

Using Visual Representations to Solve Quantitative Physics Problems

A pack of examples

Introduction

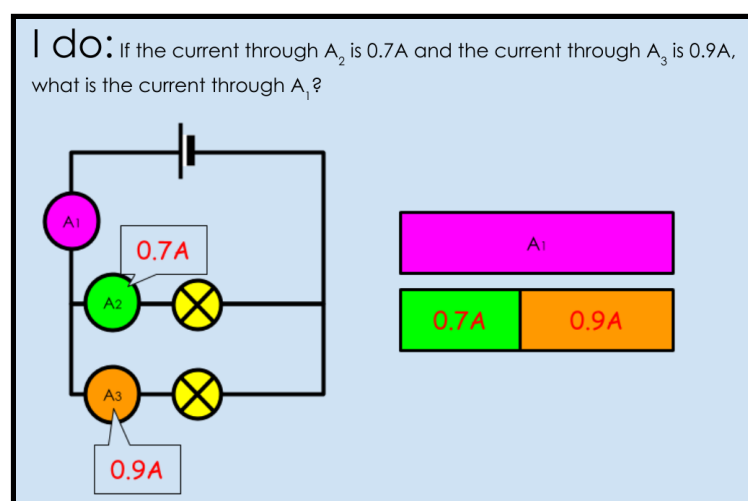
The laws of Nature are written in the language of mathematics.

Galileo in The Assayer

To understand the physics, you have to solve the problems. Physics isn't really qualitative. So maths is the gateway to physics. But for many learners the gate is closed.

Cognitive load theory has found that when the cognitive load is high, learning is impaired. For many learners algebra presents a high cognitive load - high enough to impair or prevent learning.

Mathematics education research shows that there are strategies teachers can use to reduce the cognitive load of mathematical problem solving¹. One of the most effective strategies is to use visual representations of abstract concepts. In this booklet I have provided examples of physics problems with visual representations of abstract concepts.



Example slide making use of the bar-model to represent currents either side of a junction.

¹ https://ies.ed.gov/ncee/wwc/Docs/PracticeGuide/mps_pg_052212.pdf#page=29

Why Use Bar-Model?

The bar-model is well known among primary maths teachers for helping pupils develop their maths problem solving skills. It originated in Singapore as part of their maths revolution over the past 20 years.

An example maths question with bar-model visual representation:

A refrigerator is in the sales. It is 20% off and now costs £100. How much was the original price?

A: £75

B: £80

C: £120

D: £125

Model answer using the bar-model:



$$20\% \text{ is } \frac{1}{5} \text{ of } £100 = £25$$

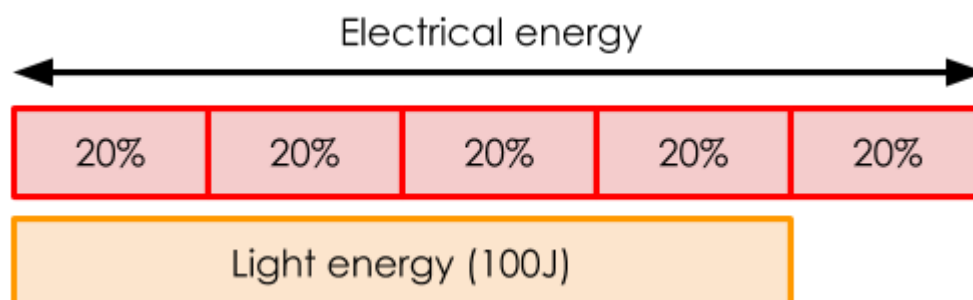
$$\text{So } 100\% \text{ is } 5 \times £25 = £125$$

A Physics Example

An LED is 80% efficient. If it produces 100J of light, how much electrical energy did it use?

- A: 75J
- B: 80J
- C: 120J
- D: 125J

Model answer using bar-model:



$$20\% \text{ is } \frac{1}{5} \text{ of } 100\text{J} = 25\text{J}$$

$$\therefore 100\% \text{ is } 5 \times 25 = 125\text{J}$$

With thanks to With thanks to Jonathan Wragg, Lyndsay Sawyer, Ryan Doney and Anand Chauhan of Paradigm Trust for their knowledge, support and enthusiasm for this project

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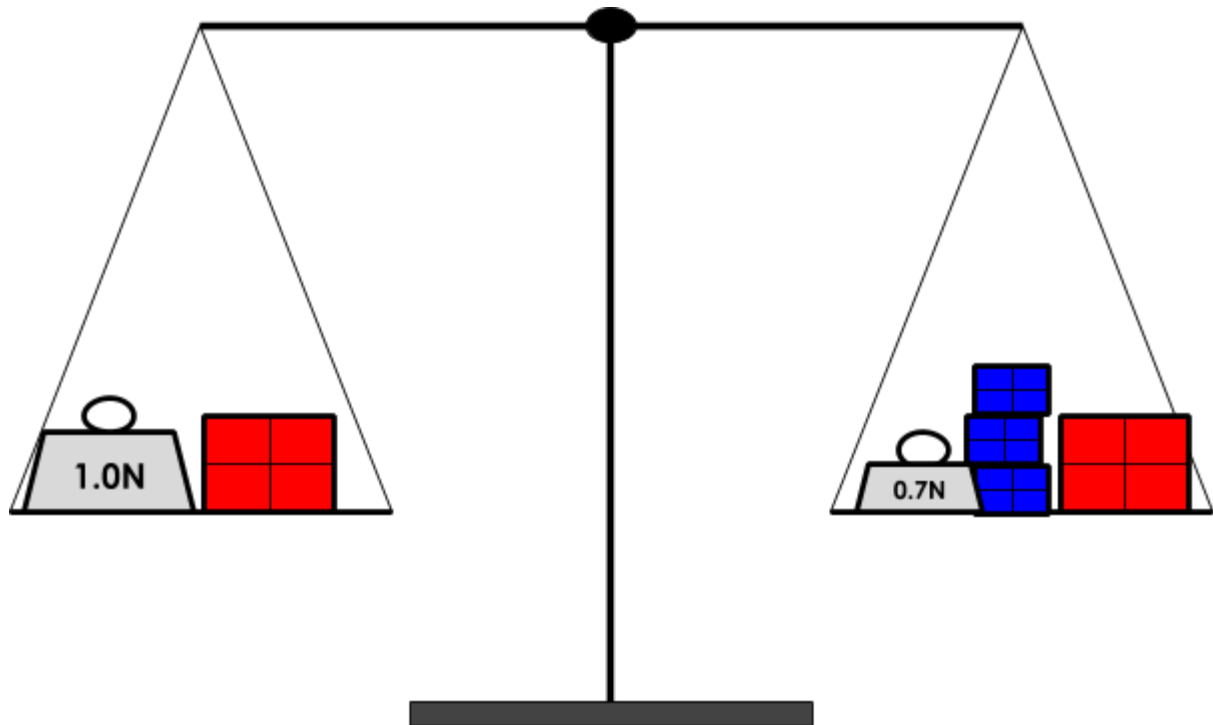
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How-Much-Does-One-Weigh? Questions

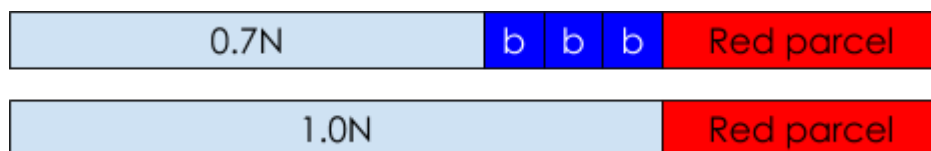
Adapted from the SATs reasoning question.

