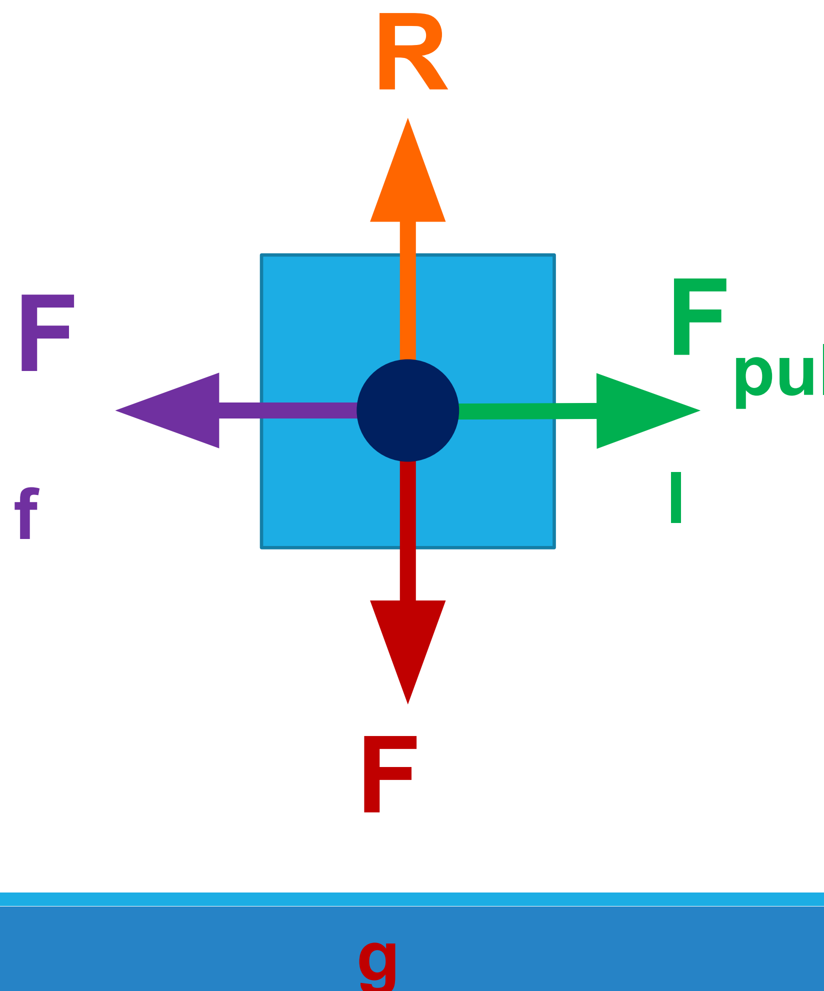
3.3

Calculating Friction

IB PHYSICS | UNIT 3 | FORCES

Free Body Diagrams

Draw a FBD for Santa's Sleigh it is moving at a constant 5



$R = F_g$ $F_f = F_{pull}$

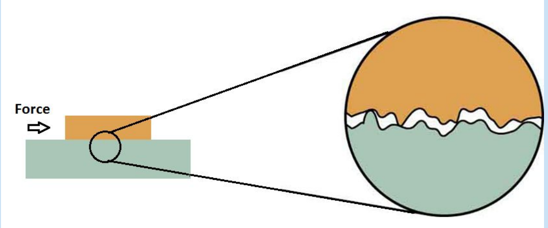
What is Friction?

The force opposing ______________ the motion between two objects that are in contact ______________.

