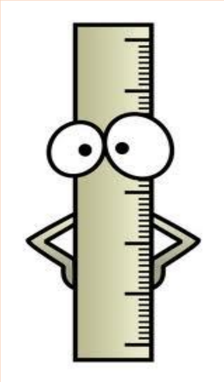
Tuesday, December 13, 2022

Physics - session 2



Learning Objectives:

- Projectile Motion
- Moments & torques (couples)
- Newton's Laws of motion (momentum, collisions and impulse, 3rd law interactions)
- Practical Skills

Whilst we wait…

Is your Physics brain working?

- Can you define a vector and a scalar?
- Moment and momentum – vector or scalar and why?
- Force F at an angle θ to the horizontal. What are the horizontal and vertical components?
- Can you describe two different ways of calculating a resultant vector?

Projectiles:

What do we mean by projectiles?

A projectile is an object that is propelled by the application of an external force and then moves freely under the influence of gravity and air resistance.

Examples of projectiles?

- Throwing a ball to someone
- An arrow fired at a target
- A tennis ball being hit

Projectiles:

Thinking about projectiles means that we are considering motion in 2 directions.

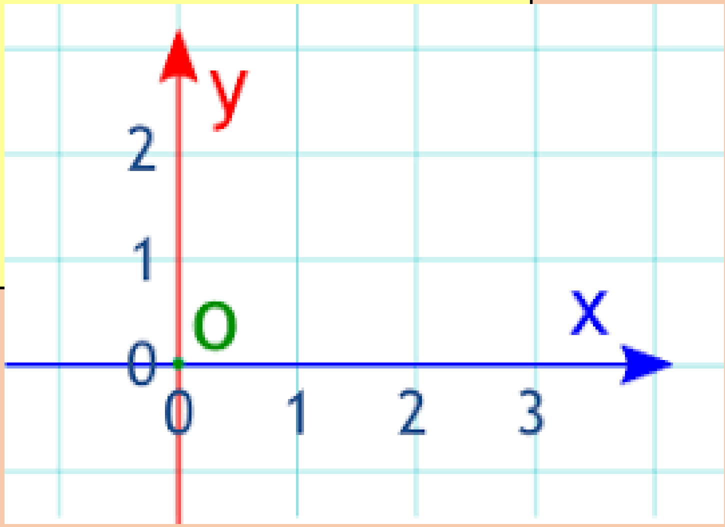
Before we start, we need to be familiar with using the four suvat equations.

