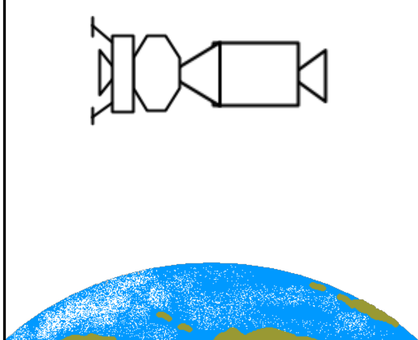
FREE FALL

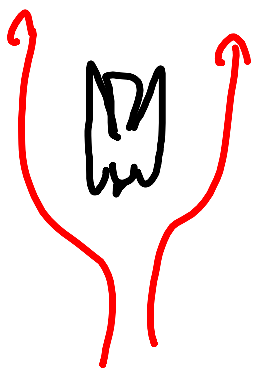
Motion under the influence of gravity ONLY.

No other forces acting.



True

Free Fall



Close to

Free Fall

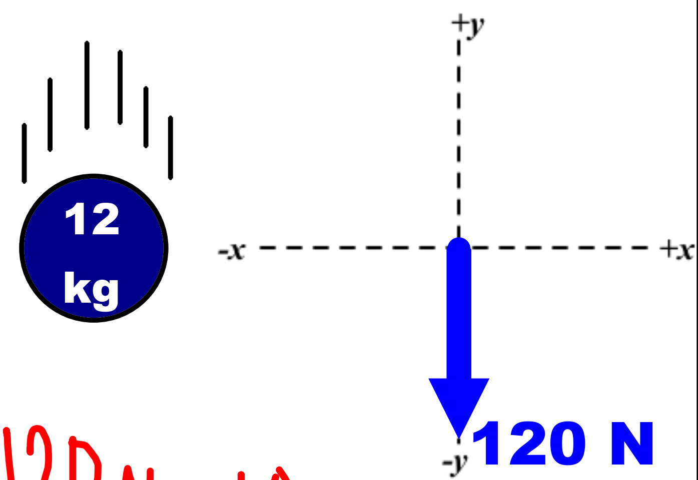
Not even

close.

Free Fall Acceleration on Earth:

g = 10 m/s/s (actually 9.8 m/s/s)

(DOWNWARD)



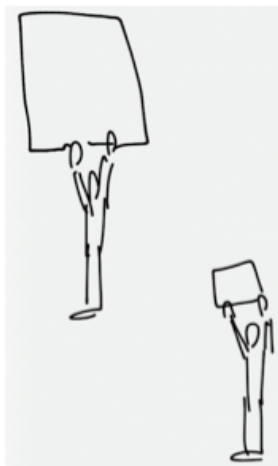
$$a = \frac{F_{net}}{m} = \frac{F_w}{m} = \frac{-120\ N}{12\ kg} = -10\ m/s/s$$

$$a = \frac{F_{net}}{m} = \frac{F_W}{m} = \frac{mg}{m} = g$$

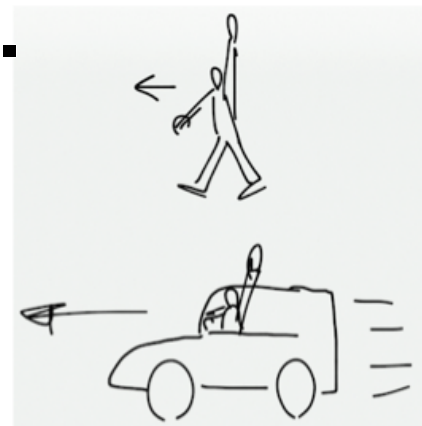
Drag depends on...

1.

2.



3.



4.

Close to FREE FALL

If an object...

- **Isn't moving too fast.**
- **Doesn't have large flat surface areas.**
- **Has an aerodynamic shape.**

Then we won't be too far off if we assume

$$a = -g = -10 \text{ m/s/s}$$

"...assume drag is negligible..."

"...assume minimal drag..."

"...assuming the object is in free fall..."

"dropped" = "dropped from rest"

$a = -10\,m/s^2$

$v_o = 0$

For problems in the up-and-down direction, we should begin to use Δy instead of Δx.

$$\Delta y = v_0 t + \tfrac{1}{2} a t^2$$

$$\Delta y = \tfrac{1}{2}\left(v_0 + v\right)t$$

$$v = v_0 + at$$

$$v^2 = v_0^2 + 2a\Delta y$$

A kid falls from rest on a rooftop onto a trampoline. (Assume minimal drag.) If she fell for 2.5 seconds,

a) What was her final velocity?
b) How far did she fall?