Types of Friction

Static Friction-

Not Moving



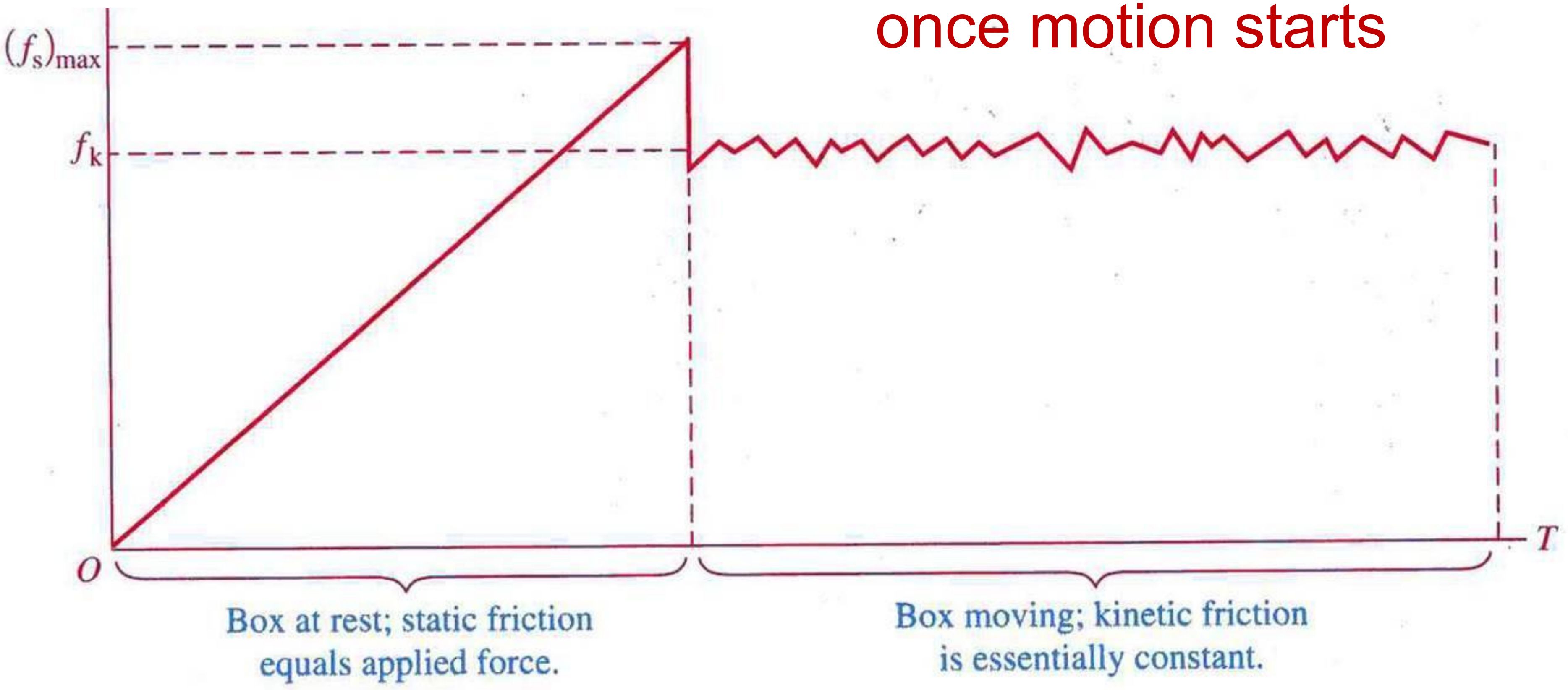
Dynamic (Kinetic) Friction-

In Motion

Static > Dynamic

Static vs. Dynamic Friction

Friction decreases once motion starts



How do we Calculate Friction?

$$F_f = \mu \times R$$

Normal Reaction Force

Coefficient of Friction

**unitless*

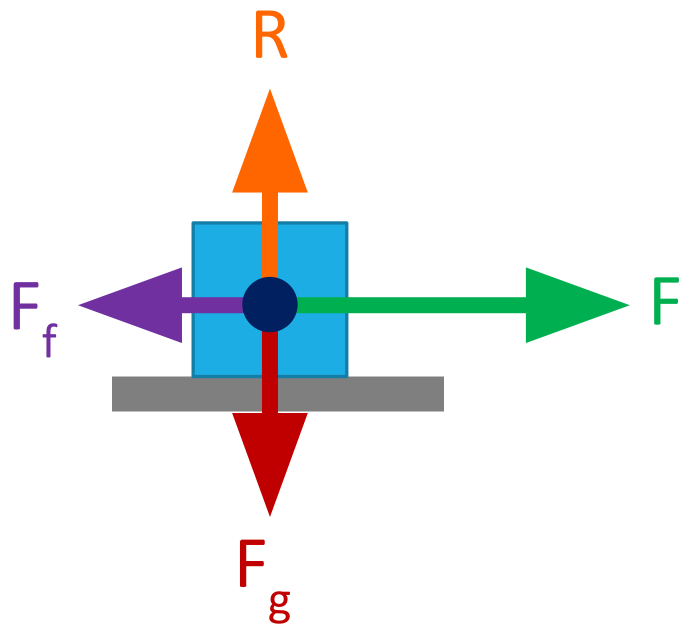
Large μ □ "Sticky"

Small μ □ "Slippery"

Materials	μ_s	μ_d
Steel on ice	0.1	0.05
Steel on steel (dry)	0.6	0.4
Steel on steel (greased)	0.1	0.05
Rope on wood	0.5	0.3
Teflon on steel	0.04	0.04
Shoes on ice	0.1	0.05
Climbing boots on rock	1.0	0.8

How do we Calculate Friction?

F_g	mg ← $g = 9.81\ m\ s^{-2}$
R	F_g *when flat
F_f	μR
F	External Force



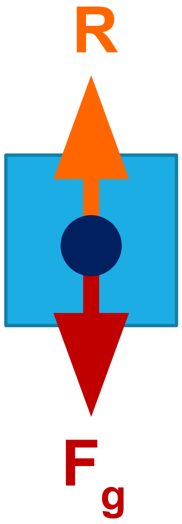
Physics Data Booklet

Sub-topic 2.2 – Forces
$F = ma$
$F_f \le \mu_s R$
$F_f = \mu_d R$

$F_f = \mu R$

Calculate Friction | Try This...

Santa's Sleigh is loaded up with toys for all the good little girls and boys until it has a total mass of 2000 kg. What is the **static friction** force that must be overcome if μ_s is 0.1?