$$v = u + at$$

$$s = \frac{(u + v)}{2} t$$

$$s = ut + \frac{1}{2} at^2$$

$$v^2 = u^2 + 2as$$



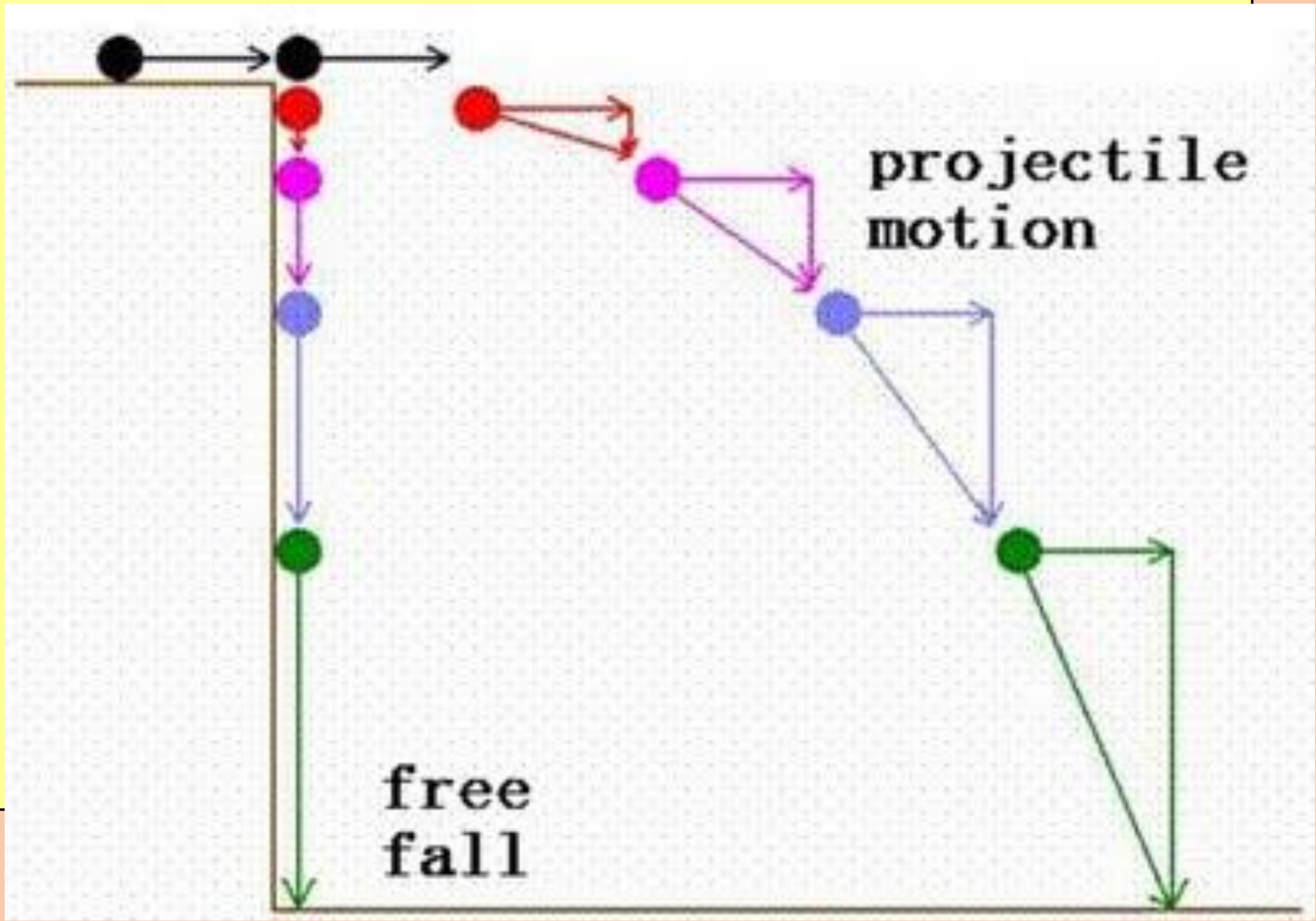
In order for us to analyse projectile motion, we need to separate out the vertical and horizontal motion. Why?

When two objects are dropped from the same height and one of them is given a horizontal motion, but the other is not, they will still land at the same time.

What's the big assumption here?

This shows us that horizontal and vertical motion are independent of each other. No matter how much horizontal movement one object experiences, the vertical motion of both remains the same.

Why does the vertical arrow increase?



Vertical velocity (in Y direction) increases.
Because the acceleration experienced is constant ($a = g$)

Horizontal velocity (in X direction) is constant (as air resistance is ignored). So acceleration is ZERO

This means that we ***must*** consider motion in each direction *separately*

It is only **time** that links to the two directions.

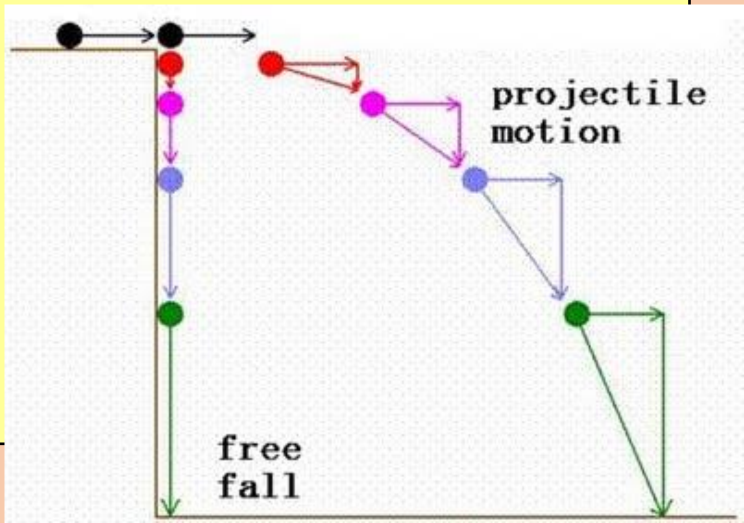
The horizontal and vertical components can be combined to give us the overall or resultant velocity of a **projectile**.

