

Work and Energy

Problem B**KINETIC ENERGY****PROBLEM**

Silvana Cruciana from Italy set a record in one-hour running by running 18.084 km in 1.000 h. If Cruciana's kinetic energy was 694 J, what was her mass?

SOLUTION**1. DEFINE**

Given: $\Delta x = 18.084 \text{ km} = 1.8084 \times 10^4 \text{ m}$
 $\Delta t = 1.000 \text{ h} = 3.600 \times 10^3 \text{ s}$
 $KE = 694 \text{ J}$

Unknown: $m = ?$

2. PLAN

Choose the equation(s) or situation: Use the definition of average velocity to calculate Cruciana's speed.

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

Use the equation for kinetic energy, using v_{avg} for the velocity term, to solve for m .

$$KE = \frac{1}{2} m v_{avg}^2$$

Rearrange the equation(s) to isolate the unknown(s): Substitute the average velocity equation into the equation for kinetic energy and solve for m .

$$m = \frac{2KE}{v_{avg}^2} = \frac{2KE}{\left(\frac{\Delta x}{\Delta t}\right)^2} = \frac{2KE\Delta t^2}{\Delta x^2}$$

3. CALCULATE

Substitute the values into the equation(s) and solve:

$$m = \frac{(2)(694 \text{ J})(3.600 \times 10^3 \text{ s})^2}{(1.8084 \times 10^4 \text{ m})^2} = \boxed{55.0 \text{ kg}}$$

4. EVALUATE

If the average speed is rounded to 5.0 m/s, and the kinetic energy is rounded to 700 J, the estimated mass is 56 kg, which is close to the calculated value.

ADDITIONAL PRACTICE

- In 1994, Leroy Burrell of the United States set what was then a new world record for the men's 100 m run. He ran the $1.00 \times 10^2 \text{ m}$ distance in 9.85 s. Assuming that he ran with a constant speed equal to his average speed, and his kinetic energy was $3.40 \times 10^3 \text{ J}$, what was Burrell's mass?
- The fastest helicopter, the Westland Lynx, has a top speed of $4.00 \times 10^2 \text{ km/h}$. If its kinetic energy at this speed is $2.10 \times 10^7 \text{ J}$, what is the helicopter's mass?

3. Dan Jansen of the United States won a speed-skating competition at the 1994 Winter Olympics in Lillehammer, Norway. He did this by skating 500 m with an average speed of 50.3 km/h. If his kinetic energy was 6.54×10^3 J, what was his mass?
4. In 1987, the fastest auto race in the United States was the Busch Clash in Daytona, Florida. That year, the winner's average speed was about 318 km/h. Suppose the kinetic energy of the winning car was 3.80 MJ. What was the mass of the car and its driver?
5. In 1995, Karine Dubouchet of France reached a record speed in downhill skiing. If Dubouchet's mass was 51.0 kg, her kinetic energy would have been 9.96×10^4 J. What was her speed?
6. Susie Maroney from Australia set a women's record in long-distance swimming by swimming 93.625 km in 24.00 h.
 - a. What was Maroney's average speed?
 - b. If Maroney's mass was 55 kg, what was her kinetic energy?
7. The brightest, hottest, and most massive stars are the brilliant blue stars designated as spectral class O. If a class O star with a mass of 3.38×10^{31} kg has a kinetic energy of 1.10×10^{42} J, what is its speed? Express your answer in km/s (a typical unit for describing the speed of stars).
8. The male polar bear is the largest land-going predator. Its height when standing on its hind legs is over 3 m and its mass, which is usually around 500 kg, can be as large as 680 kg. In spite of this bulk, a running polar bear can reach speeds of 56.0 km/h.
 - a. Determine the kinetic energy of a running polar bear, using the maximum values for its mass and speed.
 - b. What is the ratio of the polar bear's kinetic energy to the kinetic energy of Leroy Burrell, as given in item 1?
9. Escape speed is the speed required for an object to leave Earth's orbit. It is also the minimum speed an incoming object must have to avoid being captured and pulled into an orbit around Earth. The escape speed for a projectile launched from Earth's surface is 11.2 km/s. Suppose a meteor is pulled toward Earth's surface and, as a meteorite, strikes the ground with a speed equal to this escape speed. If the meteorite has a diameter of about 3 m and a mass of 2.3×10^5 kg, what is its kinetic energy at the instant it collides with Earth's surface?

