Conditions Equilibrium 1

- The lines of action of the three forces **must all pass** through the same point.
- **The principle of moments:** the sum of all the clock-wise moments about any point must have the same magnitude as the sum of all the anti-clockwise moments about the same point.

Conditions Equilibrium 2

The **sum of all the forces** acting **vertically** upwards must have the same magnitude as the sum of all the forces acting vertically downwards.

Conditions Equilibrium 3

The **sum of all the forces** acting **horizontally** to the right must have the same magnitude as the sum of all the forces acting horizontally to the left.

Conditions Equilibrium 4

If you **resolve all of the forces** the 'ups' will equal the 'downs' and the 'rights' will equal the 'lefts

Scalars

A scalar quantity is very simply a numerical item such as 7°C or 5kg. It can be in any direction and other examples are mass, density, energy or volume.

Vector

This is a "scalar" which has a direction or bearing. This means that we can now think about displacement instead of distance travelled. This enables us to think about the motion of objects in more complex ways and define formulae with directions.

Vector Equations

When applying Mathematics to Physics problems we find that a scalar such as mass converts one vector to another. F = ma where both "F" and "a" are vectors. Example vectors are force, velocity, acceleration and momentum.

Units

When looking at vector equations such as F=ma the units must balance… Force is measured in Newtons (N), mass in kilograms (kg), and acceleration in ms^{-2}. The units on both sides must be equal, so 1 N = 1 $kgms^{-2}$.

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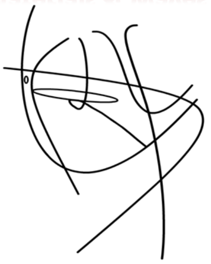

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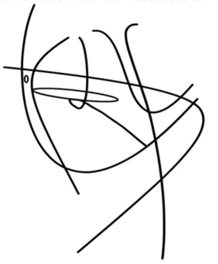

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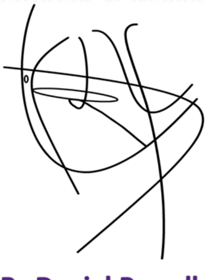

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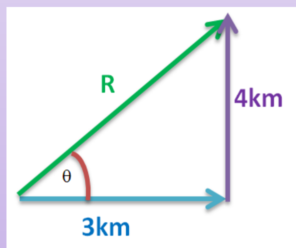
Vector Journeys

When we have a journey which consists of two vectors such as displacement we find that it adds up to form a triangle. We can then go direct or indirect.



Resultant

This is the most direct route or "result" of the two vectors. We can find this by simple Pythagoras. If we had two vectors at right angles of 3km and 4km…

$R^2 = 4^2 + 3^2$

$\tan\theta = opp/adj = 4/3$

$\theta = 53.1°$

Vector Components

Sometimes it is more useful to work out a component of a resultant force in vertical or horizontal direction. This also uses Pythagorean Maths…

$R = 6 ms^{-1}$ at 60°

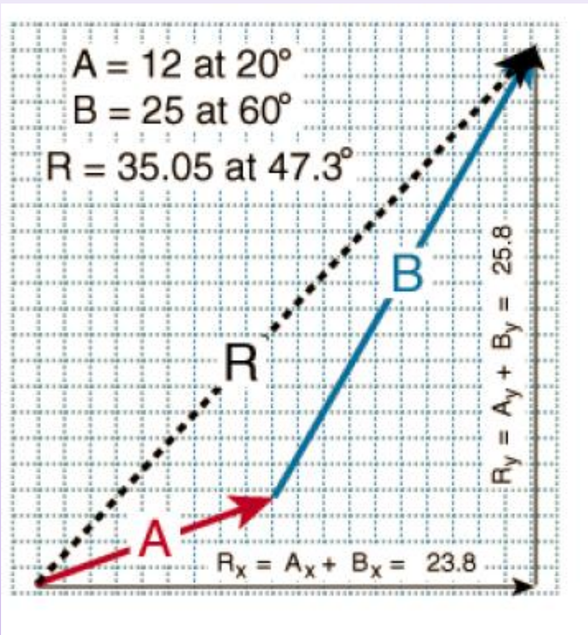
$6\cos 60° = x = \mathbf{3\ ms^{-1}}$

$6\sin 60° = y = \mathbf{5.2\ ms^{-1}}$

Vector Triangles

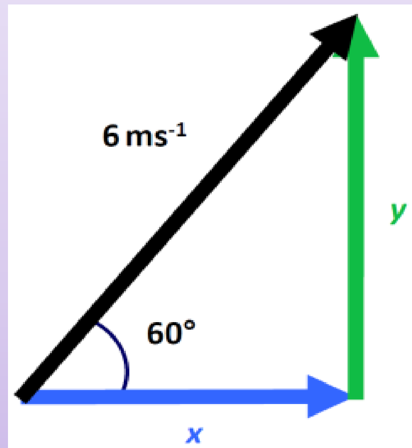
We find that if a vector triangle works for distances it can also mirror the situation with the forces involved. For example if we know the geometry of a car on a slope it will enable us to predict the friction or support forces acting on the slope if we know for example the weight of the car.

