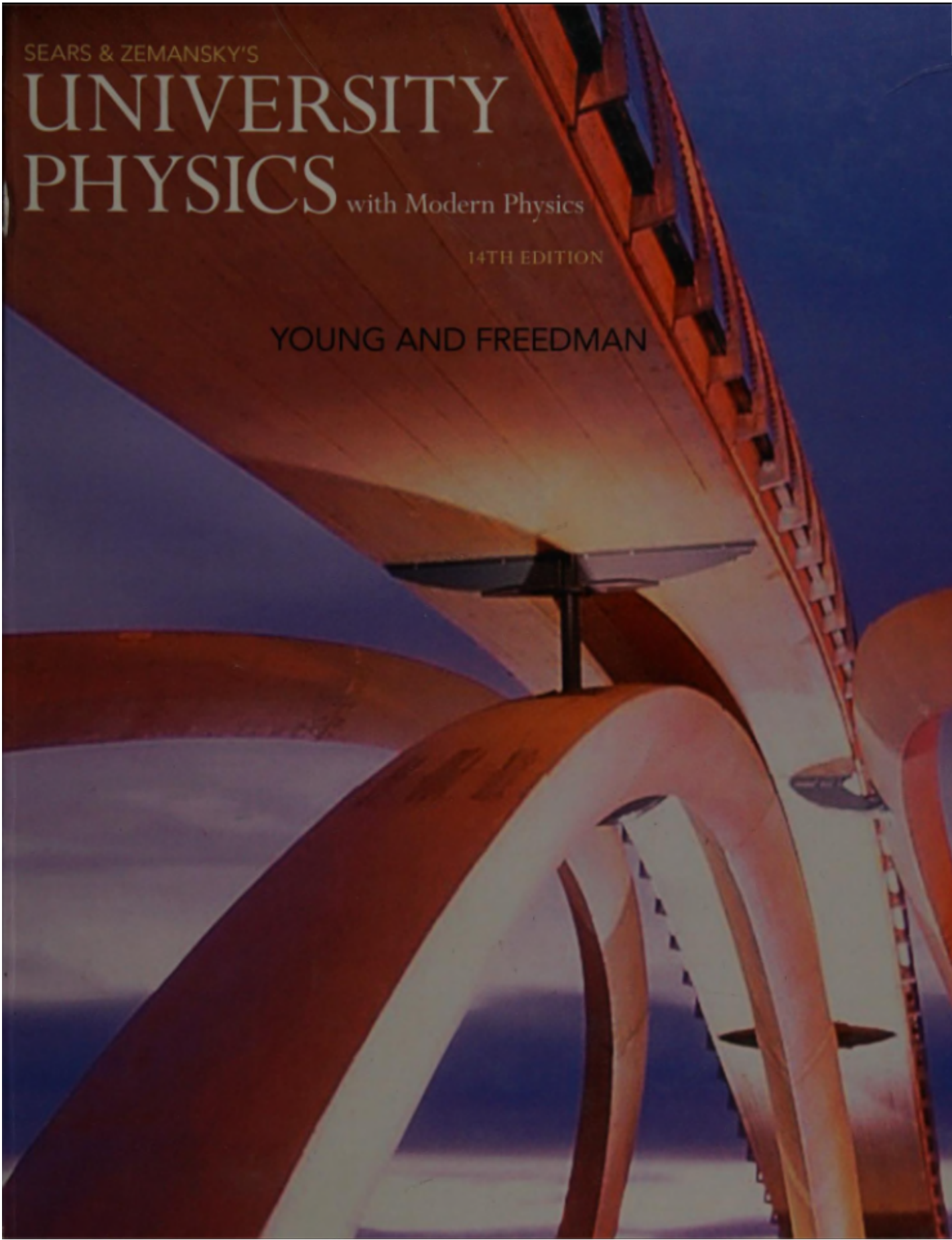




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The Leonardo Bridge Project is a project to build functional interpretations of Leonardo da Vinci's Golden Horn Bridge design, conceived and built first in Norway by artist Vebjørn Sand as a global public art project, linking people and cultures in communities in every continent.

