Length density, area density, and volume density

Most of us first learned about density as "mass divided by volume". This made sense in considering a specific object of uniform composition. We can separately measure the mass M and the volume V of the object and then compute density as M/V. We will use the symbol ρ (the lower case Greek letter "rho") to denote this density. A formula for density is thus $\rho = M/V$.

Exercise 1: The density of aluminum is about $2.7\,\mathrm{g/cm^3}$. Determine the mass of an aluminum cube with sides of length 2 cm.

Some objects are more naturally measured in terms of length or area rather than volume. For something like a rope or rod, we can use *length density* defined as "mass per length". We will typically use the symbol λ (the lower case Greek letter "lambda") to denote length density.

Exercise 2: A particular type of rope has a length density of $\lambda = 0.15$ kg per meter. What is the mass of a 3 meter piece of this rope?

For something like a sheet of paper or a piece of plywood, we can use *area density* defined as "mass per area". To denote area density, we will generally use σ (the lower case Greek letter "sigma").

Exercise 3: A standard type of newsprint has an area density of $48.8\,\mathrm{g/m^2}$. Determine the mass of a roll of this newprint that is 2 meters wide and 100 meters long.

You will encounter many references to density that do not specifically refer to length, area, or volume. You will need to use context and units to determine which type of density is in play.

You will also find that density need not refer to *mass*. In other disciplines, you will find use of density of a variety of quantities including number, cost, charge, and probability. For example, the advertised cost of flooring is often given in dollars per square foot so a particular carpet might be listed as \$4.25 per square foot. This is an area density for cost.

Exercise 4: The following passage includes mention of two densities. For each density mentioned, identify the type (length, area, volume) of density and the relevant quantity (mass, charge, cost, number,...).

> "Abstract: This study examines the ecology of a population of Geoffroy's side-necked turtle *Phrynops geoffroanus* inhabiting a polluted urban river in Ribeiro Preto city, So Paulo state, south-eastern Brazil. Adult turtles fed mainly on Chironomidae larvae and pupae (*Chironomus cf. plumosus*, 100% of occurrence frequency) and domestic waste, but they also consumed terrestrial items (cockroach, snails) and carrion. Juvenile turtles showed more feeding diversity than the adults and exhibited a trend for predation on Chironomidae pupae, but this is not reflected in resource partitioning. The elevated number of turtles (170–230 turtles/ha of river) and biomass (255–345 kg/ha of river) inhabiting this urban river is probably the result of the abundance of sewage and organic waste produced by humans, the absence of predators, and increased availability of nesting areas. Such factors convert this area into an environment highly advantageous for the survival of Geoffroy's side-necked turtle." (From "Feeding ecology, density and biomass of the freshwater turtle, Phrynops geoffroanus, inhabiting a polluted urban river in south-eastern Brazil", Franco Leandro Souza and Augusto Shinya Abe, *Journal of Zoology* (2000), 252:4:437-446.)