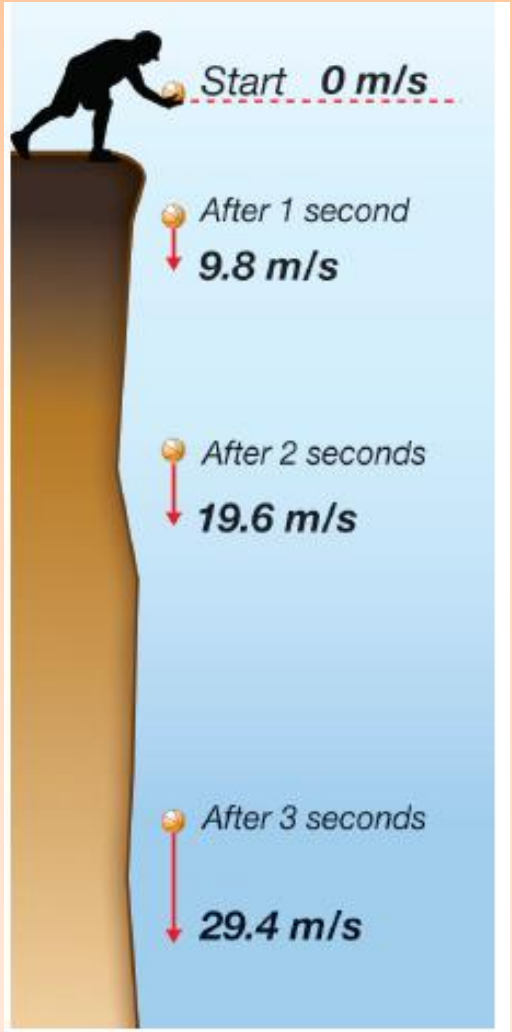
4.3 Free Fall and the Acceleration due to Gravity



- **An object is in free fall if it is moving under the sole influence of gravity.**
- **Free-falling objects speed up, or accelerate, as they fall.**
- **The acceleration of 9.8 m/s^2 is given its own name and symbol—acceleration due to gravity (*g*).**

4.3 Free fall with initial velocity

- The motion of an object in free fall is described by the equations for speed and position with constant acceleration.
- The acceleration (*a)* is replaced by the acceleration due to gravity (*g*) *and t*he variable (*x*) is replaced by (*y).*

FREE FALL MOTION FORMULAS

(choosing up as positive)

$$v = v_0 - gt$$

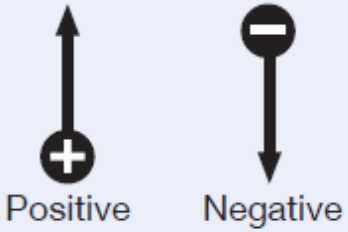
$$y = y_0 + v_0 t + \frac{1}{2} g t^2$$

v	Speed (m/s)
v_0	Initial speed (m/s)
g	9.8 (m/s^2)

y	Height (m)
y_0	Initial height (m)
t	Time (s)

Free Fall Motion Formulas

(choosing up as positive)



$$v = v_0 - gt$$

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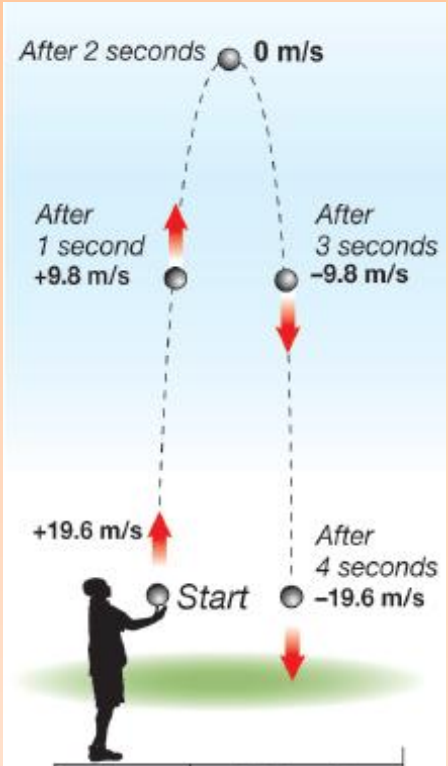
v	Speed (m/s)
v_0	Initial speed (m/s)
g	9.8 (m/s^2)

y	Height (m)
y_0	Initial height (m)
t	Time (s)