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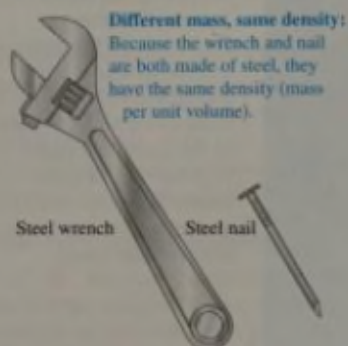
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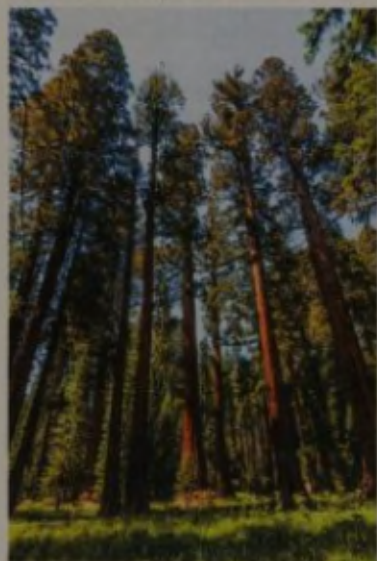
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12.1 Two objects with different masses and different volumes but the same density.



BIO Application Liquid Cohesion in Trees How do trees—some of which grow to heights greater than 100 m—supply water to their highest leaves? The answer lies in the strong cohesive forces between molecules of liquid water. Narrow pipes within the tree extend upward from the roots to the leaves. As water evaporates from the leaves, cohesive forces pull replacement water upward through these pipes.



same density throughout. We use ρ (the Greek letter rho) for density. For a homogeneous material,

$$\text{Density of a homogeneous material} \rightarrow \rho = \frac{m}{V} \quad (12.1)$$

m ← Mass of material
 V ← Volume occupied by material

Two objects made of the same material have the same density even though they may have different masses and different volumes. That's because the *ratio* of mass to volume is the same for both objects (Fig. 12.1).

The SI unit of density is the kilogram per cubic meter (1 kg/m^3). The cgs unit, the gram per cubic centimeter (1 g/cm^3), is also widely used:

$$1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$$

The densities of some common substances at ordinary temperatures are given in Table 12.1. Note the wide range of magnitudes. The densest material found on earth is the metal osmium ($\rho = 22,500 \text{ kg/m}^3$), but its density pales by comparison to the densities of exotic astronomical objects, such as white dwarf stars and neutron stars.

The **specific gravity** of a material is the ratio of its density to the density of water at 4.0°C , 1000 kg/m^3 ; it is a pure number without units. For example, the specific gravity of aluminum is 2.7. “Specific gravity” is a poor term, since it has nothing to do with gravity; “relative density” would have been a better choice.

The density of some materials varies from point to point within the material. One example is the material of the human body, which includes low-density fat (about 940 kg/m^3) and high-density bone (from 1700 to 2500 kg/m^3). Two others are the earth's atmosphere (which is less dense at high altitudes) and oceans (which are denser at greater depths). For these materials, Eq. (12.1) describes the **average density**. In general, the density of a material depends on environmental factors such as temperature and pressure.

TABLE 12.1 Densities of Some Common Substances

Material	Density (kg/m^3) ^a	Material	Density (kg/m^3) ^a
Air (1 atm, 20°C)	1.20	Iron, steel	7.8×10^3
Ethanol	0.81×10^3	Brass	8.6×10^3
Benzene	0.90×10^3	Copper	8.9×10^3
Ice	0.92×10^3	Silver	10.5×10^3
Water	1.00×10^3	Lead	11.3×10^3
Seawater	1.03×10^3	Mercury	13.6×10^3
Blood	1.06×10^3	Gold	19.3×10^3
Glycerine	1.26×10^3	Platinum	21.4×10^3
Concrete	2×10^3	White dwarf star	10^{30}
Aluminum	2.7×10^3	Neutron star	10^{18}

^aTo obtain the densities in grams per cubic centimeter, simply divide by 10^3 .

EXAMPLE 12.1 THE WEIGHT OF A ROOMFUL OF AIR

Find the mass and weight of the air at 20°C in a living room with a $4.0 \text{ m} \times 5.0 \text{ m}$ floor and a ceiling 3.0 m high, and the mass and weight of an equal volume of water.

SOLUTION

IDENTIFY and SET UP: We assume that the air density is the same throughout the room. (Air is less dense at high elevations than near sea level, but the density varies negligibly over the room's

3.0-m height; see Section 12.2.) We use Eq. (12.1) to relate the mass m_{air} to the room's volume V (which we'll calculate) and the air density ρ_{air} (given in Table 12.1).

EXECUTE: We have $V = (4.0 \text{ m})(5.0 \text{ m})(3.0 \text{ m}) = 60 \text{ m}^3$, so from Eq. (12.1),

$$m_{\text{air}} = \rho_{\text{air}} V = (1.20 \text{ kg/m}^3)(60 \text{ m}^3) = 72 \text{ kg}$$

$$w_{\text{air}} = m_{\text{air}} g = (72 \text{ kg})(9.8 \text{ m/s}^2) = 700 \text{ N} = 160 \text{ lb}$$

