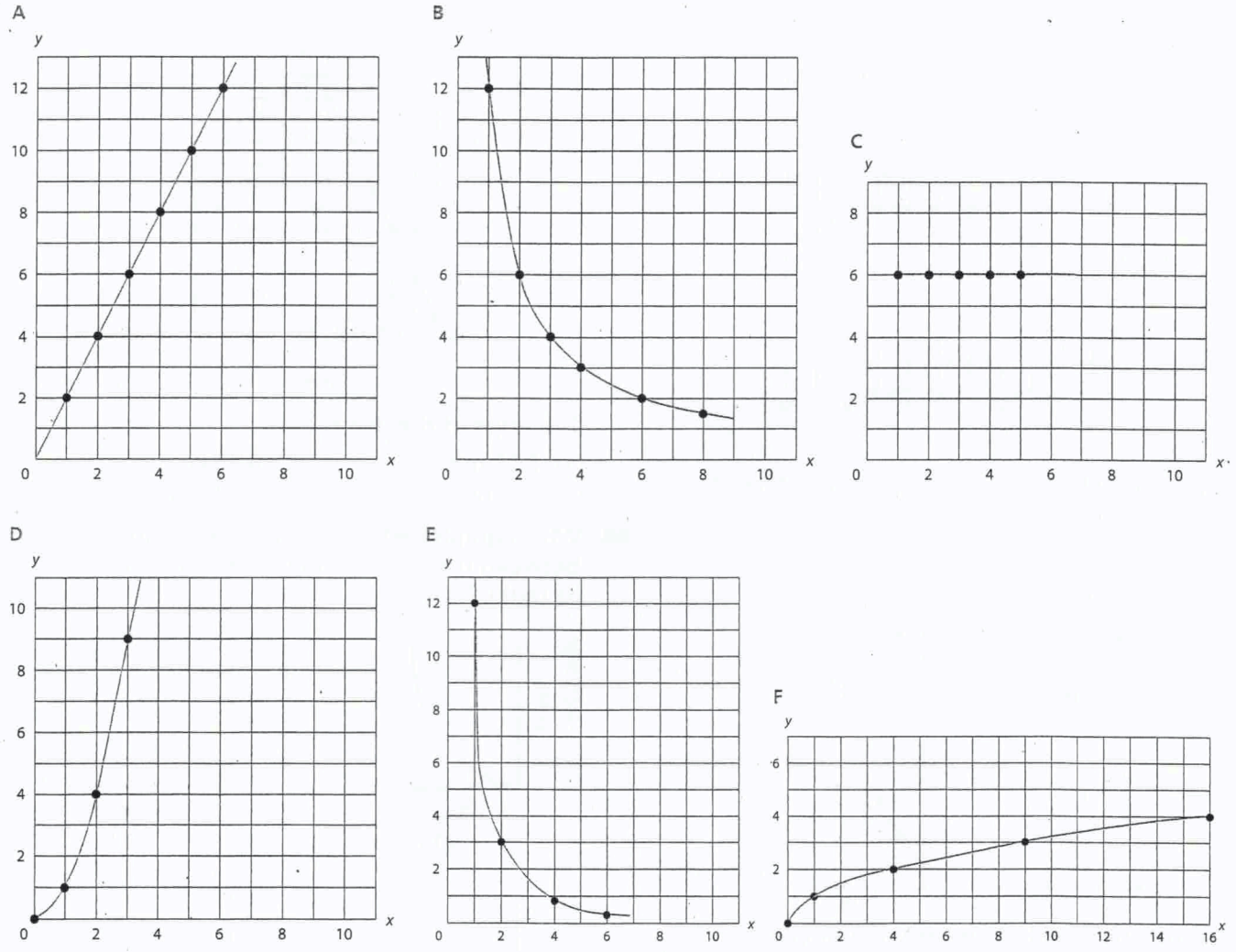
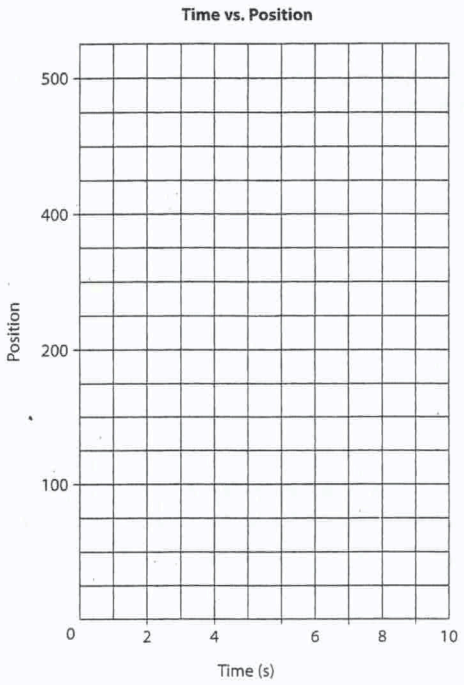
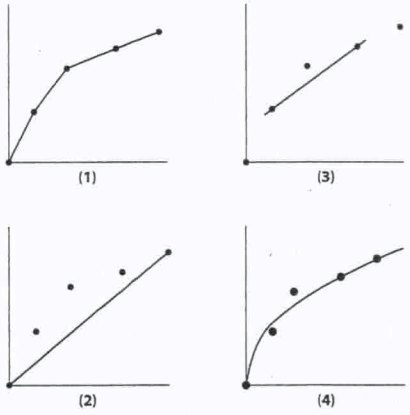


Figure 1-11. Graphs showing shapes of different proportions: (A) The graph of the direct proportion $y = 2x$ (B) The graph of the inverse proportion $y = \frac{12}{x}$ (C) The graph of the constant proportion $y = 6$ (D) The graph of the direct squared proportion $y = x^2$ (E) The graph of the indirect squared proportion $y = \frac{12}{x^2}$ (F) The graph of $y = \sqrt{x}$.

