freefall #3, 1

While holding his rifle at shoulder–level, a 1.8 meter–tall hunter accidentally discharges it straight up into the air.

If the bullet exits the barrel of the rifle at 200 m?sec how many seconds does the hunter have to "step aside" to avoid being hit by the descending bullet?

Var	Given value	Units	Description
v_i	200	$\frac{m}{s}$	initial velocity
v_f	–200	$\frac{m}{s}$	final velocity
t		s	time
a	–9.8	$\frac{m}{s^2}$	acceleration due to gravity

$$a = \frac{v_f - v_i}{t}$$

$$t\,a = v_f - v_i$$

$$t = \frac{v_f - v_i}{a}$$

$$= \frac{\left(-200\,\frac{m}{s}\right) - \left(200\,\frac{m}{s}\right)}{-9.8\,\frac{m}{s^2}}$$

$$= 41.\text{s}$$ ✓

freefall #3, 1 (continued)

How high did the bullet rise in the air before it starting falling back down to earth?

Var	Given value	Units	Description
Δx		m	max height
t_{half}		s	time for lhalf the trip

NOTE – at the top of the path, v = 0 so for the second half of the trip, the initial velocity is zero:

$$t_{half} = \frac{1}{2} t$$

$$= \frac{1}{2}(41.\,\text{s})$$

$$= 20.\,\text{s}$$ ✓

$$\Delta x = \frac{1}{2} a\, t_{half}^{\;2}$$

$$= \frac{1}{2}\left(-9.8\,\frac{\text{m}}{\text{s}^2}\right)(20.\,\text{s})^2$$

$$= -2.0\times10^{3}\,\text{m}$$ ✓

If he does not move fast enough, at what velocity would the descending bullet strike his shoulder? Assuming he shot from his shoulder, the bullet would hit his shoulder at the same magnitude of velocity that it had when it left the gun.

$$v_f = -200\,\frac{m}{s}$$

freefall #3

When rising to spike a ball in a volleyball game, a player jumps vertically 1.5 meters off the floor.

How much total time does he spend in the air, assuming he lands in the same position from which he left the ground.

Var	Given value	Units	Description
Δx	–1.5	m	displacement from top of path down
v_i	0	$\frac{m}{s}$	velocity at top of path
t_{half}		s	time for half the trip
a	–9.8	$\frac{m}{s^2}$	acc. due to grav
t		s	time for whole trip
v_f		$\frac{m}{s}$	velocity at which he hits ground

$$\Delta x = v_i t_{half} + \frac{1}{2} a t_{half}^2$$

$$\Delta x = \frac{1}{2} a t_{half}^2$$

$$2 \Delta x = a t_{half}^2$$

$$\frac{2 \Delta x}{a} = t_{half}^2$$

$$t_{half} = \sqrt{\frac{2 \Delta x}{a}}$$

freefall #3 (continued)

$$= \sqrt{\frac{2(-1.5\,\text{m})}{-9.8\,\frac{\text{m}}{\text{s}^2}}}$$

$$= 0.55\,\text{s}$$ ✓

$$t = 2\,t_{\text{half}}$$

$$= 2(0.55\,\text{s})$$

$$= 1.1\,\text{s}$$ ✓

At what velocity did he hit the ground at the end of the jump?

$$v_{\text{f}} = v_{\text{i}} + a\,t_{\text{half}}$$

$$= \left(0\,\frac{\text{m}}{\text{s}}\right) + \left(-9.8\,\frac{\text{m}}{\text{s}^2}\right)(0.55\,\text{s})$$

$$= -5.4\,\frac{\text{m}}{\text{s}}$$ ✓

freefall #3, 2

Two students are tossing a set of keys from one to the other. The first student (who initially has the keys) is 1.8 meters tall and is standing on the ground 4 meters below the second student who is on a catwalk.

The student on the ground tosses the keys upward, releasing them exactly as his hand reaches the top of his head, with just the right velocity so that their apex coincides with the second student's outreached hand.

It is very confusing, the way this problem is worded. We need to know the displacement between where the keys left the first student's hand to the second student's hand. I'm going to assume that the second student is laying on his stomach on the catwalk holding his hand out level with the catwalk.