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

When considering motion in two directions, it is important to remember which direction is positive.

You can choose – but you **must** then be consistent.

DIP: Down is Positive (a= +9.81ms^{-2})
UIP: Up is Positive (a= -9.81ms^{-2})



Step by Step:

When completing projectile motion questions, we must consider the horizontal and vertical components separately.

Horizontally, acceleration = zero

So we only need to use **s = vt**

Vertically, acceleration = g = 9.81ms^{-2}

So we can use the full range of suvat equations

A stone is thrown over the edge of a cliff with a horizontal velocity v_H = 15ms^{-1} Height of the cliff =150m

How far from the cliff will the ball land?

Vertically (DIP):

s= 150m

u= 0

v=?

a= 9.8ms^{-2}

t=?

Using $s=ut + ½ at^2$

$150 = 0 + ½ \, 9.8 \, t^2$

So t = 5s

Horizontally:

s=?

v= 15ms^{-1}

t=?

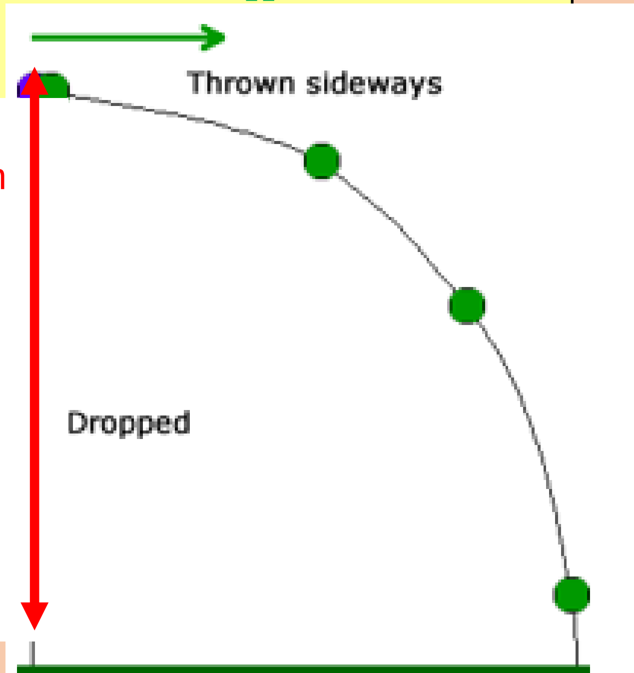
Then:

Horizontally s = vt

So s = 15x 5 = 75m

v_H =15ms^{-1}

h = 150 m



Practice Questions:

10 minutes – try the projectile motion questions in the pack

Q1 – Easy as initial motion is only horizontal
Q2 and Q3 - Harder: initial motion is at an angle to the horizontal – so you will need to resolve the velocity into its components.

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Turning Forces

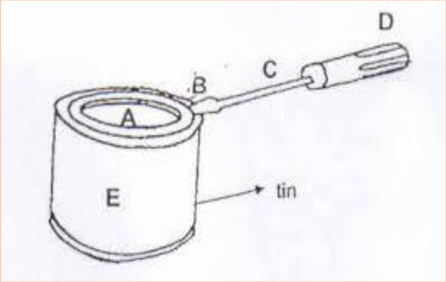
A moment is the turning effect whenever an object rotates due to a force

Can you recall the equation to calculate a moment?

What are the units?

Which equation does this look similar to?

Moment = force x perpendicular distance from the line of action of the force to the axis or point of rotation



Moment = Force x perpendicular distance
(Nm) (N) (m)

Conditions for Equilibrium

There are two conditions for equilibrium.