86. A student prepared the grid below to plot data collected in an experiment. List *four* errors the student made.



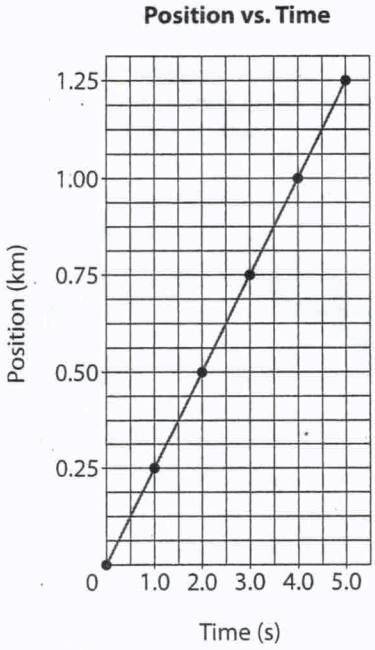
87. Which graph shows a properly drawn line of best fit?



88. A student varied the length of a simple pendulum and measured its period, which is the time required to complete one cycle of motion. In this experiment, time represents the variable that is

(1) dependent and graphed on the horizontal axis
(2) independent and graphed on the horizontal axis
(3) dependent and graphed on the vertical axis
(4) independent and graphed on the vertical axis

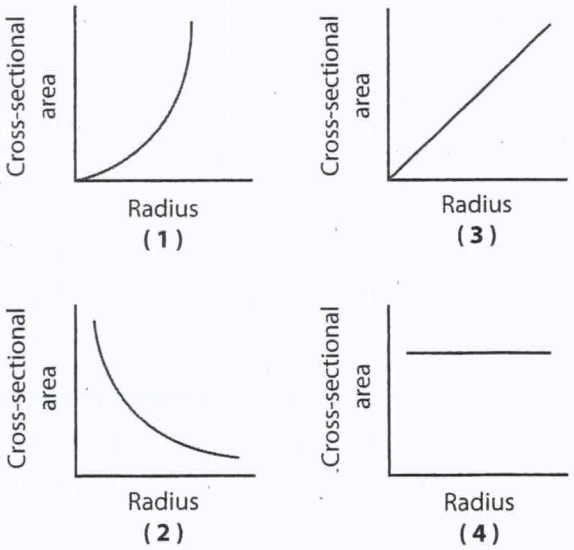
89. The graph below represents the motion of an object.



The slope of the line is

(1) 0.25 m/s
(2) 1.5 m/s
(3) 0.25 km/s
(4) 1.5 km/s

90. Which graph best represents the relationship between the cross-sectional area of a wire and its radius?



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Percent Error

Measurements made during laboratory work may stand alone or be incorporated into one or more formulas to yield an **experimental value** for a physical quantity. In some instances, scientists have determined the most probable value or **accepted value** for quantities and published them in reference books. The difference between an experimental value and the published accepted value is called the **absolute error.** The **percent error** of a measurement can be calculated by dividing the absolute error by the accepted value and multiplying the quotient by 100.

$$\text{Percent error} = \frac{\text{absolute error}}{\text{accepted value}} \times 100$$

SAMPLE PROBLEM

In an experiment, a student determines that the acceleration due to gravity in the laboratory is 9.98 meters per second^2. Calculate the percent error. (According to the *Reference Tables for Physical Setting/Physics*, the accepted value for the acceleration due to gravity is 9.81 meters per second^2.)

SOLUTION: Identify the known and unknown values.

Known
Experimental value of $g = 9.98\ m/s^2$
Accepted value of $g = 9.81\ m/s^2$

Unknown
Percent error = ? %

1. Determine the absolute error by finding the difference between the experimental measurement and the accepted value.

$$\text{Absolute error} = 9.98\ m/s^2 - 9.81\ m/s^2 = 0.17\ m/s^2$$

2. Use the following formula to determine percent error.

$$\text{Percent error} = \frac{\text{absolute error}}{\text{accepted value}} \times 100$$

3. Substitute the known and calculated values and solve.

$$\text{Percent error} = \frac{0.17\ m/s^2}{9.81\ m/s^2} \times 100 = 1.7\%$$

Review Questions

74. In an experiment, a student measures the speed of sound in air to be 318 meters per second at STP. If the accepted value for the speed of sound under those conditions is 331 meters per second, what is the student's percent error?

(1) 3.9% (2) 3.93% (3) 4.09% (4) 4.1%

75. In an experiment, a student measures the speed of yellow light in water to be 2.00×10^8 meters per second. The accepted value for the speed is 2.25×10^8 meters per second. Calculate the student's percent error.

76. In an experiment a student obtained a value of 9.6 meters per second^2 for the acceleration due to gravity. The accepted value is 9.81 meters per second^2. Calculate the student's percent error.

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