I do

Calculate the weight of each small blue parcel.



Solution, using bar model.



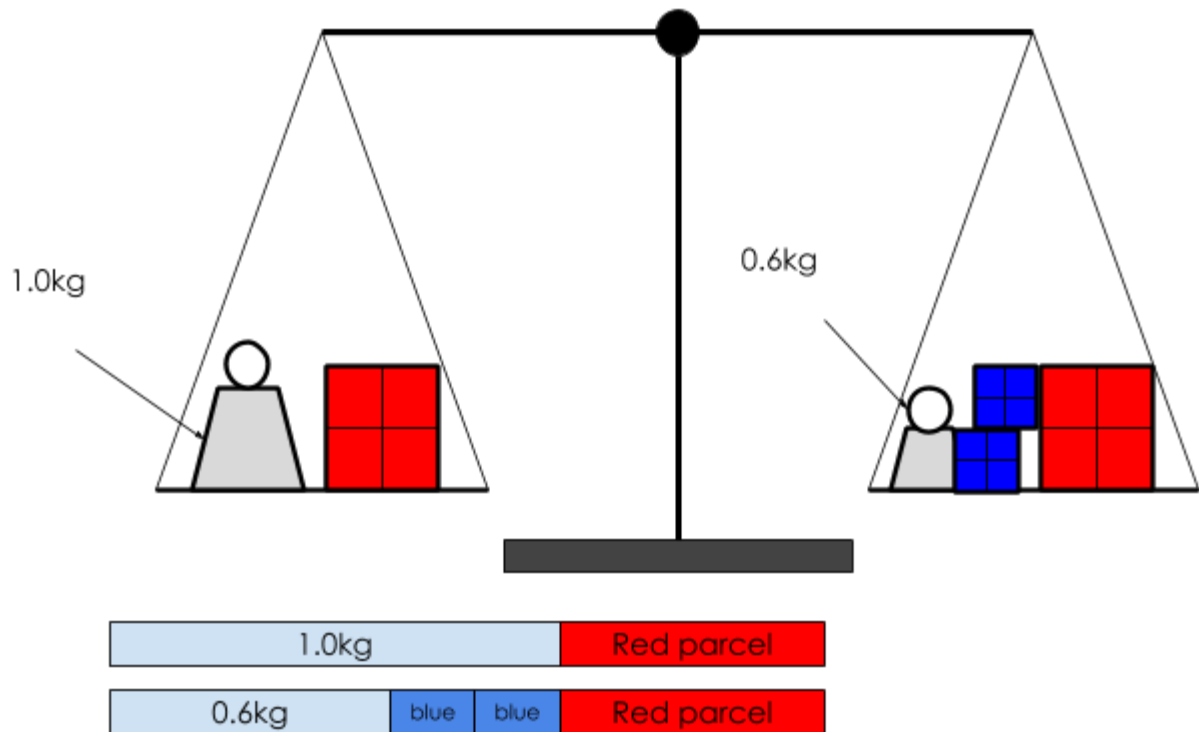
1.0N is the same as 0.7N and the three blue parcels.

So the three blue parcels added together must weigh $1.0 - 0.7 = 0.3\text{N}$

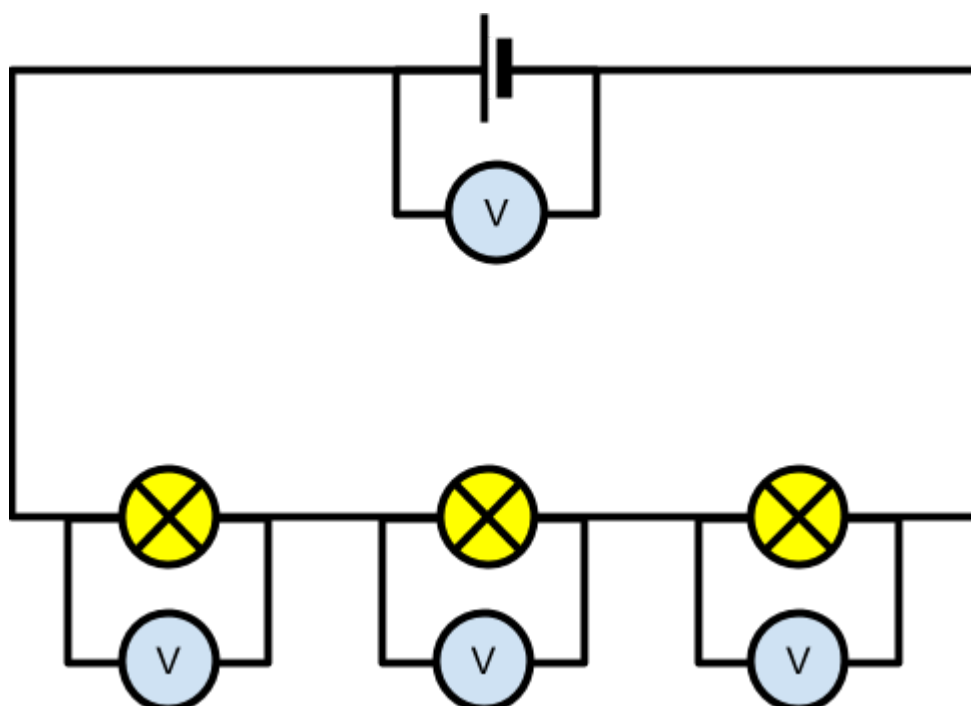
So a single blue parcel must weigh 0.3 divided by $3 = 0.1\text{N}$

We do

Calculate the weight of one blue parcel.



Electricity Questions: Voltage in Series Circuits



I do: voltage across bulbs in series

If the voltage drops an equal amount across each bulb, what will the readings on the three voltmeters be?

3V		
?	?	?