$$F_g = mg = (2000)(9.81) = 19{,}620 \text{ N}$$

$$R = F_g = 19{,}620 \text{ N}$$

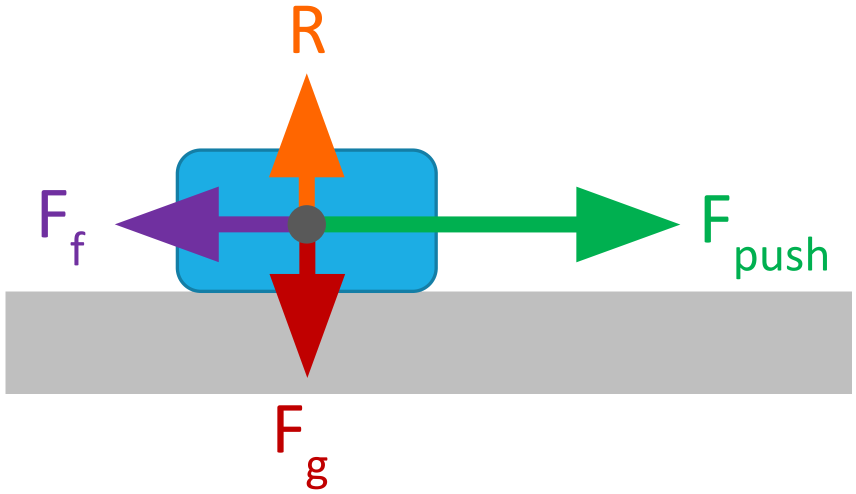
$$F_f = \mu R = (0.1)(19{,}620) = \mathbf{1{,}962\ N}$$

Calculating Acceleration w/ Friction

Step 1:

Find the Force from Friction

- $F_g = mg$
- $R = F_g$
- $F_f = \mu \times R$



Step 2:

Find F_{net}

- $F_{net} = F_{push} - F_f$

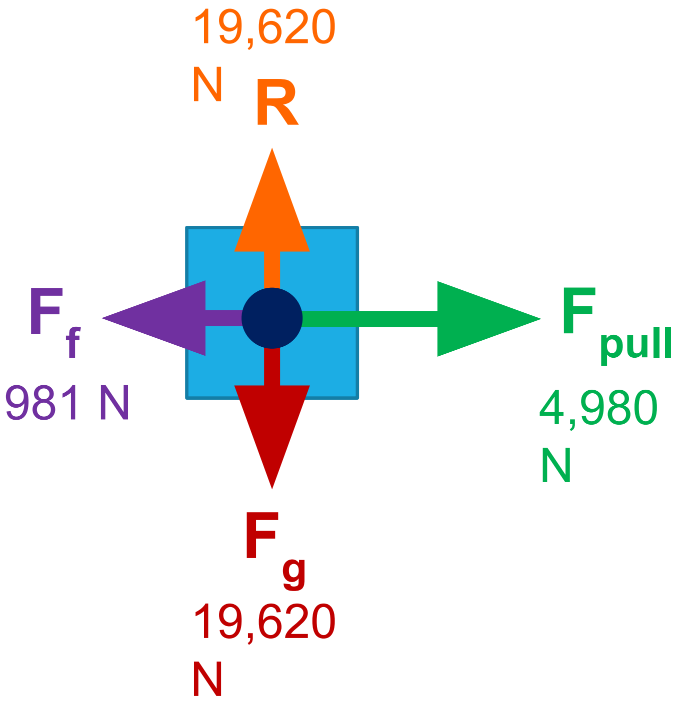
Step 3:

Find acceleration

$$F_{net} = ma \Rightarrow a = F_{net} / m$$

Calculate Friction | Try This…

Santa's reindeer pull his 2000 kg sleigh with a force of 4980 N. How fast does the sleigh accelerate if the coefficient of kinetic friction (μ_k) is 0.05?



$F_g = mg = (2000)(9.81) = 19{,}620$ N

$R = F_g = 19{,}620$ N

$F_f = \mu R = (0.05)(19{,}620) = 981$ N

$F_{net} = 4980 - 981 = 3999$ N

$a = F/m = 3999/2000 =$ **$2\ \mathrm{m\ s^{-2}}$**

Big Ideas so Far….

- Acceleration is zero when net force is zero
  - This doesn't mean just mean "stopped" (constant velocity)
- If you have acceleration of an object, you can find the net force causing that acceleration
  - (Think F = ma)
- Force of friction is related to the normal force by the coefficient of friction (μ)

3.4

Air Resistance

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Big Ideas so Far….

Acceleration is zero when net force is zero

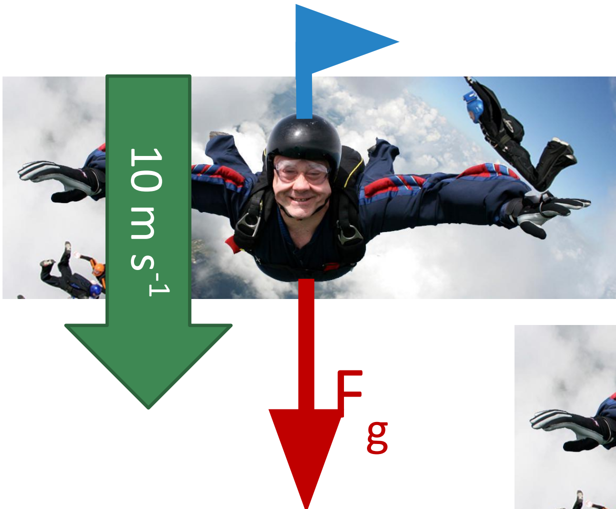
- This doesn't mean just mean "stopped" (constant velocity)

If you have acceleration of an object, you can find the net force causing that acceleration

