

Forces and Motion #1



**UNIVERSITY
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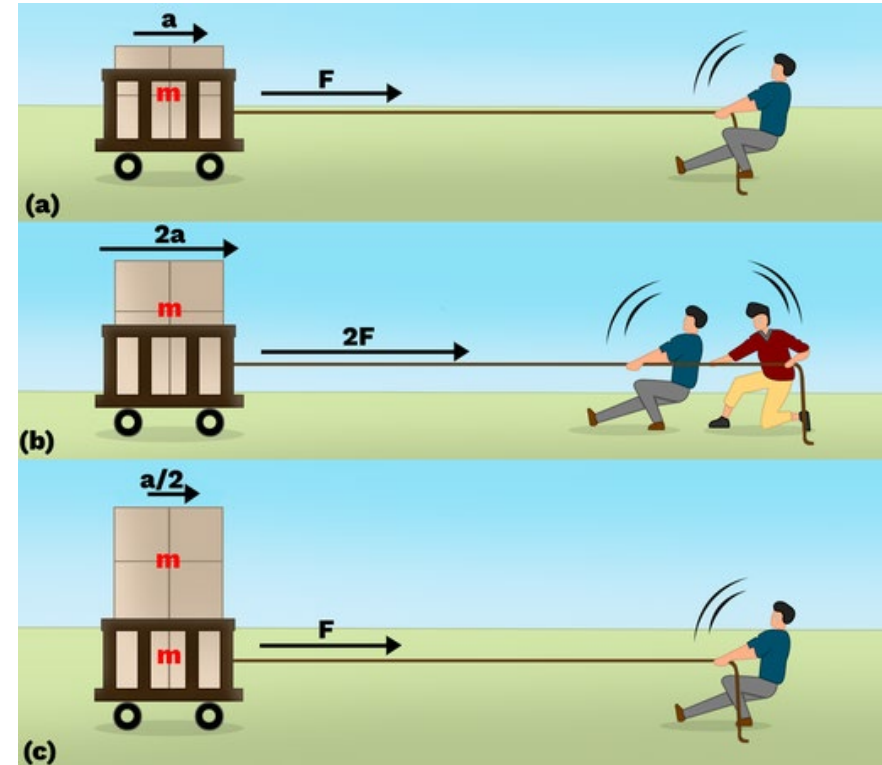
Newton's First Law

- *“An object will remain at rest or move at constant velocity unless acted upon by a resultant force.”*
- If velocity is constant \rightarrow resultant force = 0
- If acceleration exists \rightarrow resultant force \neq 0
- If an object moves at a constant speed:
 - Its acceleration is 0
 - Its resultant force is 0



Newton's Second Law

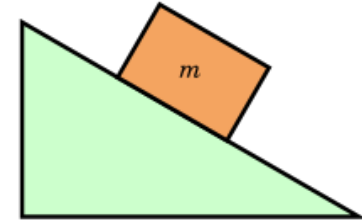
- $F = ma$
- Where:
 - F = resultant force (N)
 - m = mass (kg)
 - a = acceleration (m/s^2)
- **Note, it's the resultant and not the applied force, you must include friction!**



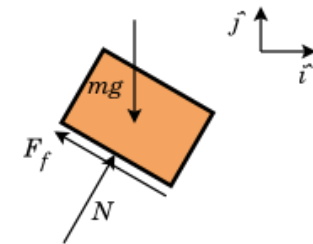
Typical Forces

- Weight (W) – Acts vertically downward
 - $W=mg$
- Normal Reaction (R or N) – Acts perpendicular to surface
- Applied Force (F) – Push or pull
- Friction (F_e or F_f) – Opposes motion (always acts opposite direction of motion.)
- Tension (T) – Force in a rope or cable