$t = 2.5\,s$

$v_0 = 0$

$a = -10\,m/s^2$

a) $v = ?$

$v = v_0 + at$

$= 0 + (-10)2.5$

$= -25\,m/s$

b) $\Delta y = ?$

$\Delta y = v_0 t + \frac{1}{2}at^2$

$\Delta y = 0 + \frac{1}{2}(-10)(2.5^2)$

$= -31.25\,m$

A kid drops a ball out of the window, 45 meters up. (Assume drag is negligible.)

a) How long before it hits ground?

b) What was its velocity just before it hit?

$\Delta y = -45\,m$

$v_0 = 0$

$a = -10\,m/s^2$

a) $t \rightarrow \Delta y = v_0 t + \frac{1}{2} a t^2$

$-45 = 0 + \frac{1}{2}(-10)t^2$

b) $v \rightarrow v^2 = v_0^2 + 2a\Delta y$

$v^2 = 0^2 + 2(-10)(-45)$

Check yourself:

a) 3 s

b) -30 m/s

after 1 sec → -10 m/s 22 mi/hr

aftr 2 sec → -20 m/s 44 mi/hr

aftr 3 sec → -30 m/s 66 mi/hr

⋮ ⋮ ⋮

after 10 sec → -100 m/s 220 mi/hr

	v	Δy
1s	−10 m/s	−5 m
2s	−20 m/s	−20 m
3s	−30 m/s	−45 m
4s	−40 m/s	−80 m
5s	−50 m/s	
6s	−60 m/s	

−15 m/s

−25 m/s

−35 m/s

Free Fall Drops

$v_0 = 0$ $a = -10\,m/s^2$

Equation	Useful for
$\Delta y = v_0 t + \frac{1}{2} a t^2$	$\Delta y \leftrightarrow t$
$v = v_0 + at$	$v \leftrightarrow t$
$v^2 = v_0^2 + 2a\Delta y$	$v \leftrightarrow \Delta y$

Upward throws...

- Have an initial velocity, $v_o \neq 0$.

- Still count as free fall.

- At maximum height, $v = 0$.

- Up and down are completely symmetrical in time and velocity.

A ball is launched upward at 40 m/s and is caught when it returns to its initial height. (Assume drag is negligible.)

a) How long does it take to get to the top?

b) What is the total time in the air?

c) How high up did it go?

d) What was its velocity when it returned to its original height?

$v_0 = 40 \, m/s$

$a = -10 \, m/s^2$

$v = 0$ at the top

a) $v = v_0 + at$

$0 = 40 + (-10)t$

$+10t \qquad +10t$

$10t = 40$

$t = 4$ sec

b) double it → 8 sec

c) $\Delta y = ?$

$v^2 = v_0^2 + 2a\Delta y$

$0 = 40^2 + 2(-10)\Delta y$

$0 = 1600 - 20\Delta y$

$+20\Delta y \qquad +20\Delta y$

$20\Delta y = 1600$

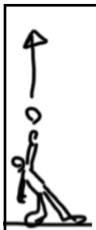
$\Delta y = 80 \, m$

d) $v = v_0 + at$

$v = 40 + (-10)(8)$

$= 40 - 80$

$= -40 \, m/s$



A ball is launched upward at 50 m/s and is caught when it returns to its initial height. (Assume minimal drag.)

a) How long does it take to get to the top?

b) What is the total time in the air?

c) How high up did it go?

d) What was its velocity when it returned to its original height?

a) 5 s $v = v_0 + at$ ($v = 0$ at top)

b) 10 s

c) 125 m $v^2 = v_0^2 + 2a\Delta y$ ($v = 0$ at top)

d) -50 m/s

Free Fall Drops

$v_0 = 0$ $a = -10\,m/s^2$

Equation	Useful for
$\Delta y = v_0 t + \frac{1}{2} a t^2$	$\Delta y \leftrightarrow t$
$v = v_0 + at$	$v \leftrightarrow t$
$v^2 = v_0^2 + 2a\Delta y$	$v \leftrightarrow \Delta y$

Upward Launches

$v = 0$ at the top $a = -10\ m/s^2$

Equation	Useful for
$\Delta y = v_0 t + \frac{1}{2} a t^2$	(set $\Delta y = 0$, solve for TOTAL time)
$v = v_0 + at$	set $v = 0$ solve for time to top.
$v^2 = v_0^2 + 2a\Delta y$	set $v = 0$ solve for Δy at the top (max ht)

A ball is launched upward at 50 m/s and is caught when it returns to its initial height. (Assume minimal drag.)

a) How long does it take to get to the top?
b) What is the total time in the air?
c) How high up did it go?
d) What was its velocity when it returned to its original height?

$v_0 = 50\ m/s$
$a = -10\ m/s^2$
$v = 0$ at the top

a) $t = ?$ → $v = v_0 + at$
$0 = 50 + (-10)t$

c) $\Delta y = ?$ → $v^2 = v_0^2 + 2a\Delta y$
$0^2 = 50^2 + 2(-10)\Delta y$

Check yourself:

a) 5 s

b) ? 10 s

c) 125 m

d) ? −50 m/s