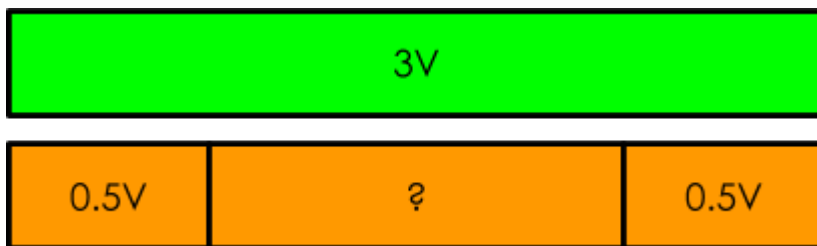
We do: voltage across bulbs in series

If the voltage drops 0.6V across the left-hand bulb and 1.2V across the middle bulb, what will the reading be on the third voltmeter?

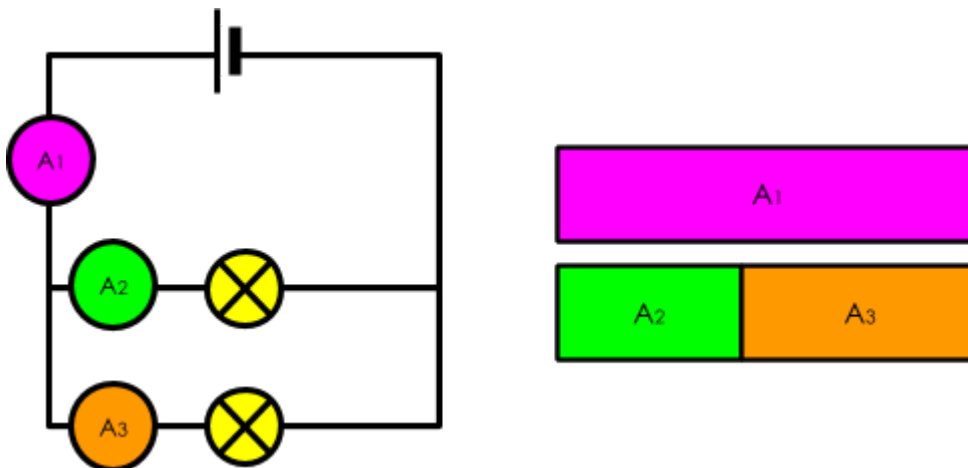


You do: voltage across bulbs in series

If the voltage drops 0.5V across the left-hand bulb and 0.5V across the right-hand bulb, what will the reading be on the middle voltmeter?

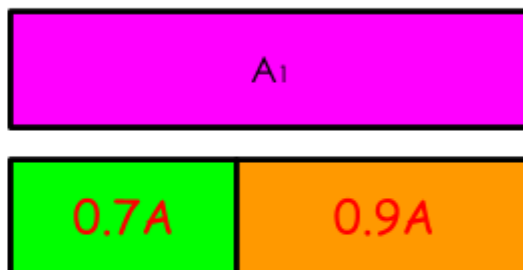
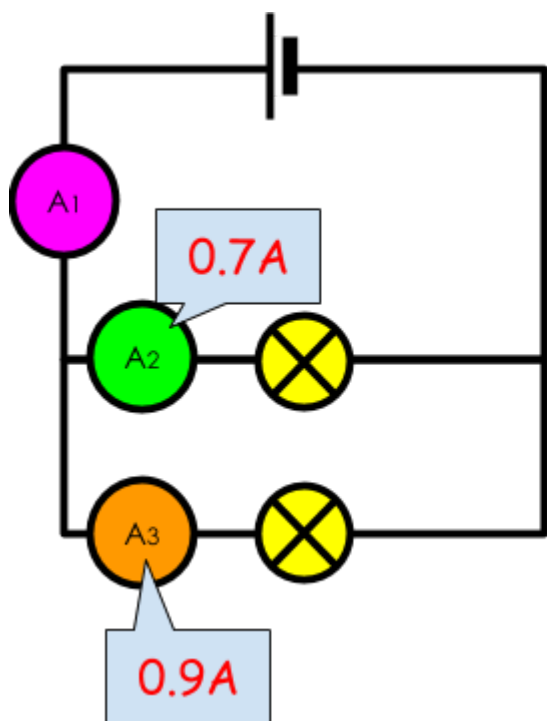


Electricity Questions: Current in Parallel Circuits



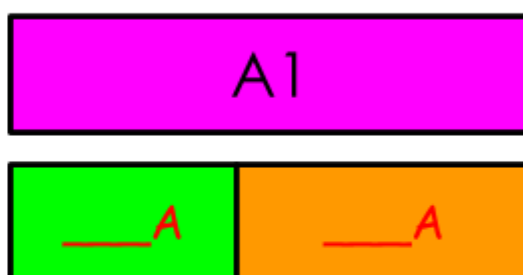
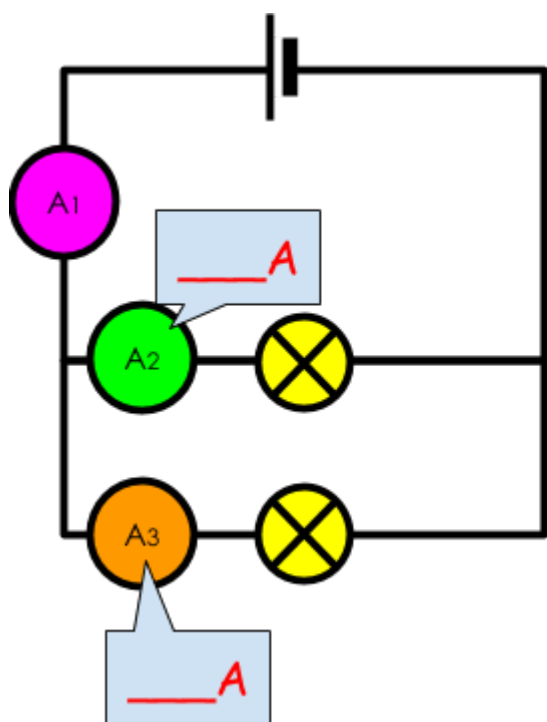
I do:

If the current through A_2 is 0.7A and the current through A_3 is 0.9A, what is the current through A_1 ?



We do:

If the current through A_2 is $0.5A$ and the current through A_3 is $0.6A$, what is the current through A_1 ?

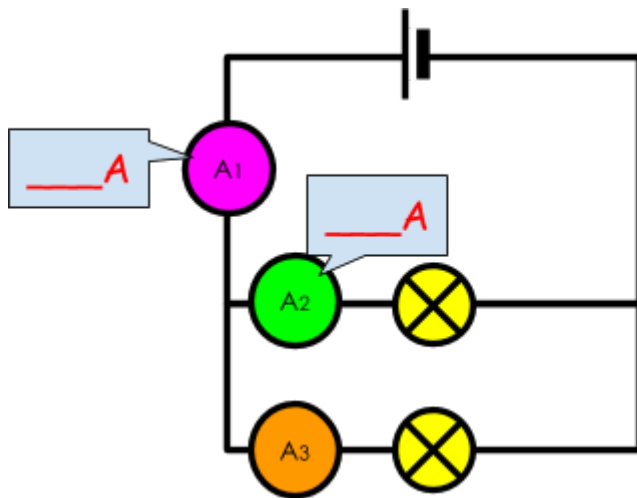


You do:

If the current through A_2 is 1.2A and the current through A_3 is 0.9A, what is the current through A_1 ?

