48. (II) Estimate the number of bus drivers (*a*) in Washington, D.C., and (*b*) in your town.

49. (III) You are in a hot air balloon, 300 m above the flat Texas plains. You look out toward the horizon. How far out can you see—that is, how far is your horizon? The Earth's radius is about 6400 km.

50. (III) I agree to hire you for 30 days. You can decide between two methods of payment: either (1) $1000 a day, or (2) one penny on the first day, two pennies on the second day and continue to double your daily pay each day up through day 30. Use quick estimation to make your decision, and justify it.

51. (III) The rubber worn from tires mostly enters the atmosphere as *particulate pollution*. Estimate how much rubber (in kg) is put into the air in the United States every year. To get started, a good estimate for a tire tread's depth is 1 cm when new, and rubber has a mass of about 1200 kg per m^3 of volume.

52. (III) Many sailboats are docked at a marina 4.4 km away on the opposite side of a lake. You stare at one of the sailboats because, when you are lying flat at the water's edge, you can just see its deck but none of the side of the sailboat. You then go to that sailboat on the other side of the lake and measure that the deck is 1.5 m above the level of the water. Using Fig. 1–14, where $h = 1.5$ m, estimate the radius R of the Earth.

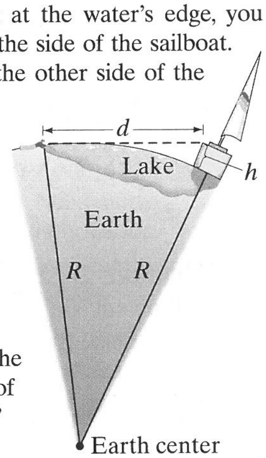

FIGURE 1–14 Problem 52. You see a sailboat across a lake (not to scale). R is the radius of the Earth. Because of the curvature of the Earth, the water "bulges out" between you and the boat.

53. (III) You are lying on a beach, your eyes 20 cm above the sand. Just as the Sun sets, fully disappearing over the horizon, you immediately jump up, your eyes now 150 cm above the sand, and you can again just see the top of the Sun. If you count the number of seconds $(= t)$ until the Sun fully disappears again, you can estimate the *Earth's radius*. But for this Problem, use the known radius of the Earth to calculate the time t.

*1–7 Dimensions

*54. (I) What are the dimensions of density, which is mass per volume?

*55. (II) The speed v of an object is given by the equation $v = At^3 - Bt$, where t refers to time. (*a*) What are the dimensions of A and B? (*b*) What are the SI units for the constants A and B?

*56. (II) Three students derive the following equations in which x refers to distance traveled, v the speed, a the acceleration (m/s^2), t the time, and the subscript zero $(_0)$ means a quantity at time $t = 0$. Here are their equations: (*a*) $x = vt^2 + 2at$, (*b*) $x = v_0 t + \frac{1}{2}at^2$, and (*c*) $x = v_0 t + 2at^2$. Which of these could possibly be correct according to a dimensional check, and why?

*57. (II) (*a*) Show that the following combination of the three fundamental constants of nature that we used in Example 1–10 (that is G, c, and h) forms a quantity with the dimensions of time:

$$t_P = \sqrt{\frac{Gh}{c^5}}.$$

This quantity, t_P, is called the **Planck time** and is thought to be the earliest time, after the creation of the Universe, at which the currently known laws of physics can be applied. (*b*) Estimate the order of magnitude of t_P using values given inside the front cover (or Example 1–10).

General Problems

58. **Global positioning satellites (GPS)** can be used to determine your position with great accuracy. If one of the satellites is 20,000 km from you, and you want to know your position to ±2 m, what percent uncertainty in the distance is required? How many significant figures are needed in the distance?

59. One mole of atoms consists of 6.02×10^{23} individual atoms. If a mole of atoms were spread uniformly over the Earth's surface, how many atoms would there be per square meter?

60. **Computer chips** (Fig. 1–15) can be etched on circular silicon wafers of thickness 0.300 mm that are sliced from a solid cylindrical silicon crystal of length 25 cm. If each wafer can hold 750 chips, what is the maximum number of chips that can be produced from one entire cylinder?

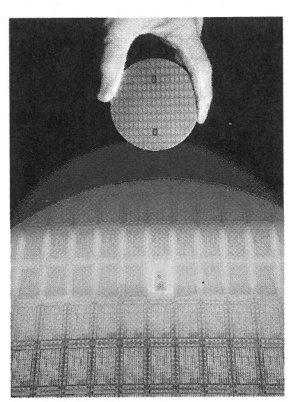

FIGURE 1–15 Problem 60. The wafer held by the hand is shown below, enlarged and illuminated by colored light. Visible are rows of integrated circuits (chips).

61. If you used only a keyboard to enter data, how many years would it take to fill up a *hard drive* in a computer that can store 1.0 terabytes $(1.0 \times 10^{12}$ bytes$)$ of data? Assume 40-hour work weeks, and that you can type 150 characters per minute, and that one byte is one keyboard character.

62. An average family of four uses roughly 1200 L (about 300 gallons) of water per day $(1\text{ L} = 1000\text{ cm}^3)$. How much depth would a lake lose per year if it covered an area of 60 km^2 with uniform depth and supplied a local town with a population of 40,000 people? Consider only population uses, and neglect evaporation, rain, creeks and rivers.

63. A certain compact disc (CD) contains 783.216 megabytes of digital information. Each byte consists of exactly 8 bits. When played, a CD player reads the CD's information at a constant rate of 1.4 megabits per second. How many minutes does it take the player to read the entire CD?

64. An *angstrom* (symbol Å) is a unit of length, defined as 10^{-10} m, which is on the order of the diameter of an atom. (*a*) How many nanometers are in 1.0 angstrom? (*b*) How many femtometers or fermis (the common unit of length in nuclear physics) are in 1.0 angstrom? (*c*) How many angstroms are in 1.0 m? (*d*) How many angstroms are in 1.0 light-year (see Problem 25)?