Adding Vectors



Vector Resolution

You can resolve a vector into two parts…



Example Scalars

- Mass
- Temperature
- Time
- length
- Speed
- Energy

Example Vectors

- Displacement
- Force
- Velocity
- Acceleration
- momentum

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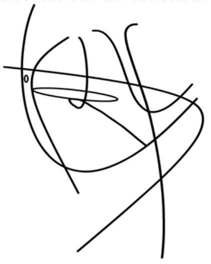

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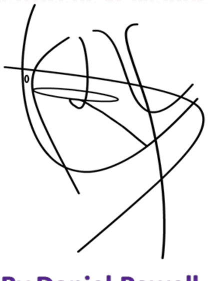

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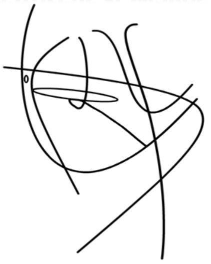

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Block of Wood

For a wooden block sat on a table it is very simple Newton's 3rd Law tells us that the forces of weight are balanced exactly by the support forces…

$0 = S - W$
$W = S$

2D Forces

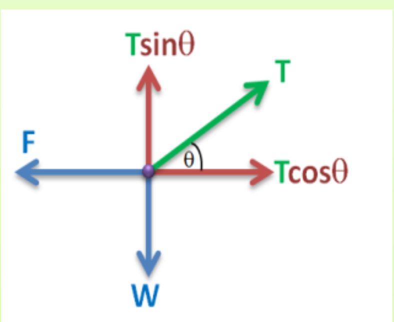
We can think of this in more detail that the sum of all forces is zero on a object moving at a constant speed or stationary. If we can resolve these directions using trigonometry we can create a balance situation…

Sum of vertical forces = 0
Sum of horizontal forces = 0

Childs Swing

When you pull back a swing the components balance..

$F = T\cos\theta$ (horizontal)
$W = T\sin\theta$ (vertical)

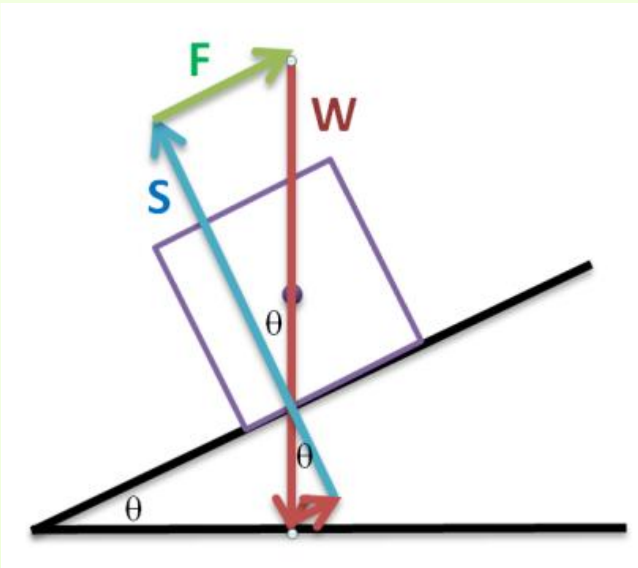


Inclined Plane

In this situation the block (or any other object) acts in a similar way to being on a table but we have to make a triangle of forces. Label them in order…

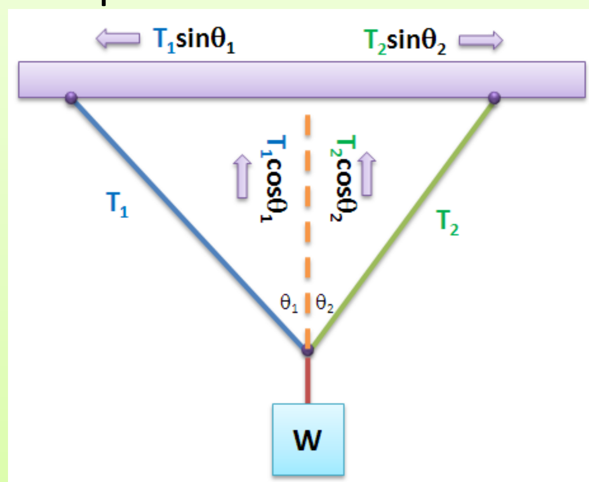
1. **Weight (Vertical)**
2. **Support Force (at 90° to inc plane)**
3. **Friction (in line with inc plane)**

Inclined Plane 2



Hanging Weight

We can use the idea of equilibrium for a weight hanging from a string held in two places. It is simple to balance.