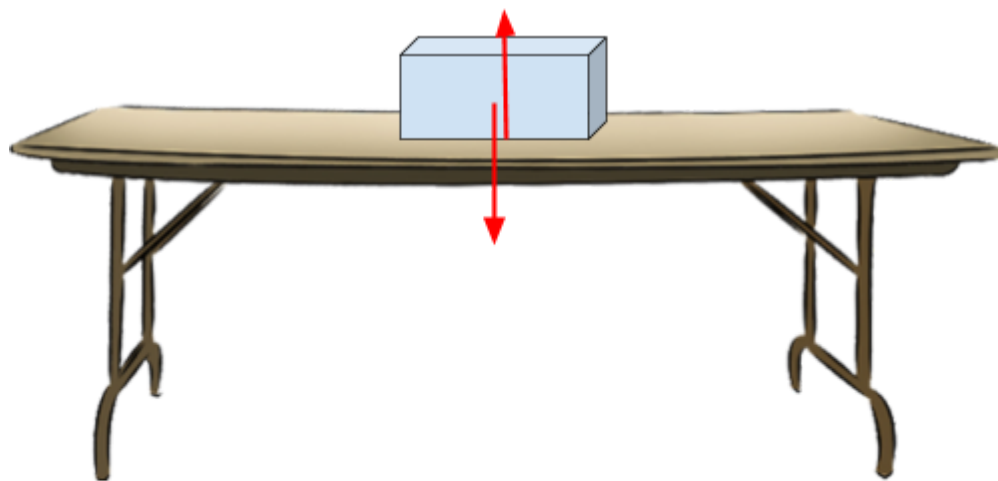
Extension:

If the current through A_1 is 1.2A and the current through A_2 is 0.9A, what is the current through A_3 ?