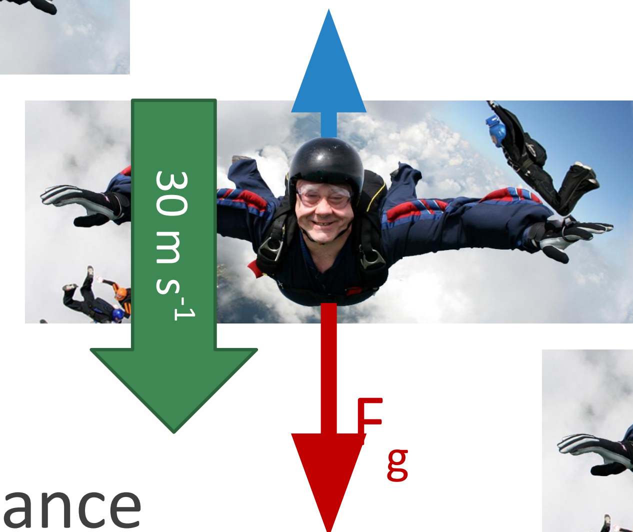
- (Think F = ma)

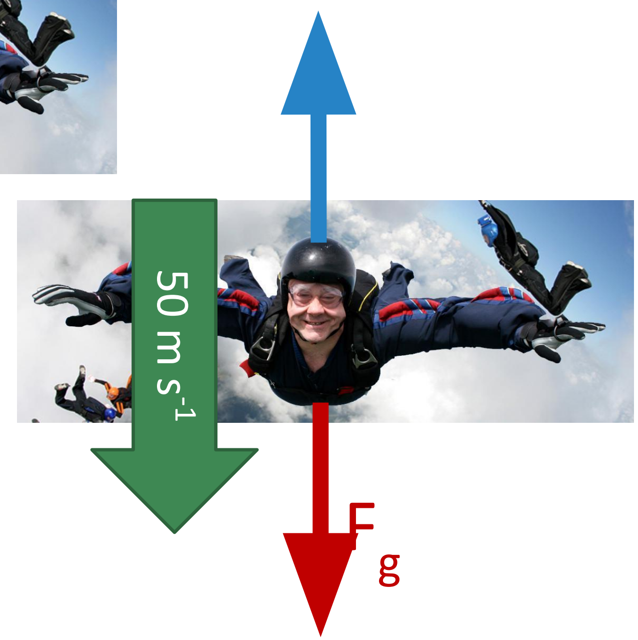
Force of friction is related to the normal force by the coefficient of friction (μ)

