Chapter 1

PROBLEMS: 8, 13, 15, 18, 39, 57, 63, 70

8 • Force has dimensions of mass times acceleration. Acceleration has dimensions of speed divided by time. Pressure is defined as force divided by area. What are the dimensions of pressure? Express pressure in terms of the SI base units kilogram, meter and second.

Determine the Concept We can use the definitions of force and pressure, together with the dimensions of mass, acceleration, and length, to find the dimensions of pressure. We can express pressure in terms of the SI base units by substituting the base units for mass, acceleration, and length in the definition of pressure.

Use the definition of pressure and the dimensions of force and area to obtain:

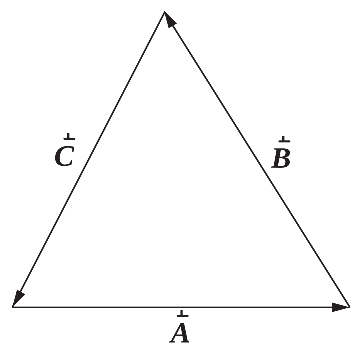
$$[P]=\frac{[F]}{[A]}=\frac{\frac{\text{ML}}{\text{T}^2}}{\text{L}^2}=\boxed{\frac{\text{M}}{\text{LT}^2}}$$

Express pressure in terms of the SI base units to obtain:

$$\frac{\text{N}}{\text{m}^2}=\frac{\text{kg}\cdot\frac{\text{m}}{\text{s}^2}}{\text{m}^2}=\boxed{\frac{\text{kg}}{\text{m}\cdot\text{s}^2}}$$

13 • **[SSM]** Is it possible for three equal magnitude vectors to add to zero? If so, sketch a graphical answer. If not, explain why not.

Determine the Concept In order for the three equal magnitude vectors to add to zero, the sum of the three vectors must form a triangle. The equilateral triangle shown to the right satisfies this condition for the vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ for which it is true that $A = B = C$, whereas $\vec{A}+\vec{B}+\vec{C}=0$.



15 • **[SSM]** Some good estimates about the human body can be made if it is assumed that we are made mostly of water. The mass of a water molecule is 29.9×10^{-27} kg. If the mass of a person is 60 kg, estimate the number of water molecules in that person.

Picture the Problem We can estimate the number of water molecules in a person whose mass is 60 kg by dividing this mass by the mass of a single water molecule.

Letting N represent the number of water molecules in a person of mass $m_{\text{human body}}$, express N in terms of $m_{\text{human body}}$ and the mass of a water molecule $m_{\text{water molecule}}$:

$$N = \frac{m_{\text{human body}}}{m_{\text{water molecule}}}$$

Substitute numerical values and evaluate N:

$$N = \frac{60\text{ kg}}{29.9\times10^{-27}\ \dfrac{\text{kg}}{\text{molecule}}} = \boxed{2.0\times10^{27}\text{ molecules}}$$

18 •• (*a*) Estimate the number of gallons of gasoline used per day by automobiles in the United States and the total amount of money spent on it. (*b*) If 19.4 gal of gasoline can be made from one barrel of crude oil, estimate the total number of barrels of oil imported into the United States per year to make gasoline. How many barrels per day is this?

Picture the Problem The population of the United States is roughly 3×10^8 people. Assuming that the average family has four people, with an average of two cars per family, there are about 1.5×10^8 cars in the United States. If we double that number to include trucks, cabs, etc., we have 3×10^8 vehicles. Let's assume that each vehicle uses, on average, about 12 gallons of gasoline per week.

(*a*) Find the daily consumption of gasoline G:

$$G = \left(3\times10^8\text{ vehicles}\right)\left(2\text{ gal/d}\right) = 6\times10^8\text{ gal/d}$$

Assuming a price per gallon P = \$3.00, find the daily cost C of gasoline:

$$C = GP = \left(6\times10^8\text{ gal/d}\right)\left(\$3.00/\text{gal}\right) = \$18\times10^8/\text{d} \approx \boxed{2\text{ billion dollars/d}}$$

(*b*) Relate the number of barrels N of crude oil required annually to the yearly consumption of gasoline Y and the number of gallons of gasoline n that can be made from one barrel of crude oil:

$$N = \frac{Y}{n} = \frac{G\Delta t}{n}$$

Substitute numerical values and estimate *N*:

$$N = \frac{\left(6\times10^{8}\ \frac{\text{gallons}}{\text{d}}\right)\left(365.24\ \frac{\text{d}}{\text{y}}\right)}{19.4\ \frac{\text{gallons}}{\text{barrel}}}$$

$$\approx \boxed{10^{10}\ \frac{\text{barrels}}{\text{y}}}$$

Convert barrels/y to barrels/d to obtain:

$$N = 10^{10}\ \frac{\text{barrels}}{\text{y}} \times \frac{1\ \text{y}}{365.24\ \text{d}}$$

$$\approx \boxed{10^{7}\ \frac{\text{barrels}}{\text{d}}}$$

39 •• The magnitude of the force that a spring exerts (*F*) when it is stretched a distance *x* from its unstressed length is governed by Hooke's law, $F = kx$. (*a*) What are the dimensions of the *force constant*, *k*? (*b*) What are the dimensions and SI units of the quantity kx^2?

Picture the Problem The dimensions of mass and velocity are *M* and *L*/*T*, respectively. We note from Table 1-2 that the dimensions of force are ML/T^2.