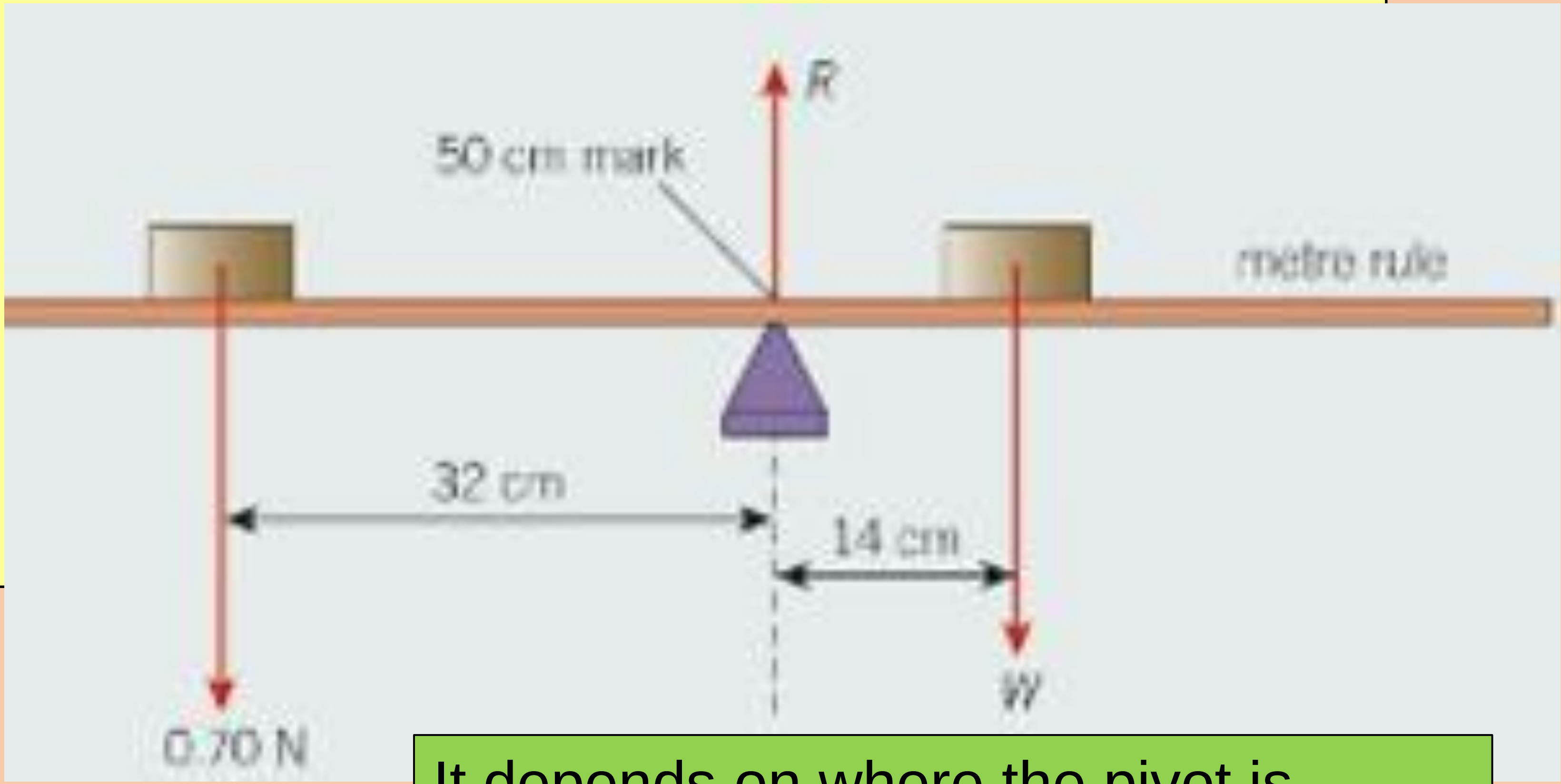
The resultant force acting on the object is zero

The sum of the clockwise moments at any point is equal to the sum of the anticlockwise moments at that point

Clockwise and Anticlockwise

Which of these forces are acting clockwise?

Which way IS clockwise??