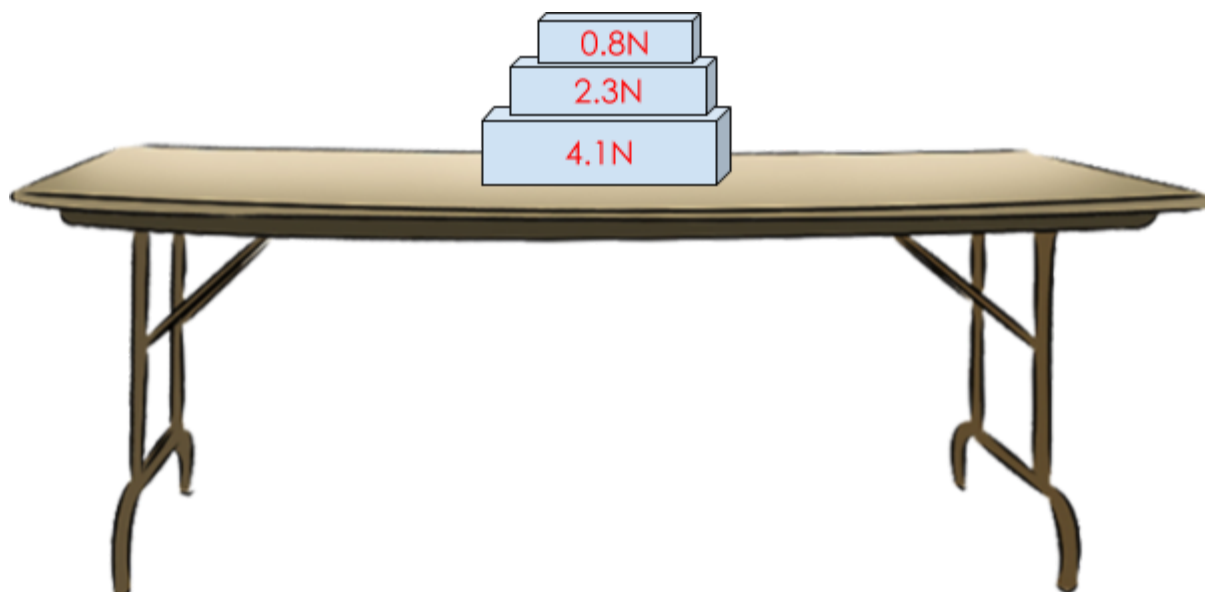
Balanced Forces

Reaction Force



Gravity pulling the block down

The table pushing back up

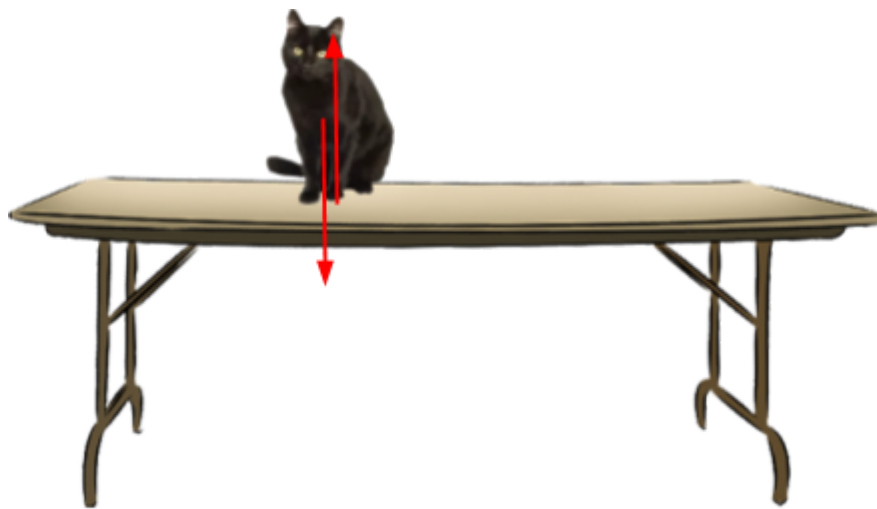


reaction

4.1N

2.3N

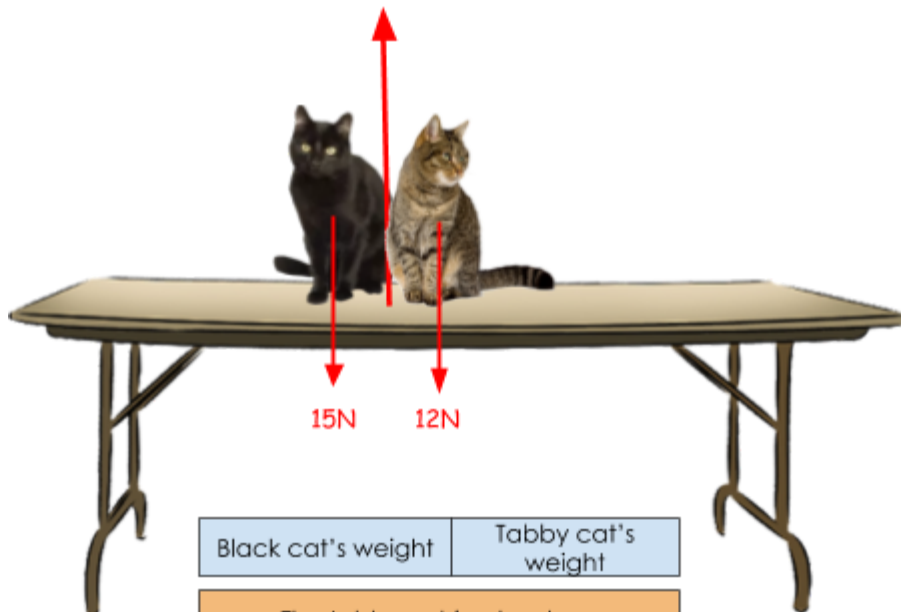
0.8N



The cat's weight

The table pushing back up

Reaction force from the table

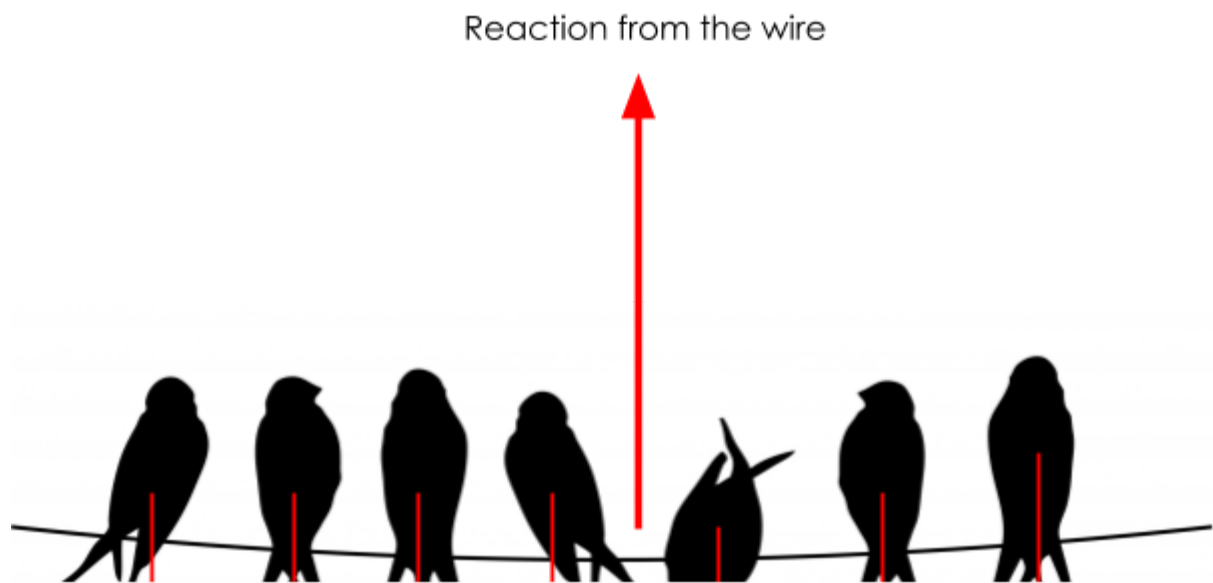


Black cat's weight

Tabby cat's weight

The table pushing back up

Birds on a Wire



Tug of War (balanced forces)



Force left

250N

I do

3 friends play tug of war against a teacher. The forces are balanced. The teacher pulls with 600N. One friend pulls with 190N. Another pulls with 290N. How much force does the third friend pull with?



600N

190N	290N	?
------	------	---

We do

3 friends play tug of war against a teacher. The forces are balanced. The teacher pulls with 500N. One friend pulls with 150N. Another pulls with 160N. How much force does the third friend pull with?



500N

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You do

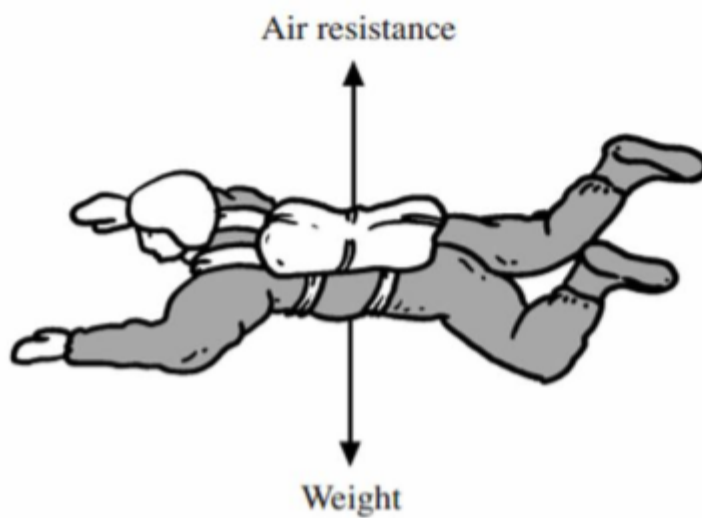
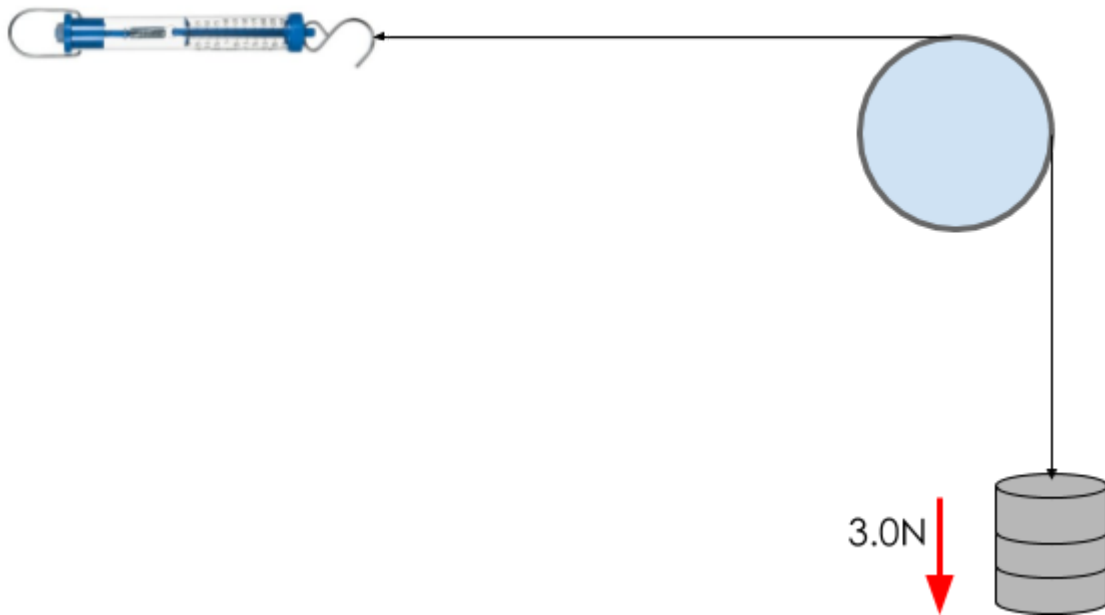
3 friends play tug of war against a teacher. The forces are balanced. The teacher pulls with 550N. One friend pulls with 130N. Another pulls with 180N. How much force does the third friend pull with?



