

Useful Data

gravitational constant	$G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
Coulomb constant	$k = 8.99 \times 10^9 \text{ J}\cdot\text{m}/\text{C}^2$ or $\text{N}\cdot\text{m}^2/\text{C}^2$
Boltzmann's constant	$k = 1.38 \times 10^{-23} \text{ J}/\text{K}$
quantum of charge	$e = 1.60 \times 10^{-19} \text{ C}$
speed of light	$c = 3.00 \times 10^8 \text{ m}/\text{s}$
Planck's constant	$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$
absolute zero	$-273.15 \text{ }^\circ\text{C}$
speed of sound in air	$340 \text{ m}/\text{s}$

- 1 Starting at rest, a terrier puppy accelerates at $3.7 \text{ m}/\text{s}^2$. Find the time she will need to travel 2.8 m.
- 2 Make an order-of-magnitude estimate of the number of grains of sand in one of those big, heavy sandbags they use for flood control.
- 3 Explain what's wrong with the following statements.
 - (a) A falling rock has an acceleration of $9.8 \text{ m}/\text{s}$.
 - (b) Maria drove down Harbor Boulevard to the 91, then increased her velocity and acceleration until she was ready to merge into the freeway traffic.
 - (c) Trang and Eric were playing frisbee in the parking lot. Trang threw the frisbee, and his force gave it an acceleration that stayed nearly constant while it was in the air. But the throw fell short, and the disk landed on the asphalt and started skidding before it got to Eric. While it was sliding, it lost more and more of its acceleration until it finally slid to a stop.
- 4 The world land speed record was set by a jet-powered British car called the Thrust SSC in the Al-Jafr desert of Jordan. The car's speed was 11.7 times greater than the typical legal freeway speed in the US. Assuming the same deceleration (limited by friction), compare the distances required to stop in the two cases.
- 5 A golf ball of mass m , moving at velocity v , hits a wood wall. It spends time Δt in contact with the wall, compressing and then reexpanding before it springs back off. Suppose for simplicity that it doesn't lose any speed on the bounce, and that the wall's force F on the ball is constant during the time they spend in contact. The ball leaves a dent in the wood, and by comparing with the dent made when we press an object against the wood with a known force, we are able to determine F .
 - (a) Find Δt in terms of the other variables, which we assume can all be measured.
 - (b) Check that your answer to part a has the right units.
 - (c) Check the dependence of your answer from part a on the variable F . This means that you should first determine its mathematical behavior (does increasing F increase the result for Δt , or decrease it?), and then compare this with the behavior that you expect physically.
 - (d) Do the same for v and m .

Answer to problem ??

We're given distance and acceleration, and we want to find time. We're not given velocity and don't want to find it. The constant-acceleration equation that has the right variables is $x = (1/2)at^2$.

$$\begin{aligned} t &= \sqrt{2x/a} \\ &= \sqrt{\frac{2(2.8 \text{ m})}{3.7 \text{ m/s}^2}} \\ &= 1.2 \text{ s} \end{aligned}$$

Answer to problem ??

As always in an order-of-magnitude estimate (Light and Matter, section 1.4), we estimate linear dimensions rather than trying to estimate volume directly. A sandbag is probably $10 \text{ cm} \times 30 \text{ cm} \times 50 \text{ cm}$, which comes out to $\sim 10^4 \text{ cm}^3$. A grain of sand might be $(0.1 \text{ cm})^3 = 10^{-3} \text{ cm}^3$. Dividing these two volumes gives an estimate of $\sim 10^7$ grains of sand in one bag.

Answer to problem ??

(a) Acceleration has units of m/s^2 , not m/s .

(b) She increased her velocity in order to merge. Her acceleration had to *decrease* at the end, since she was done speeding up. Once she was moving at constant speed and ready to merge, her acceleration was zero.

(c) Trang's force accelerated the frisbee only while his hand was touching it. After that, it had a *velocity* that stayed nearly constant while it was flying; during this time, its acceleration was nearly zero. As it slid, it lost more and more *velocity*.

Answer to problem ??

We're given information about velocity (a ratio) and acceleration (that it's the same). We want to find out about distance. We don't know anything about time and don't want to find it. The constant-acceleration equation that has the right variables in it is $v_f^2 = v_i^2 + 2ax$. The final velocity is zero, so $x = -v^2/2a$. We can now follow the standard cookbook method for ratios described in ch. 1. First we throw out constant factors, finding

$$x \propto v^2.$$

Next we convert this into an equality between ratios,

$$\frac{x_1}{x_2} = \left(\frac{v_1}{v_2}\right)^2.$$

Plugging in $v_1/v_2 = 11.7$ gives $x_1/x_2 = 137$. That's a huge ratio, which explains why the car needed to set its record in a big, flat desert.

Answer to problem ??

(a) Since we're assuming the force is constant, that means that the acceleration $a = F/m$ is constant as well, so we can use constant acceleration equations. We know velocity, and we can find acceleration from Newton's second law. We want to find time. The constant acceleration equation that has the right variables in it is $a = \Delta v/\Delta t$. Since the ball rebounds with the same speed, $v_f = -v$, and the change in velocity is $v_f - v_i = -v - v = -2v$. Solving for the time gives $\Delta t = -2mv/F$.

(b) The units are

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

which checks out.

(c) Physically, a stronger force (e.g., from a harder type of wood) would be able to turn the ball around more quickly. The answer has F in the denominator, which means that mathematically, a larger F would produce a smaller Δt .

(d) Physically, a ball moving faster would take longer for the force from the wood to turn it around. Mathematically, this checks out because v is on the top. Physically, a more massive ball would accelerate more slowly, and would also take longer to be turned around by the wood. This also checks out mathematically, because m is on top.