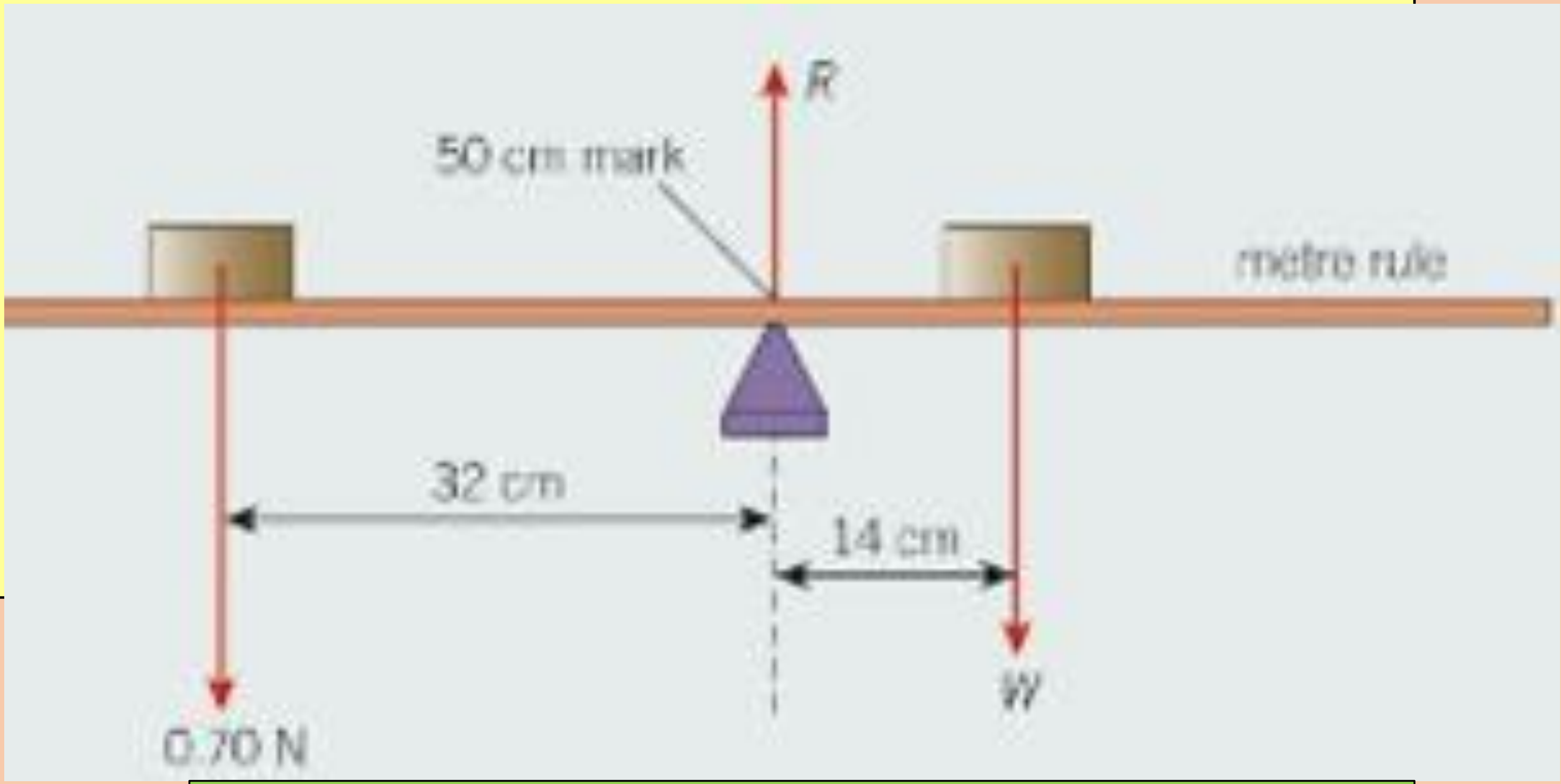


It depends on where the pivot is

TWO conditions for Equilibrium

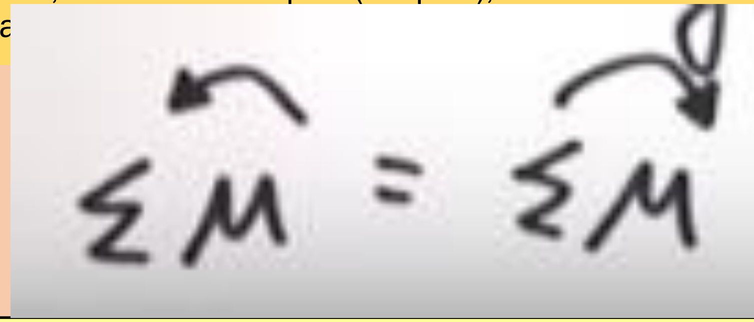
The resultant force acting on the object is zero.