550N

--	--	--

I do



If the forces are balanced, the skydiver will not speed up or slow down - she stays at the same speed!

Weight

Air Resistance

Rate Questions

<note - use harder numbers otherwise learners will not see the point.>

I do: rate of growing

A bean plant grows 15cm every day. How many days will it take to reach the top of a 135cm fence?

Solution

Using a bar model: draw one bar representing 150cm and count the number of 15cm bars needed to make a bar the same length.



Tortoise-and-Hare Questions

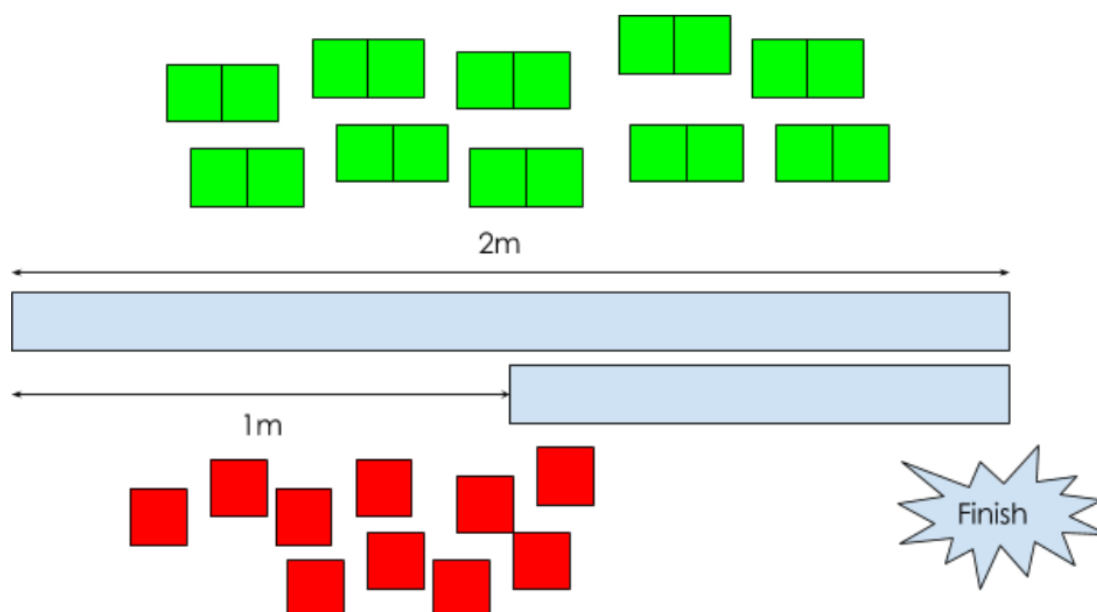
I do:

A snail and a slug are running a race. The slug is twice as fast as the snail, who has a heavy shell. The race is 2m long. The slug gives the snail a 1m head start. Who wins?

- A: the slug
- B; the snail
- C: a draw

Solution (using bar model)

Each time the slug moves 2 places forwards, the snail moves one.
See how many goes it takes for the slug to finish the race.
See how many goes it takes for the snail to finish the race.



They both take 10 goes, so it is C: a draw.

We do:

An ant and a caterpillar run a race. The race is 1m long. The caterpillar is three times faster than the ant, so the caterpillar lets the ant have a 50cm head start. Who wins the race?

- A: the caterpillar
- B: the ant
- C: it is a draw

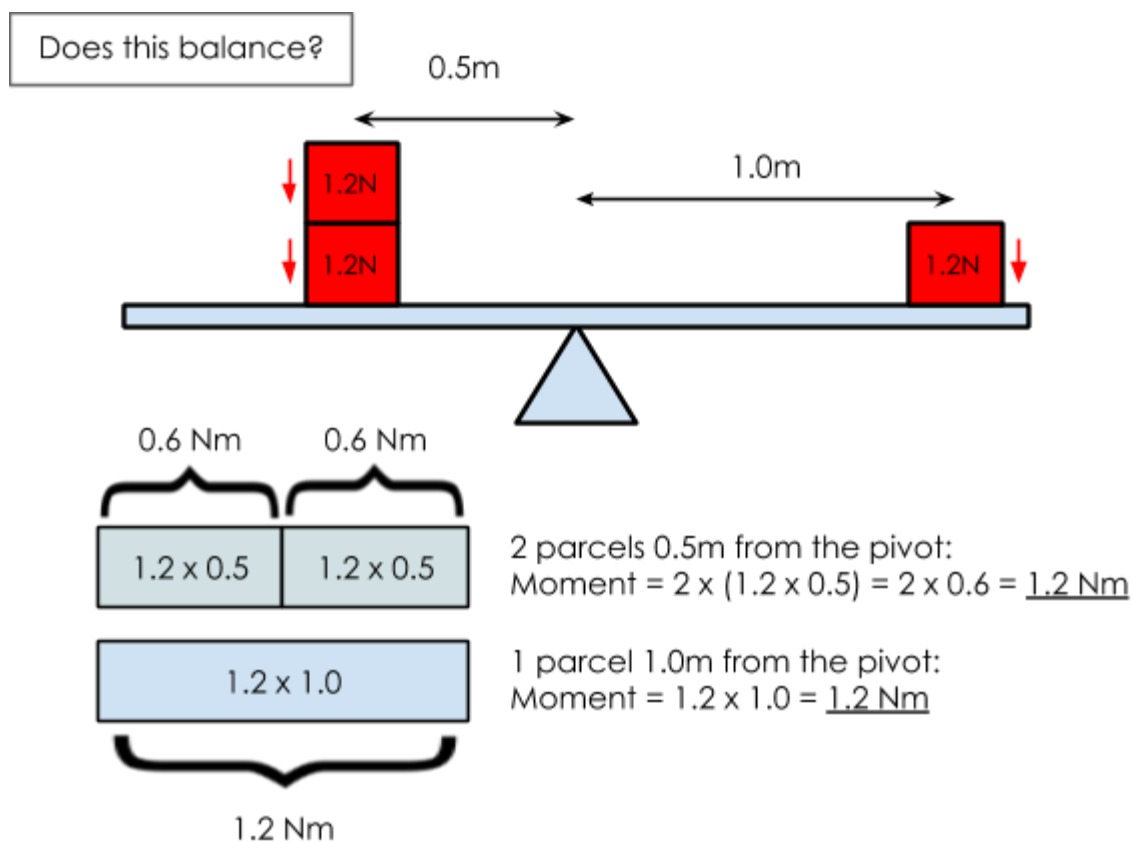
You do

An sparrow and a blue-tit fly a race. The race is 100m long. The blue-tit is twice as fast as than the sparrow, so the blue-tit lets the sparrow have a 50m head start. Who wins the race?