A block on a ramp

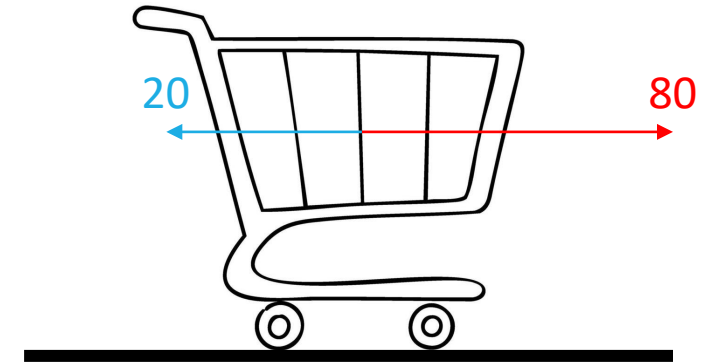


Free body diagram of just the block



Applying Newton's Second Law

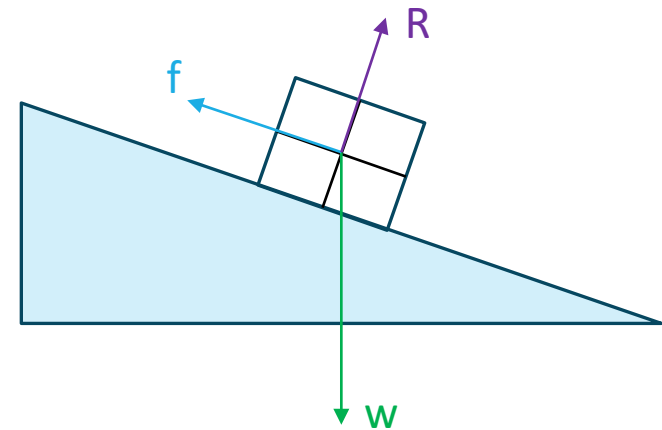
- Exam style question:
 - *A 15 kg trolley is pulled with a force of 80 N. Friction opposing motion is 20 N. Find the acceleration.*
- Step 1 – Find the resultant force:
 - $F_{\text{resultant}} = F_{\text{applied}} - F_{\text{friction}} = 80 - 20 = 60$
- Step 2 – Apply $F = ma$
 - $60 = 15a \rightarrow a = \frac{60}{15} = 4 \text{ m/s}^2$



Note: We left the value in kg as the base SI unit is kg not g

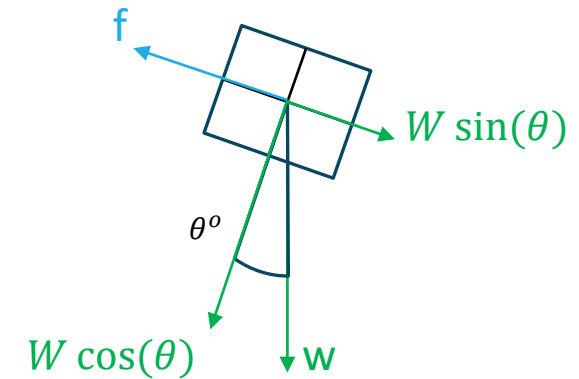
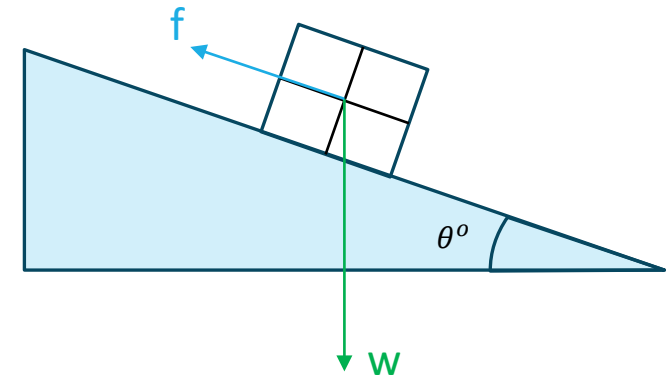
Working out components

- Our scenarios will not always be perfectly perpendicular to the floor, in that case we need to break down forces into components
- For instance, to work out whether the box will go down the slope in the diagram we need to work out the component of its weight acting parallel to the ramp
- If we know R this makes it significantly easier but its not necessary



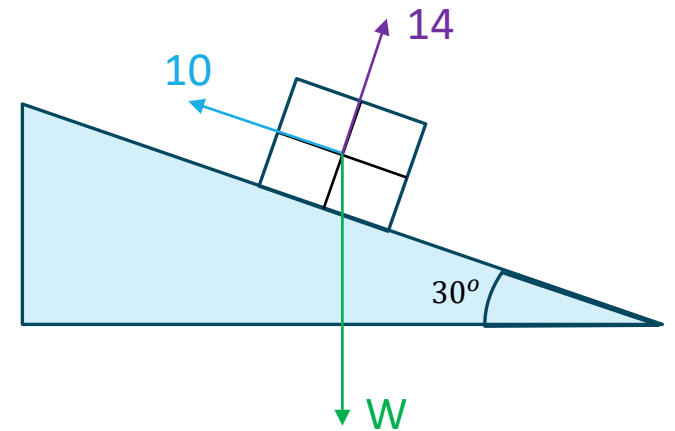
Working out components

- Exam style question:
 - A box is placed on ramp 20° and has a friction force of $5N$. The box weighs $58N$. Prove the box will accelerate down the ramp
- Step 1 - Work out the two components of the weight
 - The parallel component to the slope is always sine
 - The perpendicular component to the slope is always cos
 - $58 * \cos(20) = 54.5022N$
 - $58 * \sin(20) = 19.83N$
- Step 2 – Work out acceleration
 - $m = \frac{w}{g} = \frac{58}{9.81} = 5.91233$
 - $F_{resultant} = F_{applied} - F_{friction} = 19.83 - 5 = 14.83$
 - $F = ma \rightarrow \frac{14.83}{5.91233} = a = 2.508317$
- We can then reapply it to the question
 - The weight gives a parallel force to the ramp which is greater than friction and thus the block will accelerate down the ramp @ 2.508317 m/s^2