Hanging Weight 2

Left = Right

$T_1\sin\theta_1 = T_2\sin\theta_2$

Up = Down

$W = T_1\cos\theta_1 + T_2\cos\theta_2$

If angles same then…

$W = 2T\cos\theta$

Pulley Problems

If you have a pulley which can move freely and you attach a weight. The tension in the string is equal to the weight.

However, if acting at an angle you must apply the components rule to balance up=down, left = right.

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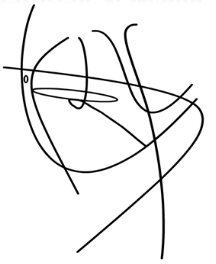

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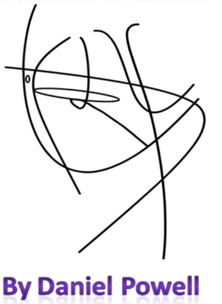

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Turning Effects

When a force is applied a distance away from the centre of mass (COM) then we produce a turning effect or "moment". If you have a situation where an object is in equilibrium then you can solve a problem by equating all the turning effects about any point in the situation…

Moments

When a force is applied it has to be **perpendicular** to the distance to be classed at a moment.

To solve problems you sum up all the moments applied "perpendicular" to a point…

Clockwise = anticlockwise

See-Saw

When we have simple see-saw we can sum up by just balancing from the middle of the see-saw and add any Wd from the pivot point..

$\mathbf{W_1d_1 = W_2d_2}$

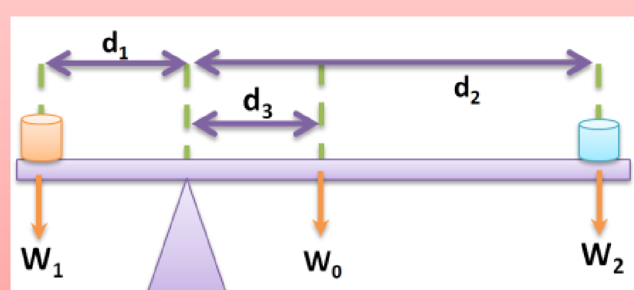
or if you have two people on one side…

$\mathbf{W_1d_1 = W_2d_2 + W_3d_3}$

Complex Moments

Weight of a ruler acts from its centre…

$\mathbf{W_1d_1 = W_2d_2 + W_3d_3}$

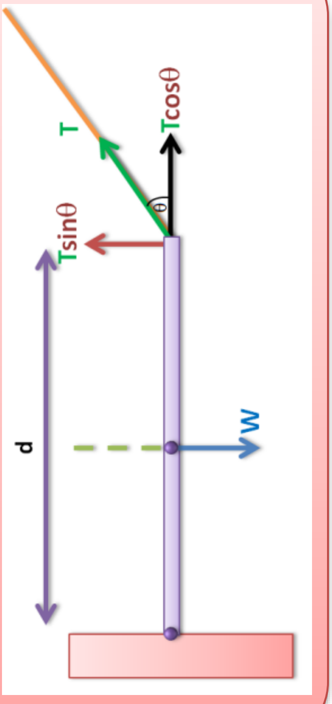


Non-Perp Moments

These get more complex

= W*d/2

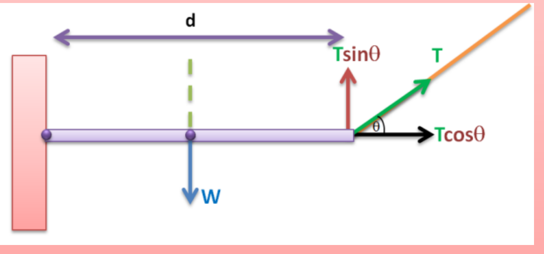
= Tsinθ*d



Non-Perp Moments

Work out the component of the moment which is working at 90° to the slope or perpendicular.

Then create the same balance of moments



Moments Units

Remember to use gravity to convert any masses to newtons for moments.

1kg = 9.81N

100g = 0.1kg

W = 9.81N/kg x 0.1kg

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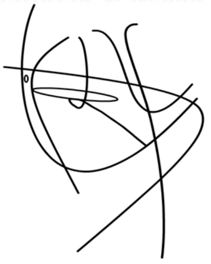

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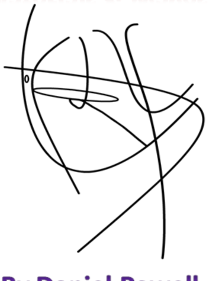