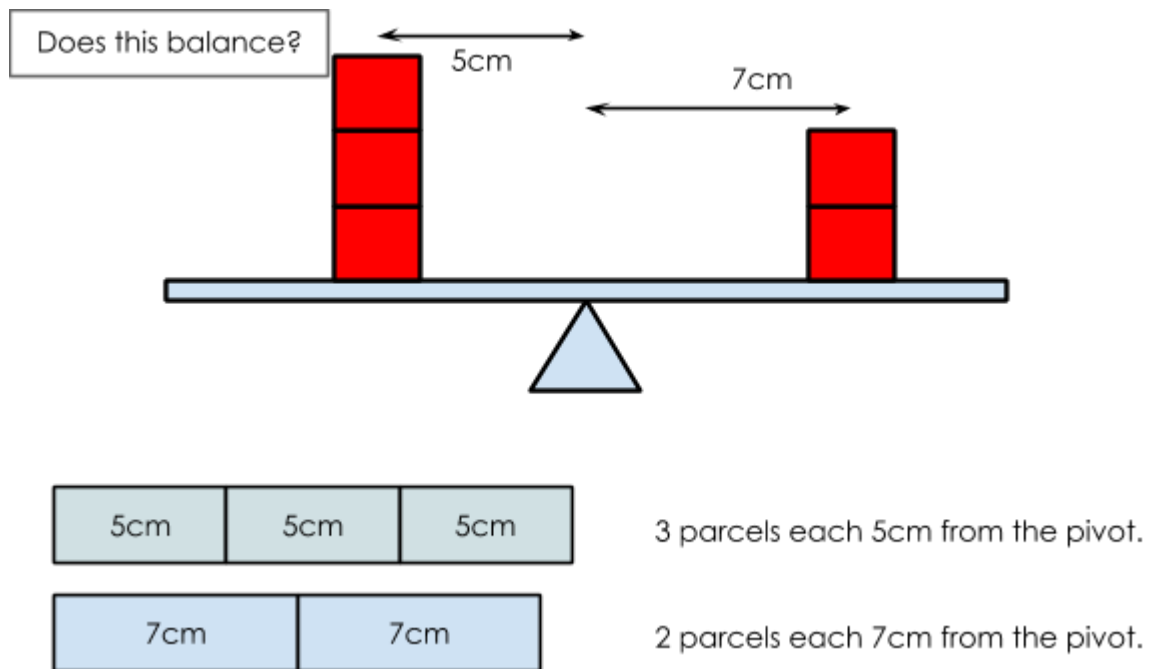
- A: the sparrow
- B: the blue-tit
- C: it is a draw

Moments Questions

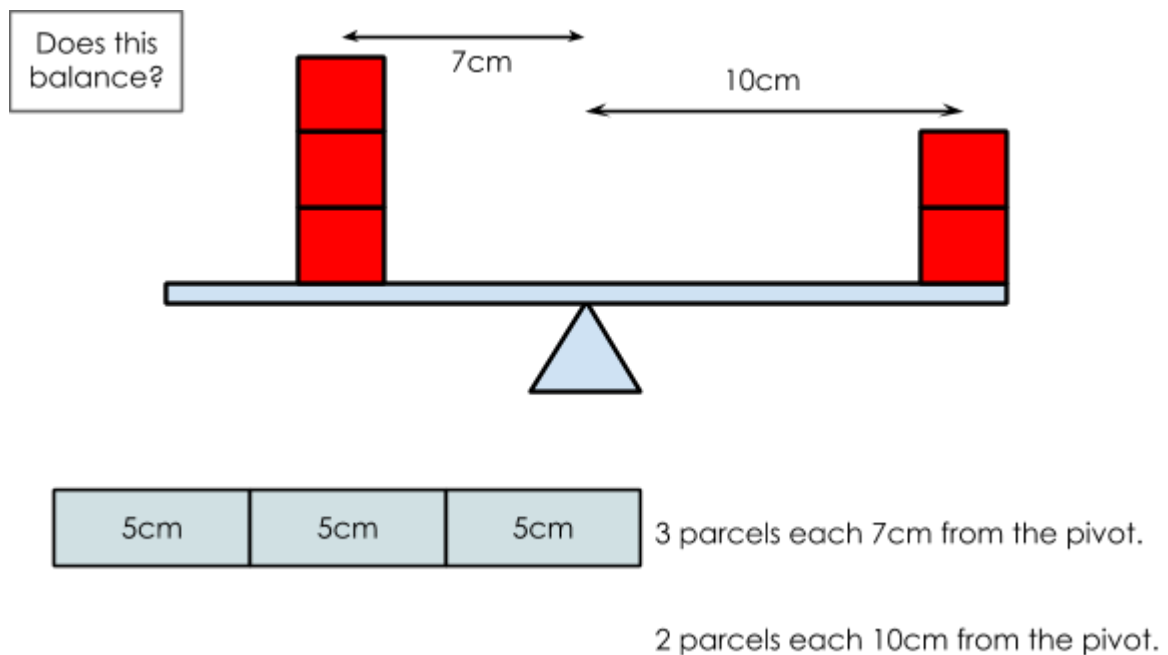
I do



We do



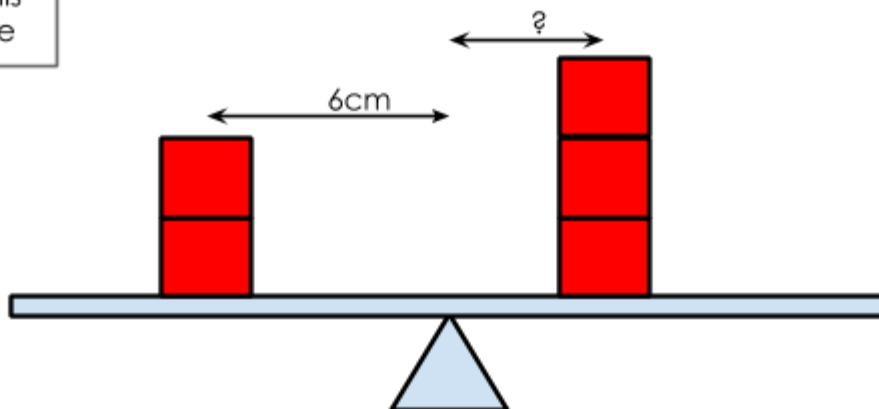
You do



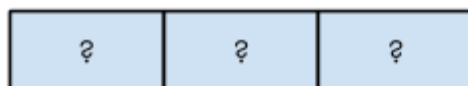
Moments - Missing Distance

I do

Make this
balance



3 parcels each 6cm from the pivot.