(*a*) From Hooke's law:

$$k = \frac{F}{x}$$

Write the corresponding dimensional equation:

$$[k] = \frac{[F]}{[x]}$$

Substitute the dimensions of *F* and *x* and simplify to obtain:

$$[k] = \frac{\text{M}\frac{\text{L}}{\text{T}^2}}{\text{L}} = \boxed{\frac{\text{M}}{\text{T}^2}}$$

(*b*) Substitute the dimensions of *k* and x^2 and simplify to obtain:

$$[kx^2] = \frac{\text{M}}{\text{T}^2}\text{L}^2 = \boxed{\frac{\text{ML}^2}{\text{T}^2}}$$

Substitute the units of kx^2 to obtain:

$$\boxed{\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}}$$

57 •• Given the following vectors: $\vec{A} = 3.4\hat{i} + 4.7\hat{j}$, $\vec{B} = (-7.7)\hat{i} + 3.2\hat{j}$, and $\vec{C} = 5.4\hat{i} + (-9.1)\hat{j}$. (*a*) Find the vector $\vec{D}$, in unit vector notation, such that $\vec{D} + 2\vec{A} - 3\vec{C} + 4\vec{B} = 0$. (*b*) Express your answer in Part (*a*) in terms of magnitude and angle with the +*x* direction.

Picture the Problem We can find the vector $\vec{D}$ by solving the equation $\vec{D} + 2\vec{A} - 3\vec{C} + 4\vec{B} = 0$ for $\vec{D}$ and then substituting for the vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$. In (*b*) we can use the components of $\vec{D}$ to find its magnitude and direction.

(*a*) Solve the vector equation that gives the condition that must satisfied for $\vec{D}$:

$$\vec{D} = -2\vec{A} + 3\vec{C} - 4\vec{B}$$

Substitute for $\vec{A}, \vec{C}$ and $\vec{B}$ and simplify to obtain:

$$\begin{aligned}\vec{D} &= -2(3.4\hat{i} + 4.7\hat{j}) + 3(5.4\hat{i} - 9.1\hat{j}) - 4(-7.7\hat{i} + 3.2\hat{j})\\ &= (-6.8 + 16.2 + 30.8)\hat{i} + (-9.4 - 27.3 - 12.8)\hat{j}\\ &= 40.2\hat{i} - 49.5\hat{j} = \boxed{40\hat{i} - 50\hat{j}}\end{aligned}$$

(*b*) Use the Pythagorean Theorem to relate the magnitude of $\vec{D}$ to its components D_x and D_y:

$$D = \sqrt{D_x^2 + D_y^2}$$

Substitute numerical values and evaluate *D*:

$$D = \sqrt{(40.2)^2 + (-49.5)^2} = \boxed{63.8}$$

Use trigonometry to express and evaluate the angle θ:

$$\theta = \tan^{-1}\left(\frac{D_y}{D_x}\right) = \tan^{-1}\left(\frac{-49.5}{40.2}\right) = \boxed{-51°}$$

where the minus sign means that $\vec{D}$ is in the 4th quadrant.

63 • If you could count \$1.00 per second, how many years would it take to count 1.00 billion dollars?

Picture the Problem We can use a series of conversion factors to convert 1 billion seconds into years.

Multiply 1 billion seconds by the appropriate conversion factors to convert into years:

$$10^9\ \text{s} = 10^9\ \text{s} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1\ \text{day}}{24\ \text{h}} \times \frac{1\ \text{y}}{365.24\ \text{days}} = \boxed{31.7\ \text{y}}$$

70 •• If the average density of the universe is at least $6 \times 10^{-27}\ \text{kg/m}^3$, then the universe will eventually stop expanding and begin contracting. (*a*) How many electrons are needed in each cubic meter to produce the critical density? (*b*) How many protons per cubic meter would produce the critical density?
($m_e = 9.11 \times 10^{-31}$ kg; $m_p = 1.67 \times 10^{-27}$ kg.)

Picture the Problem Let N_e and N_p represent the number of electrons and the number of protons, respectively and ρ the critical average density of the universe. We can relate these quantities to the masses of the electron and proton using the definition of density.

(*a*) Using its definition, relate the required density ρ to the electron density N_e/V:

$$\rho = \frac{m}{V} = \frac{N_e m_e}{V} \Rightarrow \frac{N_e}{V} = \frac{\rho}{m_e} \qquad (1)$$

Substitute numerical values and evaluate N_e/V:

$$\frac{N_e}{V} = \frac{6 \times 10^{-27}\ \text{kg/m}^3}{9.11 \times 10^{-31}\ \text{kg/electron}}$$
$$= 6.586 \times 10^3\ \text{electrons/m}^3$$
$$\approx \boxed{7 \times 10^3\ \text{electrons/m}^3}$$

(*b*) Express and evaluate the ratio of the masses of an electron and a proton:

$$\frac{m_e}{m_p} = \frac{9.11 \times 10^{-31}\ \text{kg}}{1.67 \times 10^{-27}\ \text{kg}} = 5.455 \times 10^{-4}$$

Rewrite equation (1) in terms of protons:

$$\frac{N_p}{V} = \frac{\rho}{m_p} \qquad (2)$$

Divide equation (2) by equation (1) to obtain:

$$\frac{\frac{N_p}{V}}{\frac{N_e}{V}} = \frac{m_e}{m_p} \text{ or } \frac{N_p}{V} = \frac{m_e}{m_p}\left(\frac{N_e}{V}\right)$$

Substitute numerical values and use the result from part (*a*) to evaluate N_p/V:

$$\frac{N_p}{V} = \left(5.455 \times 10^{-4}\right)\left(6.586 \times 10^3\ \text{electrons/m}^3\right) \approx \boxed{4\ \text{protons/m}^3}$$