Air Resistance



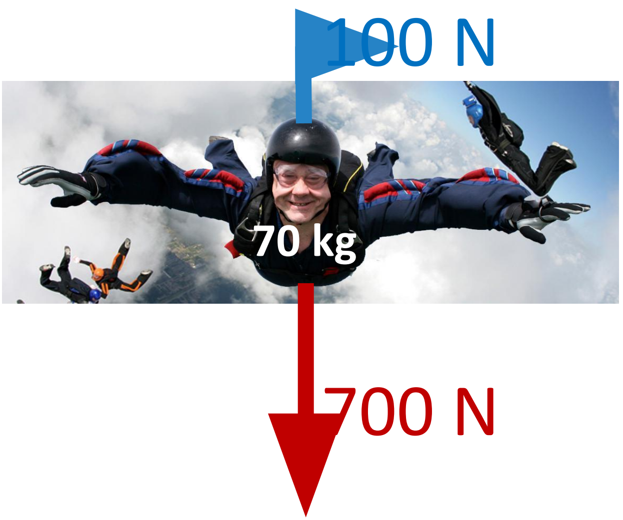
Force of gravity is always constant





Force of air resistance increases when velocity increases

Calculate the Acceleration

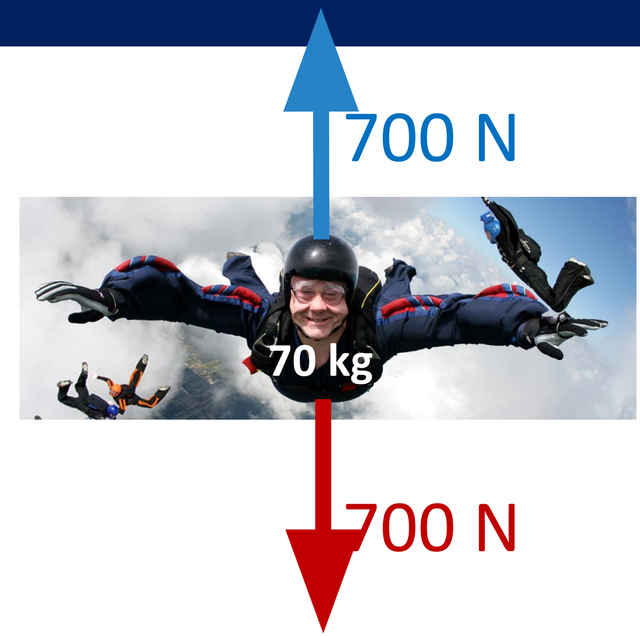


$F_{net} = 600\ N$ ▼

$$a = \frac{F}{m} = \frac{600}{70} = \mathbf{8.57\ m\ s^{-2}}$$

$F_{net} = 300\ N$ ▼

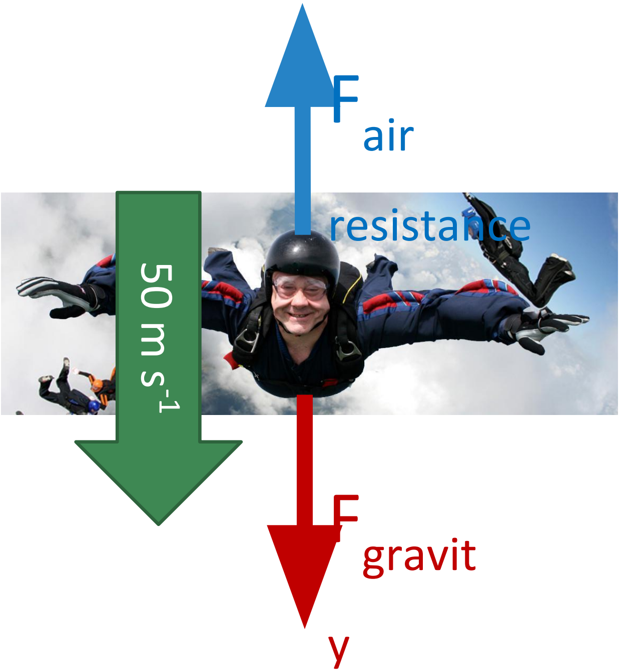
$$a = \frac{300}{70} = \mathbf{4.29\ m\ s^{-2}}$$



$F_{net} = 0\ N$

$$a = \frac{0}{70} = \mathbf{0\ m\ s^{-2}}$$

Terminal Velocity

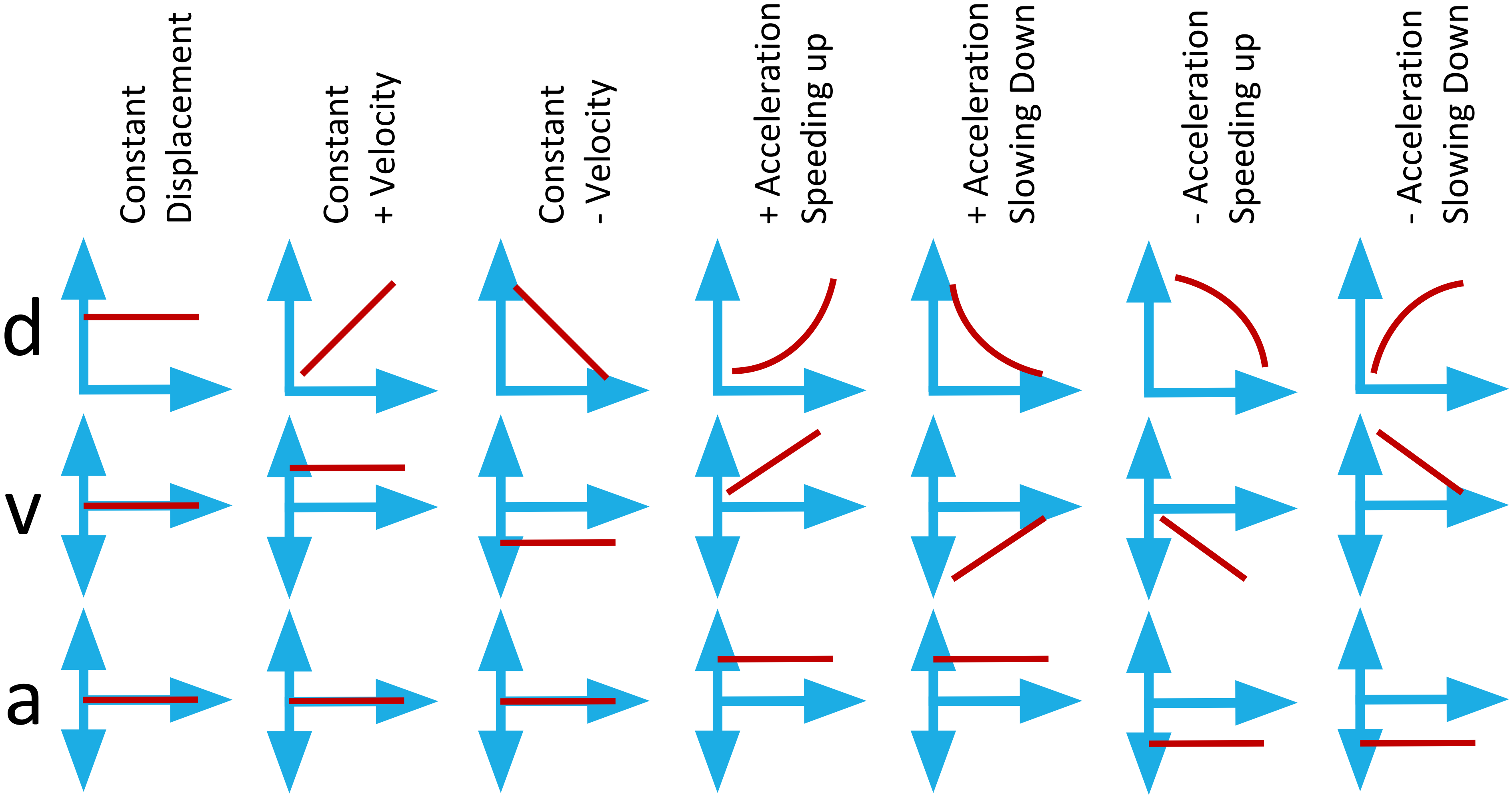


At a certain velocity, the air resistance acting on an object (or person) is equal to the force of gravity.