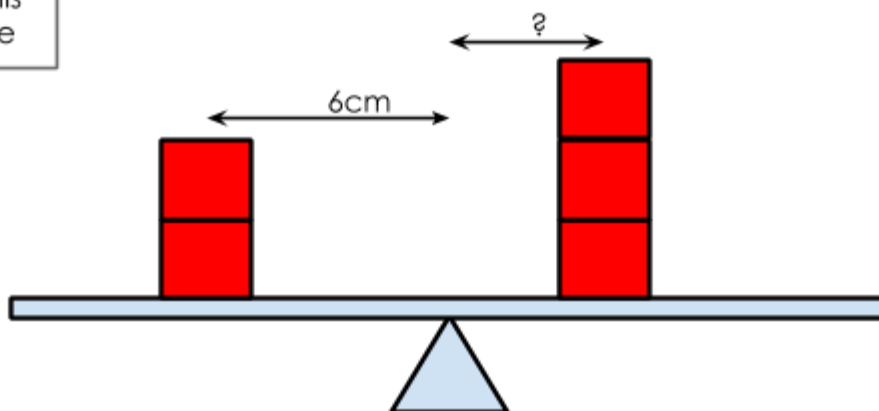


3 parcels each _____ from the pivot.

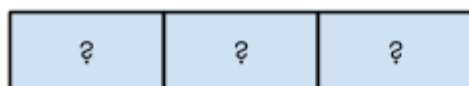
Moments - Missing Distance

I do

Make this
balance



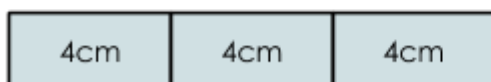
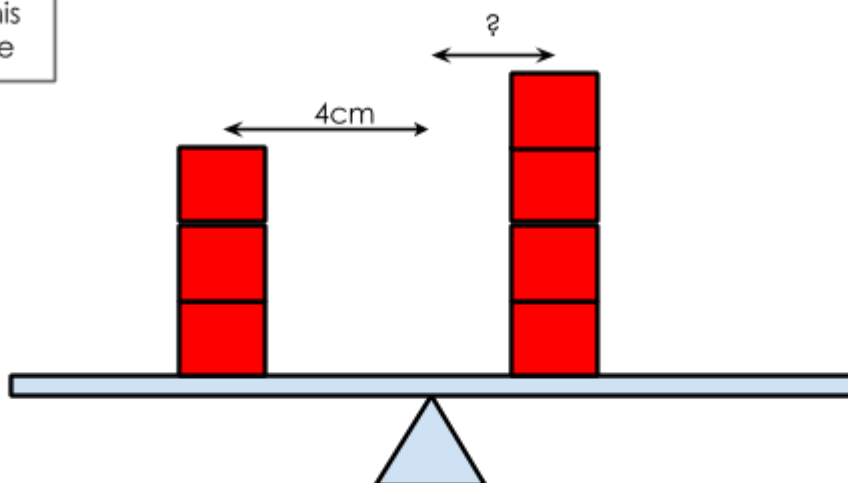
2 parcels each 6cm from the pivot.



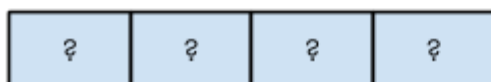
3 parcels each **4cm** from the pivot.

We do

Make this
balance



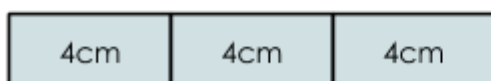
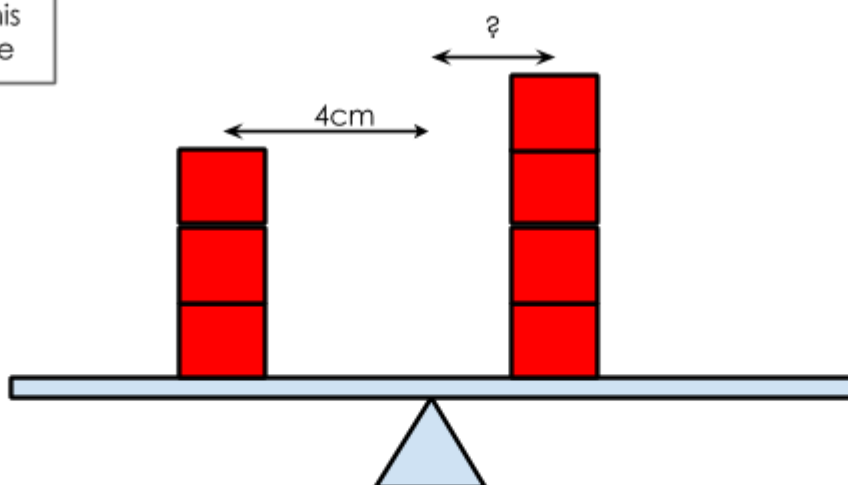
3 parcels each 4cm from the pivot.



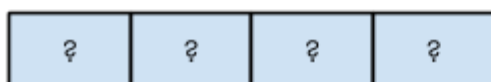
4 parcels each _____ from the pivot.

You do

Make this
balance



3 parcels each 4cm from the pivot.

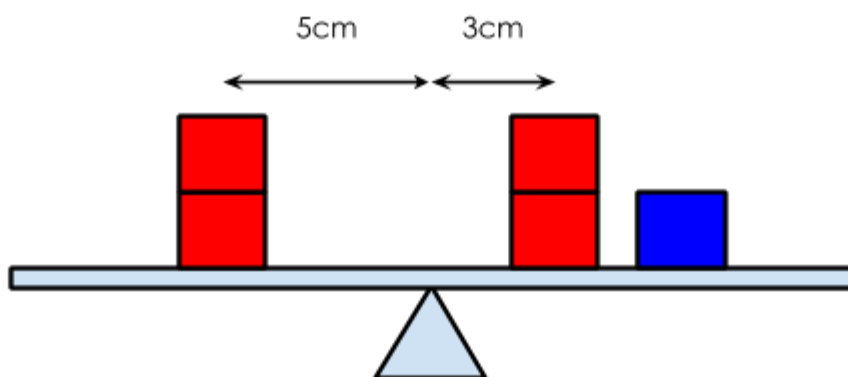


4 parcels each _____ from the pivot.

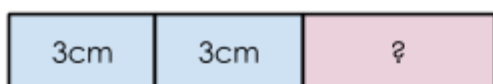
Moments - Multiple Distances

We do

Make this
balance



2 parcels each 5cm from the pivot.



2 parcels each 3cm from the pivot plus
1 parcel _____ from the pivot.