How does this help us work out the missing forces?



upward forces + downward forces = zero

So R = 0.7 + W



Using the Principle of Moments

Like with SUVAT questions, it helps if you lay your working out very clearly.

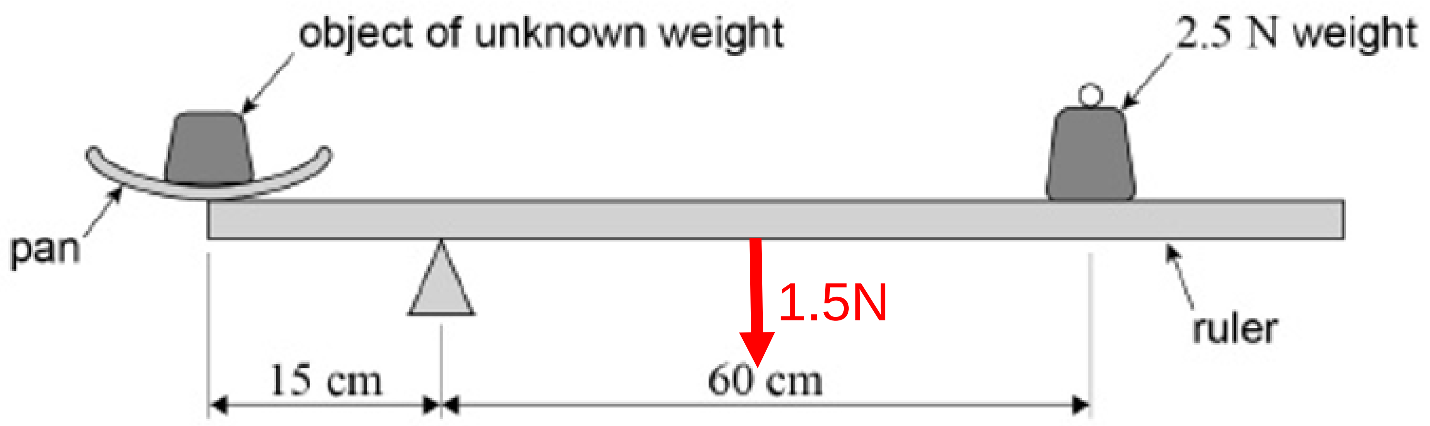
Work out clockwise moments and anticlockwise moments separately

Remember we can also use **resultant force = zero**.

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Calculating Moments

The diagram shows a uniform metre ruler of weight 1.5 N pivoted 15 cm from one end for use as a simple balance.



A scale pan of weight 0.5 N is placed at the end of the ruler and an object of unknown weight is placed in the pan. The ruler moves to a steady horizontal position when a weight of 2.5 N is added at a distance of 60 cm from the pivot as shown.

What is the weight of the object?