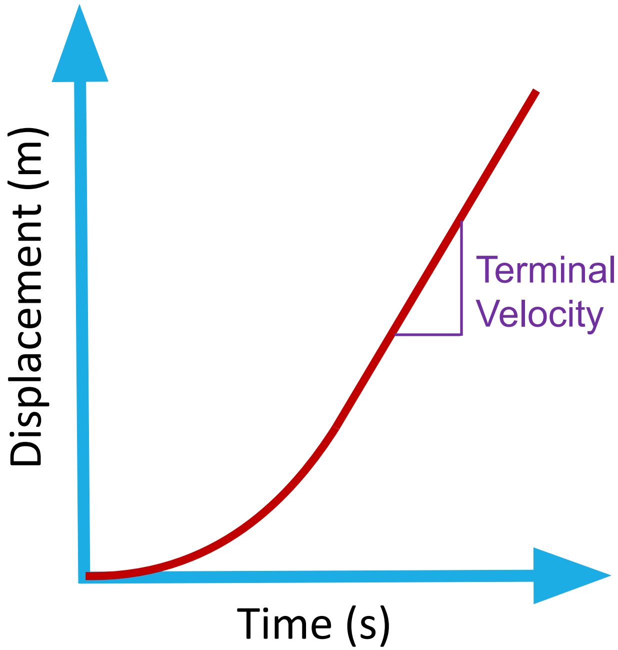
F_{net} = **0 N**

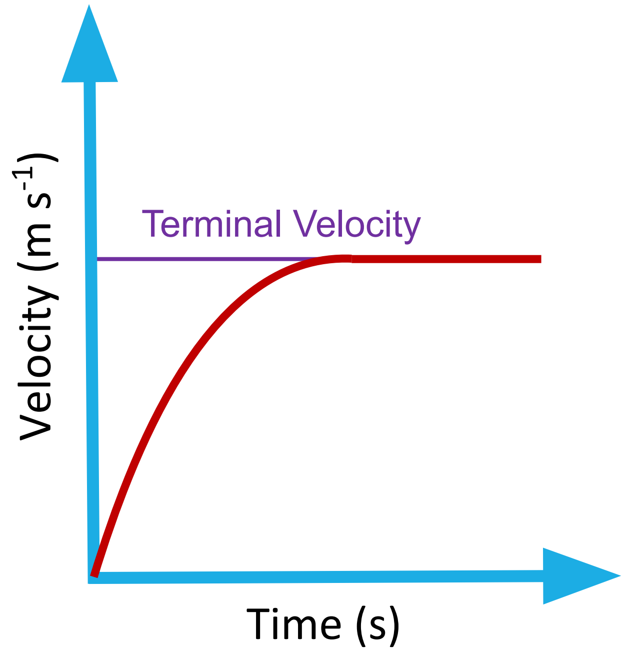
This is the top speed for a falling object in AIR or in any FLUID (gas or liquid).