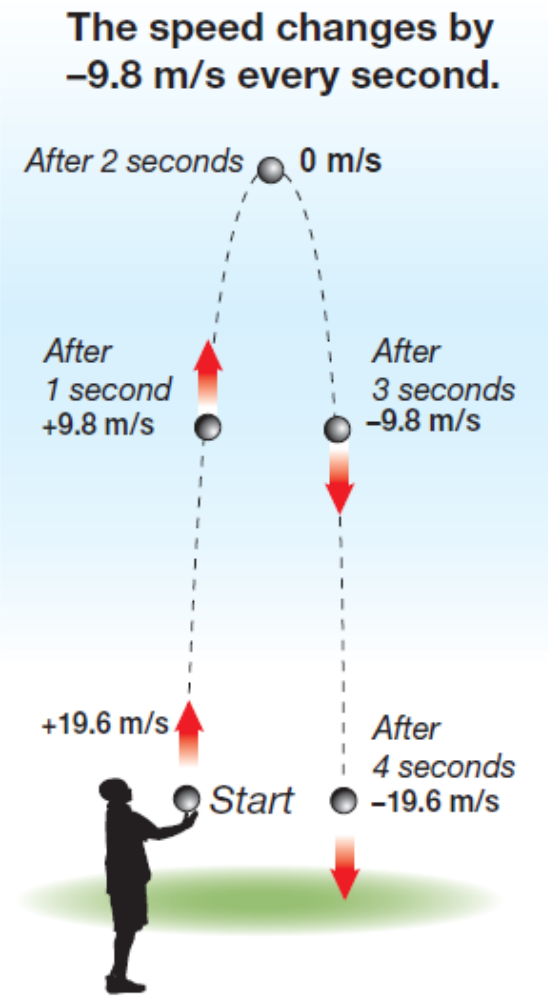
4.3 Free fall with initial velocity

- When the initial speed is upward, at first the acceleration due to gravity causes the speed to *decrease*.
- After reaching the highest point, its speed increases exactly as if it were dropped from the highest point with zero initial speed.



Time (s)	Velocity (m/s)
0.0	19.60
1.0	9.80
2.0	0.00
3.0	−9.80
4.0	−19.60

Launched Ball

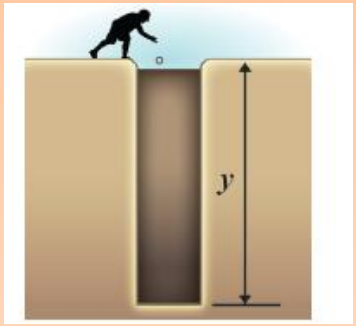


Time (s)	Velocity (m/s)
0.0	19.60
1.0	9.80
2.0	0.00
3.0	–9.80
4.0	–19.60

4.3 Solving problems with free fall

- **Most free-fall problems ask you to find either the height or the speed.**
- **Height problems often make use of the knowledge that the speed becomes zero at the highest point of an object's motion.**
- **If a problem asks for the *time of flight*, remember that an object takes the same time going up as it takes coming down.**

Calculating height from the time of falling



A stone is dropped down a well and it takes 1.6 seconds to reach the bottom. How deep is the well? You may assume the initial speed of the stone is zero.

1. You are asked for distance.
2. You are given an initial speed and time of flight.
3. *Use* $v = v_0 - gt$ and $y = y_0 + v_0t - \frac{1}{2} gt^2$
4. Since y_0 and $v_0 = 0$, the equation reduces to $x = -\frac{1}{2} gt^2$
   - $y = - (0.5) (9.8 \text{ m/s}^2) (1.6\text{s})^2$
   - $y =$ -12.5 m (The negative sign indicates the height is lower than the initial height)

4.3 Air Resistance and Mass

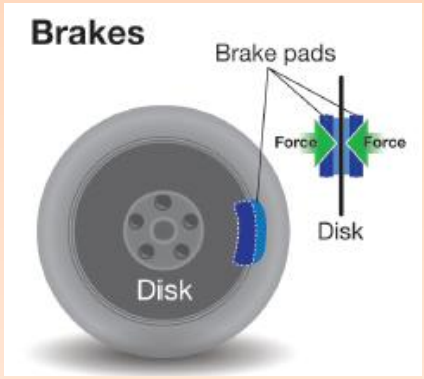
- **The acceleration due to gravity does not depend on the mass of the object which is falling.**
- **Air creates friction that resists the motion of objects moving through it.**
- **All of the formulas and examples discussed in this section assume a *vacuum* (no air).**

4.3 Terminal Speed

- You may safely assume that $a = g = 9.8$ m/sec^2 for speeds up to several meters per second.
- The *air resistance* from friction increases as a falling object's speed increases.
- Eventually, the rate of acceleration is reduced to zero and the object falls with constant speed.
- The maximum speed at which an object falls when limited by air friction is called the *terminal velocity*.

Anti-lock Brakes

Connection



- Antilock braking systems (ABS) are standard on most new cars and trucks.
- If brakes are applied too hard or too fast, a rolling wheel *locks up*, which means it stops turning and the car skids.
- With the help of constant computer monitoring, these systems give the driver more control when stopping quickly.