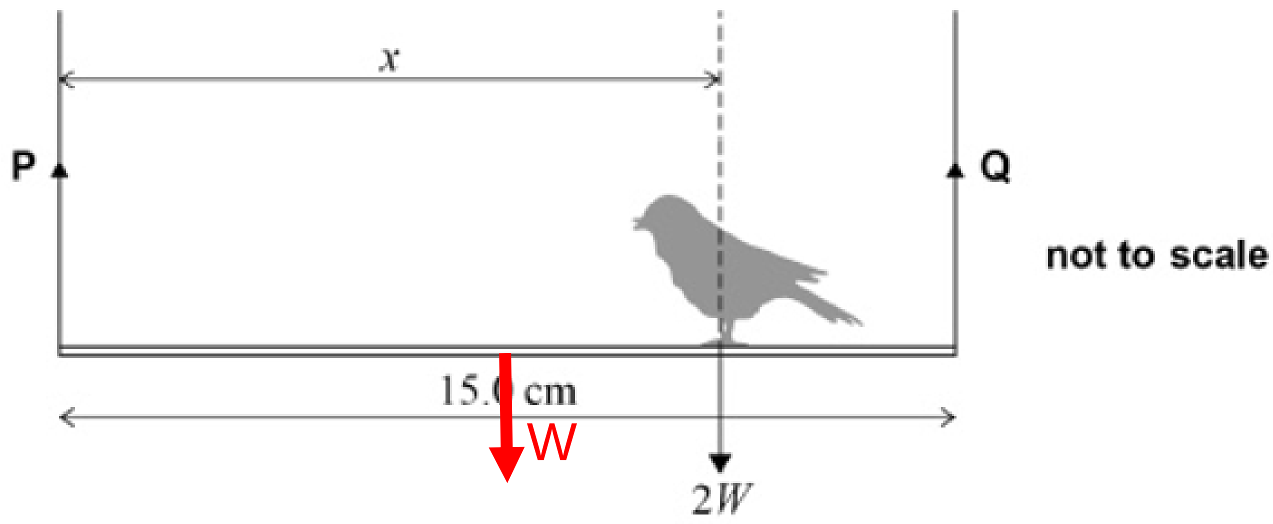
W = 13N

What is missing from the diagram?

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Calculating Moments

A bird sits on a uniform rod suspended from vertical wires **P** and **Q**.



x = 11.25cm

The rod has a weight W and is 15.0 cm long.
The weight of the bird is $2W$ and acts at a distance x from **P**.

What is the value of x when the tension in **P** is half the tension in **Q**?

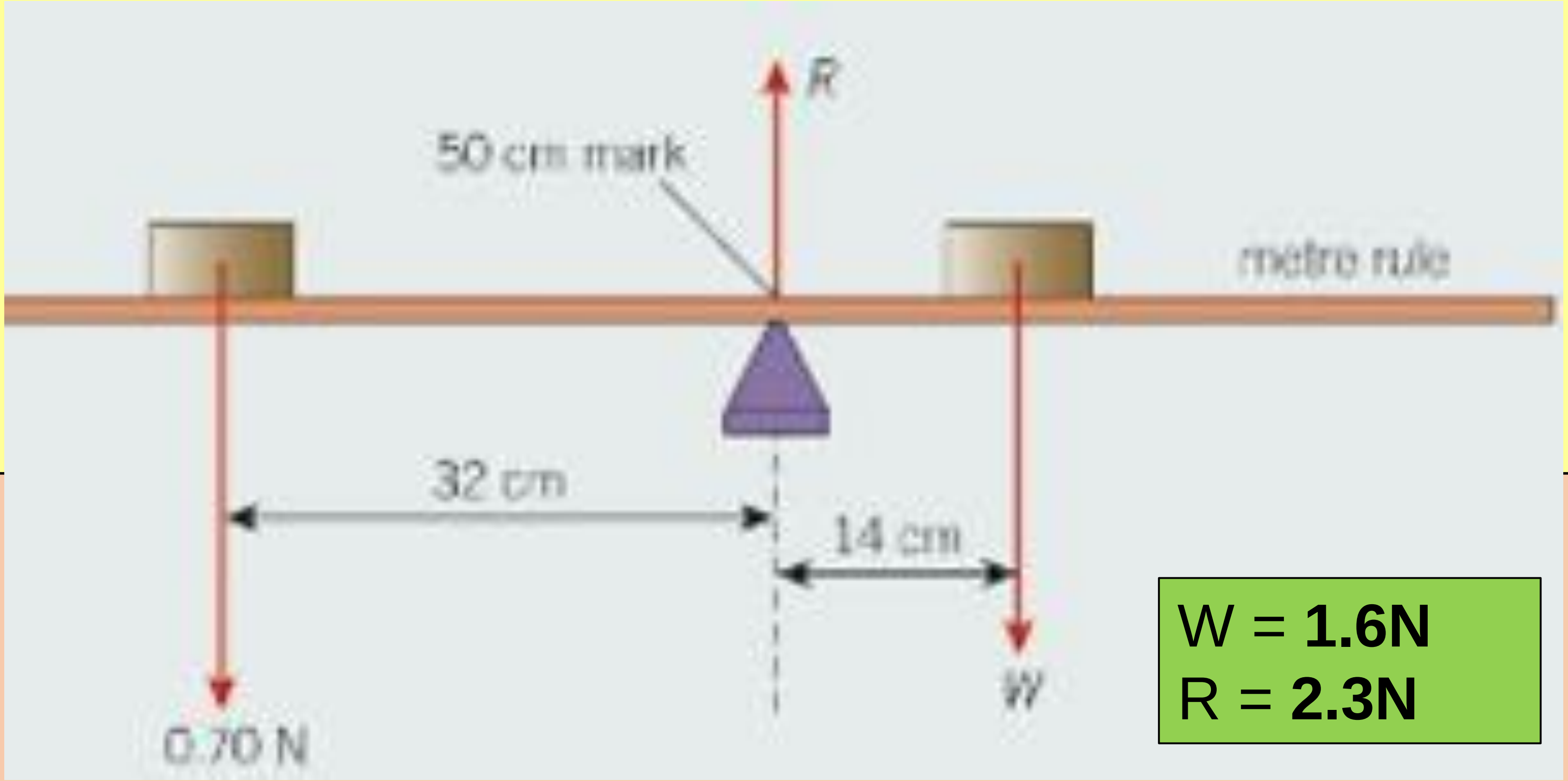
What is missing from the diagram?