Motion Graphs Guide



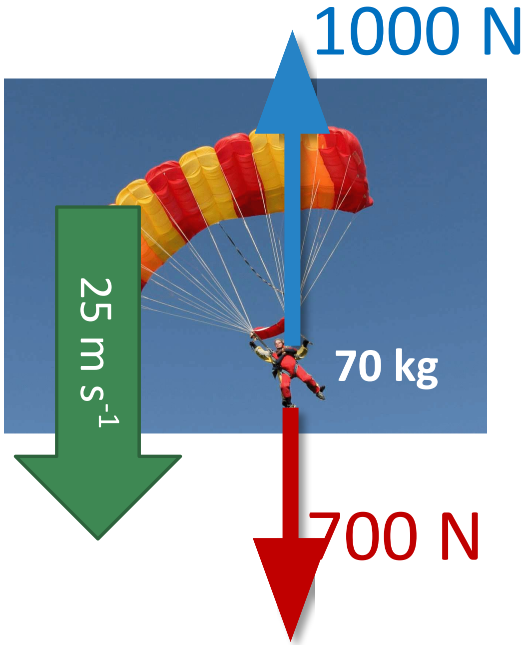
Terminal Velocity

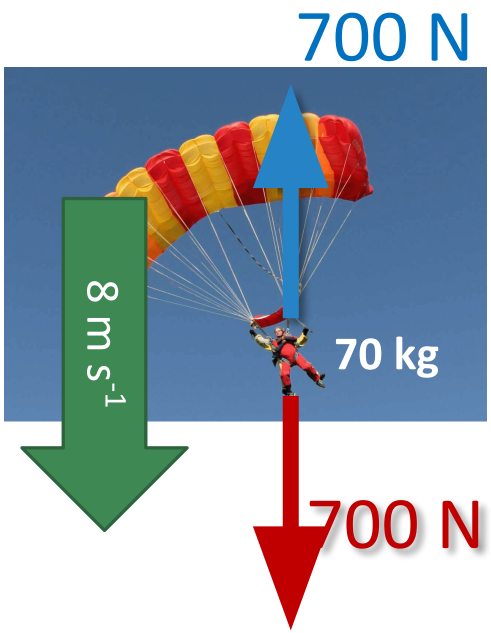




Note: these graphs treat the downward direction as positive

When the Parachute opens…





F_{net} = 500 N ▲

$$a = \frac{F}{m} = \frac{500}{70} = \mathbf{7.14\,m\,s^{-2}}$$

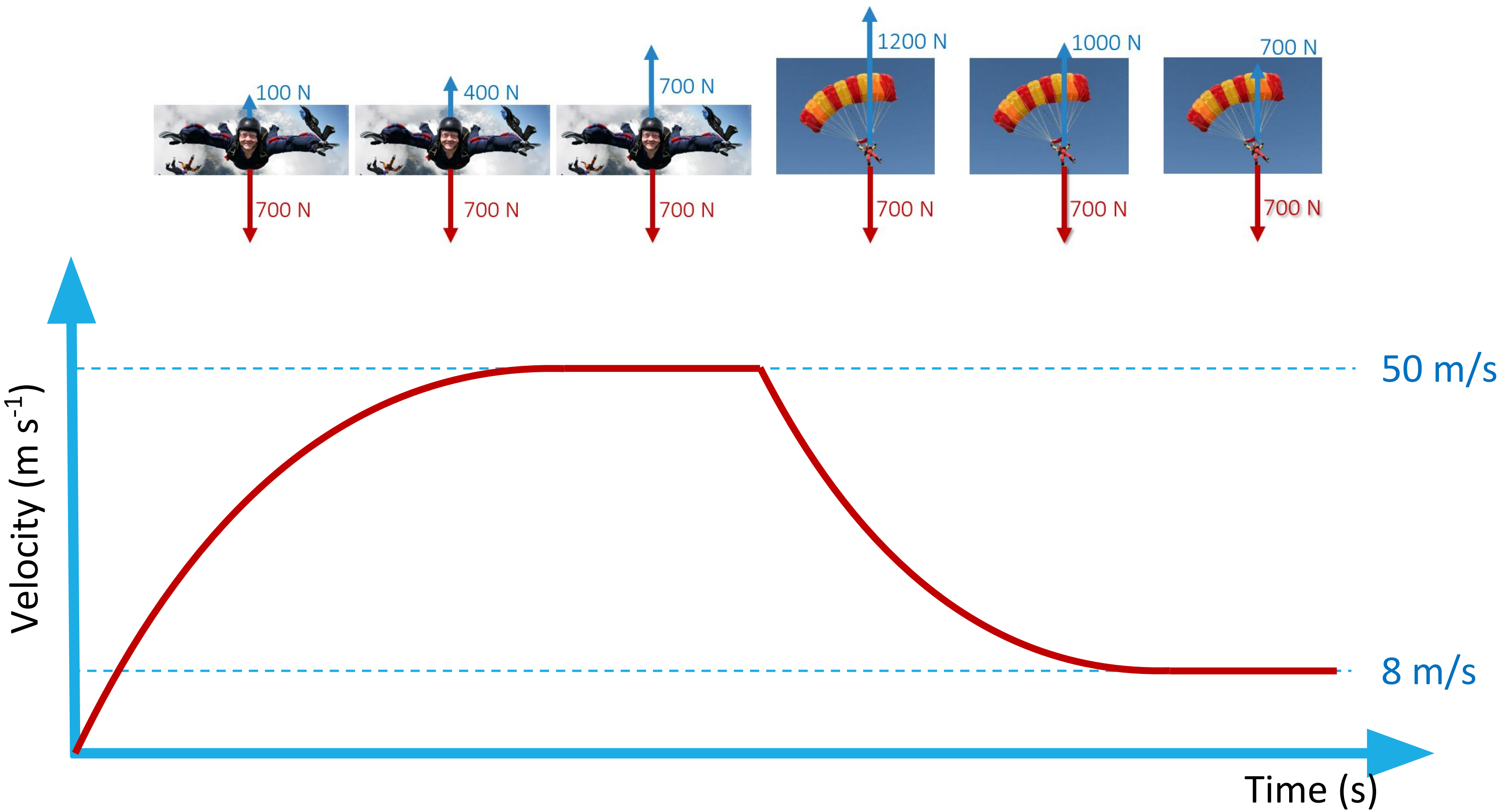
F_{net} = 300 N ▲

$$a = \frac{300}{70} = \mathbf{4.29\,m\,s^{-2}}$$

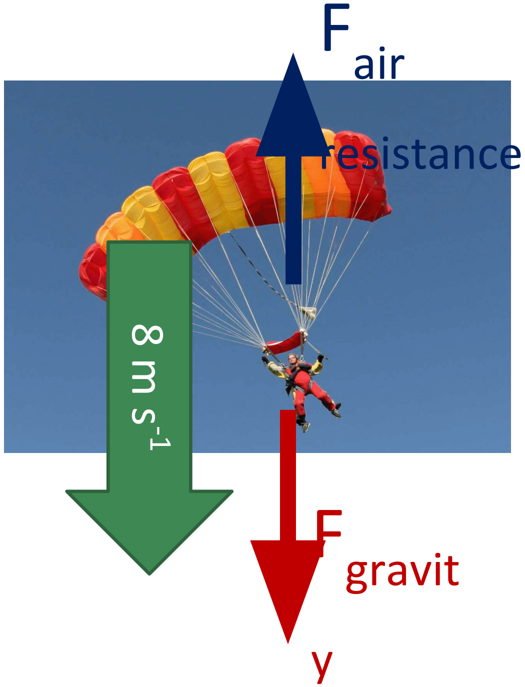
F_{net} = 0 N

$$a = \frac{0}{70} = \mathbf{0\,m\,s^{-2}}$$

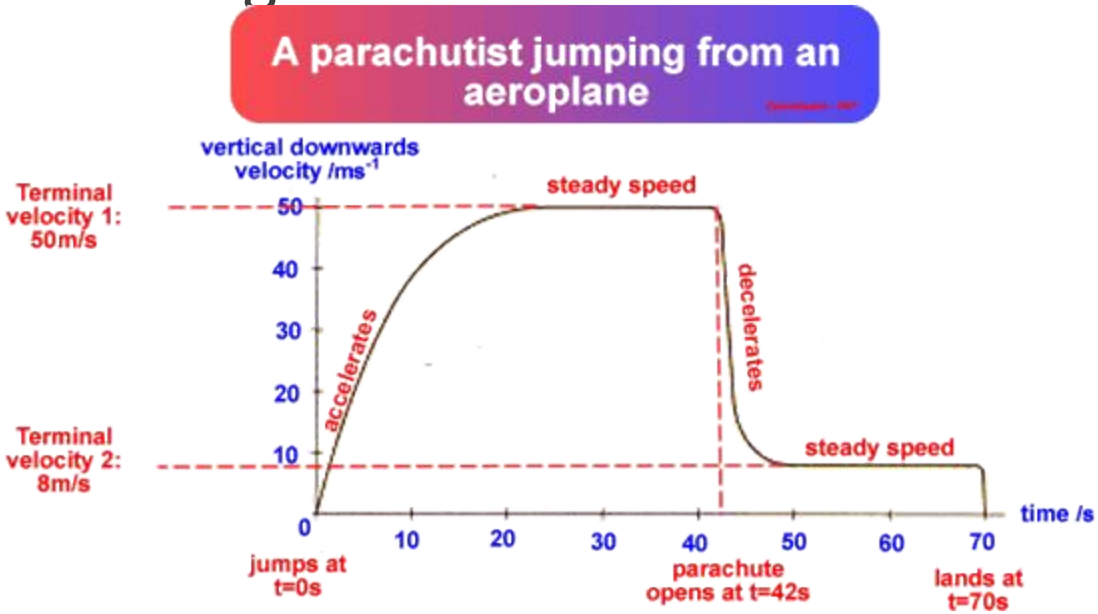
Terminal Velocity



Terminal Velocity



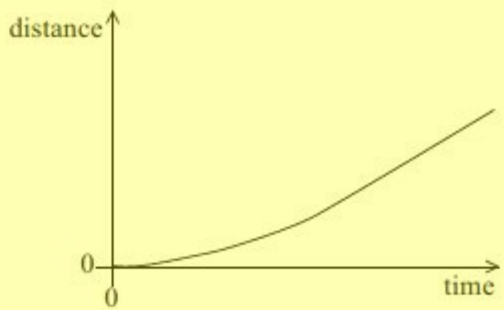
A parachute dramatically decreases the terminal velocity where air resistance balances out the weight



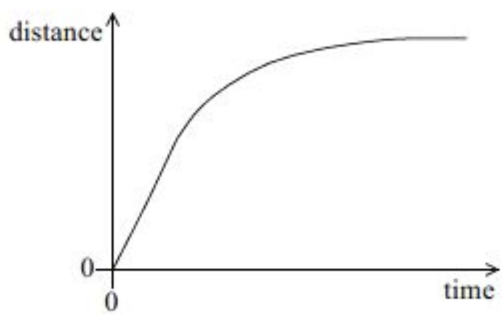
Sample IB Problem

An object falls vertically from rest. Air resistance acts on the object and it reaches a terminal speed. Which of the following is the distance-time graph for its motion?