Rearranging the formula

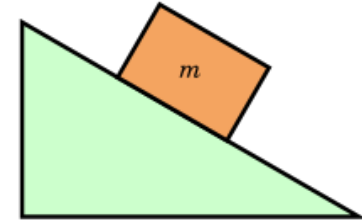
- If you have the value for R, you can work out the overall weight
- As R will be equal to the perpendicular component, we can set them equal
- $14 = W \cos(30) \rightarrow W = \frac{14}{\cos(30)} = 16.166N$
- We can then use this to work out the parallel component



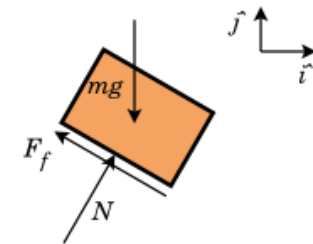
Free Body Diagram (FBD)

- A free body diagram is a simplified diagram showing only the object and all external forces acting on it
- We isolate the object from the system.
- Do NOT draw:
 - The floor
 - The rope
 - The person pushing
- Only draw:
 - The object (as a box or dot)
 - Arrows for forces
 - Labels on every arrow

A block on a ramp

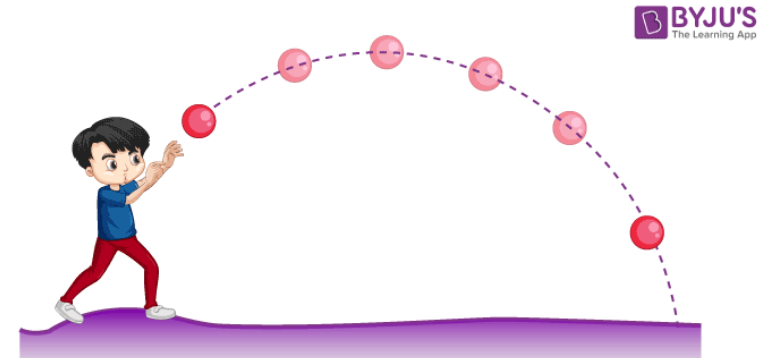


Free body diagram of just the block



Kinematics

- When working with kinematics we use the *suvat* equations
- Kinematics is the study of motion without considering forces.
- We describe motion using:
 - Displacement (s)
 - Velocity (v)
 - Acceleration (a)
 - Time (t)
- If acceleration is constant → use SUVAT equations.



The 5 suvat variables

- We use five motion variables:
 - s = displacement (m)
 - u = initial velocity (m/s)
 - v = final velocity (m/s)
 - a = acceleration (m/s^2)
 - t = time (s)
- Note:
 - Displacement is not distance.
 - Displacement includes direction.

Suvat Equations

- There are 5 main suvat equations however we only really need to use 3:
- $s = u + at$
- $s = ut + \frac{1}{2}at^2$
- $v^2 = u^2 + 2as$
- Its important that you not only memorise these but know when to use them!

$$V = U + AT$$

$$S = \left(\frac{U+V}{2}\right) T$$

$$V^2 = U^2 + 2AS$$

$$S = UT + \frac{1}{2}AT^2$$

$$S = VT - \frac{1}{2}AT^2$$

Choosing the correct equation

- Step 1:
 - Write down what values you are given.
- Step 2:
 - Identify what you need to find.
- Step 3:
 - Choose equation that contains:
 - The variables you know
 - The variable you want
 - No unnecessary variable

$$V = U + AT$$

$$S = \left(\frac{U+V}{2}\right) T$$

$$V^2 = U^2 + 2AS$$

$$S = UT + \frac{1}{2}AT^2$$

$$S = VT - \frac{1}{2}AT^2$$

Example of picking a suvat

- Have no time?
 - Use: $v^2 = u^2 + 2as$
- Have no acceleration?
 - Use: $s = ut + \frac{1}{2}at^2$

Example solving suvat

- A car starts from rest and accelerates at 3 m/s^2 for 5 seconds. Find final velocity.
- Step 1 – Write out our variables
 - s = Not present
 - $u = 0$
 - $v = ?$
 - $a = 3$
 - $t = 5$
- Step 2 – Decide on a suvat equation
 - $s = u + at$
 - Has all the right variables
- Step 3 – work out the answer
 - $s = 0 + (3 * 5)$
 - $s = 15 \text{ m/s}$

Example solving suvat

- A train accelerates from 10 m/s to 20 m/s at 2 m/s². Find displacement.
- Step 1 – Write out our variables
 - $s = ?$
 - $u = 10$
 - $v = 20$
 - $a = 2$
 - $t = \text{not present}$
- Step 2 – Decide on a suvat equation
 - $v^2 = u^2 + 2as$
 - Has all the right variables
- Step 3 – work out the answer
 - $20^2 = 10^2 + 2 * 2 * s$
 - $400 = 100 + 4s$
 - $400 - 100 = 4s$
 - $s = \frac{300}{4} = 75m$