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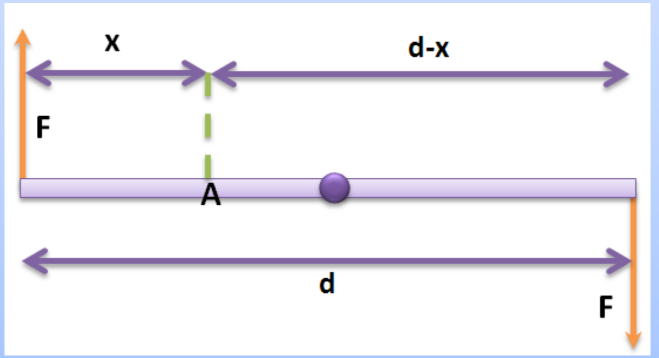
Couples

Couples Maths

Couples: These are simple pairs of equal and opposite forces acting on a body which cause a turning force or "torque". We can take moments about any point on a couple.
It does not matter where you take the moments as the couple always comes out to be **Fd**

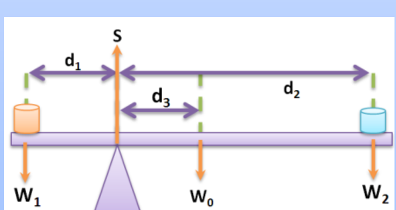
Take moments about "A"
Moments = Fx - F(d-x)
Moments = Fx + F(d-x)
Moments = Fx + Fd-Fx
Moments = Fd



Single Support Probs

Single Support Probs Maths

The pivot point in this prism supports the weights acting downwards we simply summate the **forces** regardless of where they are acting. This can be used in conjunction with a **moments** equation as well.

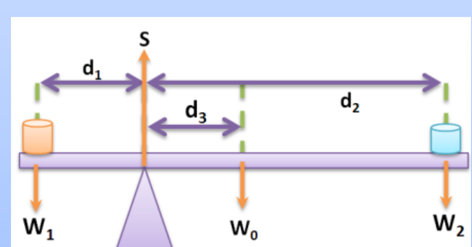


Balance Forces…

$$S = W_1 + W_2 + W_0$$

Balance Moments…

$$W_1 d_1 = W_2 d_2 + W_3 d_3$$



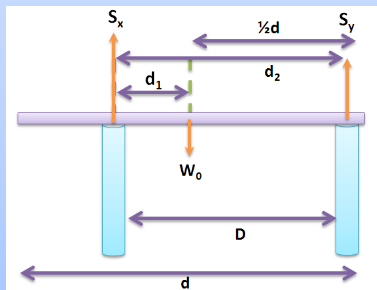
Double Support Forces

If we think of a simple table as an example the same principles of forces and moments applies.

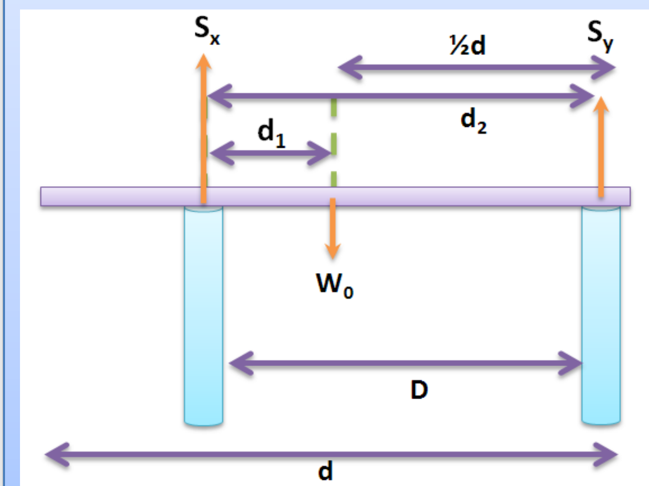
$S_x + S_y = W_0$

$S_y D = W_0 d_1$

$S_x D = W_0 d_2$



Double Support Diagram



Moments Units

Remember to use gravity to convert any masses to newtons for moments.

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100g = 0.1kg

W = 9.81N/kg x 0.1kg

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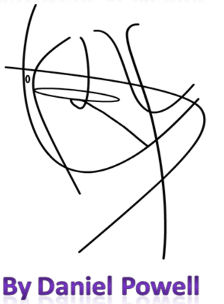

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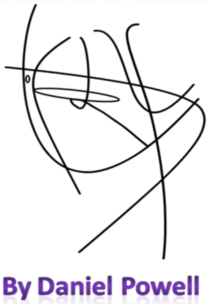

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Toppling Vehicles

We also find trig and moments useful when deciding at which angle a vehicle will topple over on a slope.

If we know the geometry of the centre of mass and middle of the base we can construct a triangle of an angle which creates the ratio of similar forces.

Toppling Maths

hyp x sin θ = opp
F = W x sin θ

hyp x cos θ = adj
S = W x cos θ

Divide the two equations….

F/s = sinθ/cosθ =

tanθ = (b/2)/d

Toppling Geometry