Practice B KE

#1 $d = 100\text{m}$

$t = 9.85\text{s}$

$KE = 3.40 \times 10^3 \text{ J}$

$KE = \frac{1}{2}mv^2$

$= \frac{1}{2}(x)\left(\frac{100}{9.85}\right)^2$

$3.4 \times 10^3 = \frac{1}{2}(10.15)^2 x$

$\frac{3.43 \times 10^3}{51.5} = \frac{51.5}{51.5} x$

$x = 66.6 \text{ kg}$

#2

$V = 400 \text{ km/h} = 111.11 \text{ m/s}$

$KE = 2.1 \times 10^7 \text{ J}$

$m = x$

$KE = \frac{1}{2}mv^2$

$2.1 \times 10^7 = \frac{1}{2}(x)(111.11^2)$

$2.1 \times 10^7 = 6172.7 x$

$x = 3402 \text{ kg}$

#3 $d = 500\text{m}$

$V = 50.3 \text{ km/h} = 13.97 \text{ m/s}$

$KE = 6.54 \times 10^3 \text{ J}$

$m = x$

$KE = \frac{1}{2}mv^2$

$= \frac{1}{2}(x)(13.97^2)$

$6.54 \times 10^3 = 97.58 x$

$x = 67 \text{ kg}$

#4

$V = 318 \text{ km/h} = 88.33 \text{ m/s}$

$KE = 3.80 \times 10^6$

$m =$

$KE = \frac{1}{2}mv^2$

$3.8 \times 10^6 = \frac{1}{2}x(88.33^2)$

$3.8 \times 10^6 = 3901.34 x$

$974 = x$
 kg

#5

$$m = 51 \text{ kg}$$

$$KE = 9.96 \times 10^4$$

$$KE = \frac{1}{2} m v^2$$

$$9.96 \times 10^4 = \frac{1}{2} (51) (x^2)$$

$$\frac{9.96 \times 10^4}{25.5} = \frac{25.5 x^2}{25.5}$$

$$25.5$$

$$25.5$$

$$3905.88 = x^2$$

$$\boxed{62.5 \text{ m/s} = x}$$

#6 a)

$$\frac{93.625}{24} =$$

$$\boxed{3.9 \text{ km/h}}$$

$$\text{or } \boxed{1.08 \text{ m/s}}$$

b) $m = 55 \text{ kg}$

$$v = 1.08 \text{ m/s}$$

$$KE = \frac{1}{2} m v^2$$

$$= \frac{1}{2} (55) (1.08^2)$$

$$= \boxed{32 \text{ J}}$$

#7 $m = 3.38 \times 10^{31} \text{ kg}$

$$KE = 1.10 \times 10^{42} \text{ J}$$

$$v = x$$

$$KE = \frac{1}{2} m v^2$$

$$1.1 \times 10^{42} = \frac{1}{2} (3.38 \times 10^{31}) x^2$$

$$1.1 \times 10^{42} = 1.69 \times 10^{31} x^2$$

$$\frac{255125}{\text{m/s}} = x$$

$$\boxed{x = 255 \text{ km/s}}$$

#8 $v = 56 \text{ km/h}$ or 15.56 m/s

$$m = 680 \text{ kg}$$

a) $KE = \frac{1}{2} m v^2$

$$= \frac{1}{2} (680) (15.56^2)$$

$$= \boxed{8.23 \times 10^4 \text{ J}}$$

b) $\frac{8.23 \times 10^4}{3.4 \times 10^3} = \boxed{\frac{24}{1}}$

#9 $v = 11.2 \text{ km/s} = 11200 \text{ m/s}$

$$m = 2.3 \times 10^5 \text{ kg}$$

$$KE = \frac{1}{2} m v^2$$

$$= \frac{1}{2} (2.3 \times 10^5) (11200^2)$$

$$= \boxed{1.44 \times 10^{13}}$$