$$\Delta x = 4\,m - 1.8\,m = 2.2\,m$$

Var	Given value	Units	Description
v_f	0	$\frac{m}{s}$	final velocity
v_i		$\frac{m}{s}$	initial velocity
a	–9.8	$\frac{m}{s^2}$	acc due to gravity
Δx	2.2	m	displacement
t		s	time

$$v_f^2 = v_i^2 + 2\,a\,\Delta x$$

$$v_f^2 - 2\,a\,\Delta x = v_i^2$$

$$v_i = \sqrt{v_f^2 - 2\,a\,\Delta x}$$

freefall #3, 2 (continued)

$$= \sqrt{\left(0\,\frac{\text{m}}{\text{s}}\right)^2 - 2\left(-9.8\,\frac{\text{m}}{\text{s}^2}\right)(2.2\,\text{m})}$$

$$= 6.6\,\frac{\text{m}}{\text{s}}$$ ✓

$$a = \frac{v_f - v_i}{t}$$

$$t\,a = v_f - v_i$$

$$t = \frac{v_f - v_i}{a}$$

$$= \frac{\left(0\,\frac{\text{m}}{\text{s}}\right) - \left(6.6\,\frac{\text{m}}{\text{s}}\right)}{-9.8\,\frac{\text{m}}{\text{s}^2}}$$

$$= 0.67\,\text{s}$$ ✓

Suppose that the student on the balcony was distracted and failed to catch the keys and they fall back down to the ground.

Var	Given value	Units	Description
$v_{f,\,2}$		$\frac{\text{m}}{\text{s}}$	final velocity when keys hit floor
Δx_2	–1.8	m	displacement of keys if they hit floor

freefall #3, 2 (continued)

$$v_{f,2}{}^2 = v_i{}^2 + 2\,a\,\Delta x_2$$

$$v_{f,2} = \left(v_i{}^2 + 2\,a\,\Delta x_2\right)^{\frac{1}{2}}$$

$$= \left(\left(6.6\,\frac{\text{m}}{\text{s}}\right)^2 + 2\left(-9.8\,\frac{\text{m}}{\text{s}^2}\right)(-1.8\,\text{m})\right)^{\frac{1}{2}}$$

$$= -8.9\,\frac{\text{m}}{\text{s}}$$ ✓

ff#3, 3

Three students are standing side–by–side next to the railing on a fifth floor balcony. Simultaneously, the three students release their pennies.

* One student proceeds to drop a penny to the ground below.
* The second student tosses his penny straight downwards at 15 m?sec, while
* The third student tosses his penny straight upwards at 15 m?sec.

Which penny or pennies strike(s) the ground first?

the penny that was tossed downwards

Which penny or pennies strike(s) the ground last?

the penny that was tossed upwards

Which penny or pennies strike(s) the ground with the greatest final velocity?

the penny that was tossed upwards and the penny that was tossed downwards

ff#3, 3 (continued)

As the pennies are falling, a person on the 3rd floor times one of the pennies as it passes her 1.5–meter tall bedroom window. If the penny took 0.15 seconds to clear her window, how fast was the penny traveling just as it entered the top of her window frame?

Var	Given value	Units	Description
Δx	–1.5	m	displacement
t	0.15	s	time to pass window
v_f		$\frac{m}{s}$	
v_i		$\frac{m}{s}$	
a	–9.8	$\frac{m}{s^2}$	acceleration due to gravity

$$\Delta x = v_i t + \frac{1}{2} a t^2$$

$$\Delta x - \frac{1}{2} a t^2 = v_i t$$

$$v_i = \frac{\Delta x - \frac{1}{2} a t^2}{t}$$

$$= \frac{(-1.5\,\text{m}) - \frac{1}{2}\left(-9.8\,\frac{\text{m}}{\text{s}^2}\right)(0.15\,\text{s})^2}{0.15\,\text{s}}$$

$$= -9.3\,\frac{\text{m}}{\text{s}}$$ ✓

freefall #3, 4

A student, while packing up his book bag that islocated near the edge of a lab table 95–cm tall, accidentally drops his pencil on the floor.

Var	Given value	Units	Description
v_f		$\frac{m}{s}$	final velocity
v_i	0	$\frac{m}{s}$	initial velocity
a	–9.8	$\frac{m}{s^2}$	acc due to grav
Δx	–0.95	m	displacement
t		s	time

With what velocity with the pencil hit the floor?

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$v_f = \sqrt{v_i^2 + 2a\Delta x}$$

$$= \sqrt{\left(0\frac{m}{s}\right)^2 + 2\left(-9.8\frac{m}{s^2}\right)(-0.95\,m)}$$

$$= 4.3\frac{m}{s}$$ ✓

freefall #3, 4 (continued)

How much time does it take the pencil to fall and strike the floor?

$$\Delta x = \frac{1}{2} a t^2$$

$$2\Delta x = a t^2$$

$$\frac{2\Delta x}{a} = t^2$$

$$t = \sqrt{\frac{2\Delta x}{a}}$$

$$= \sqrt{\frac{2(-0.95\,\text{m})}{-9.8\,\frac{\text{m}}{\text{s}^2}}}$$

$$= 0.44\,\text{s}$$ ✓