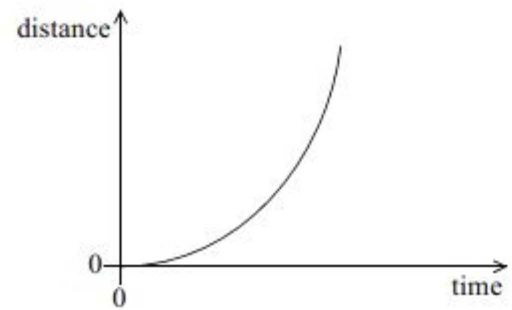
A.



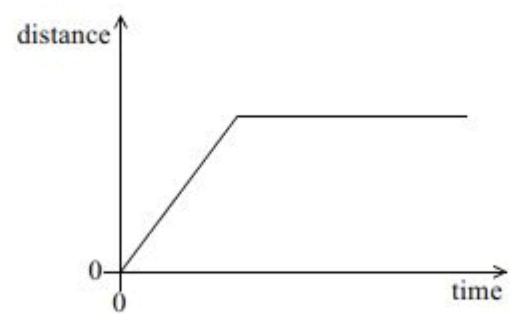
B.



C.



D.



Sample IB Problem

3. A skydiver jumped out of an airplane. On reaching a terminal speed of 60 $m\,s^{-1}$, she opened her parachute. Which of the following describes her motion after opening her parachute?

A. She went upwards for a short time, before falling to Earth at a speed of 60 $m\,s^{-1}$.

B. She continued downwards at 60 $m\,s^{-1}$, but hit the ground with less force.

C. She continued to fall but reached a new terminal speed of less than 60 $m\,s^{-1}$.

D. She went upwards for a short time, before falling to Earth at a speed of less than 60 $m\,s^{-1}$.

Sample IB Problem

4. Two identical balls are dropped from a tall building, one a few seconds after the other. Air resistance is **not** negligible. As the balls fall, the distance between the balls will

A. decrease.

B. increase.

C. increase then remain constant.

D. remain constant.