Using the Equilibrium conditions

A meter rule is pivoted at its 50cm mark.

Two objects weighing 0.7N and W are placed on the ruler as shown to balance it. Assume the weight of the ruler is negligible.

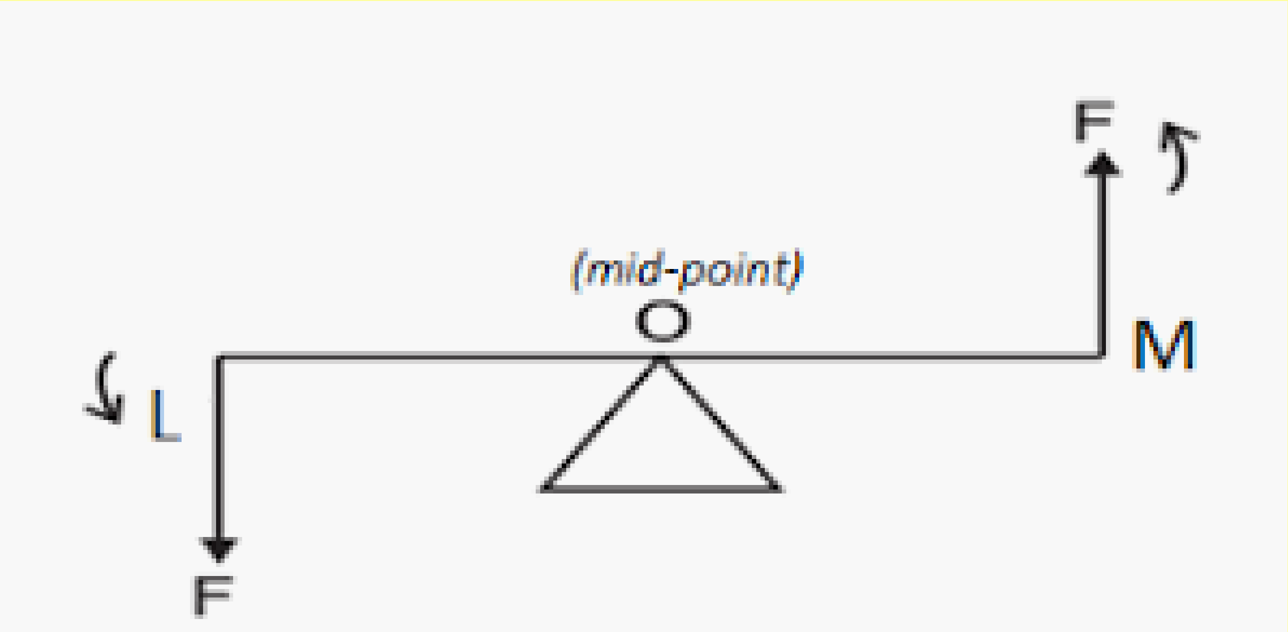
Calculate the size of W and the force acting at the pivot



W = **1.6N**
R = **2.3N**

Couple

When two equal, antiparallel (parallel but acting in opposite directions), forces act to produce a rotation - no linear motion occurs.



The moment of a couple is called a **torque**.

Couple

The turning moment (torque) due to a couple is the product of one of the forces and the perpendicular distance between them. (Nm)

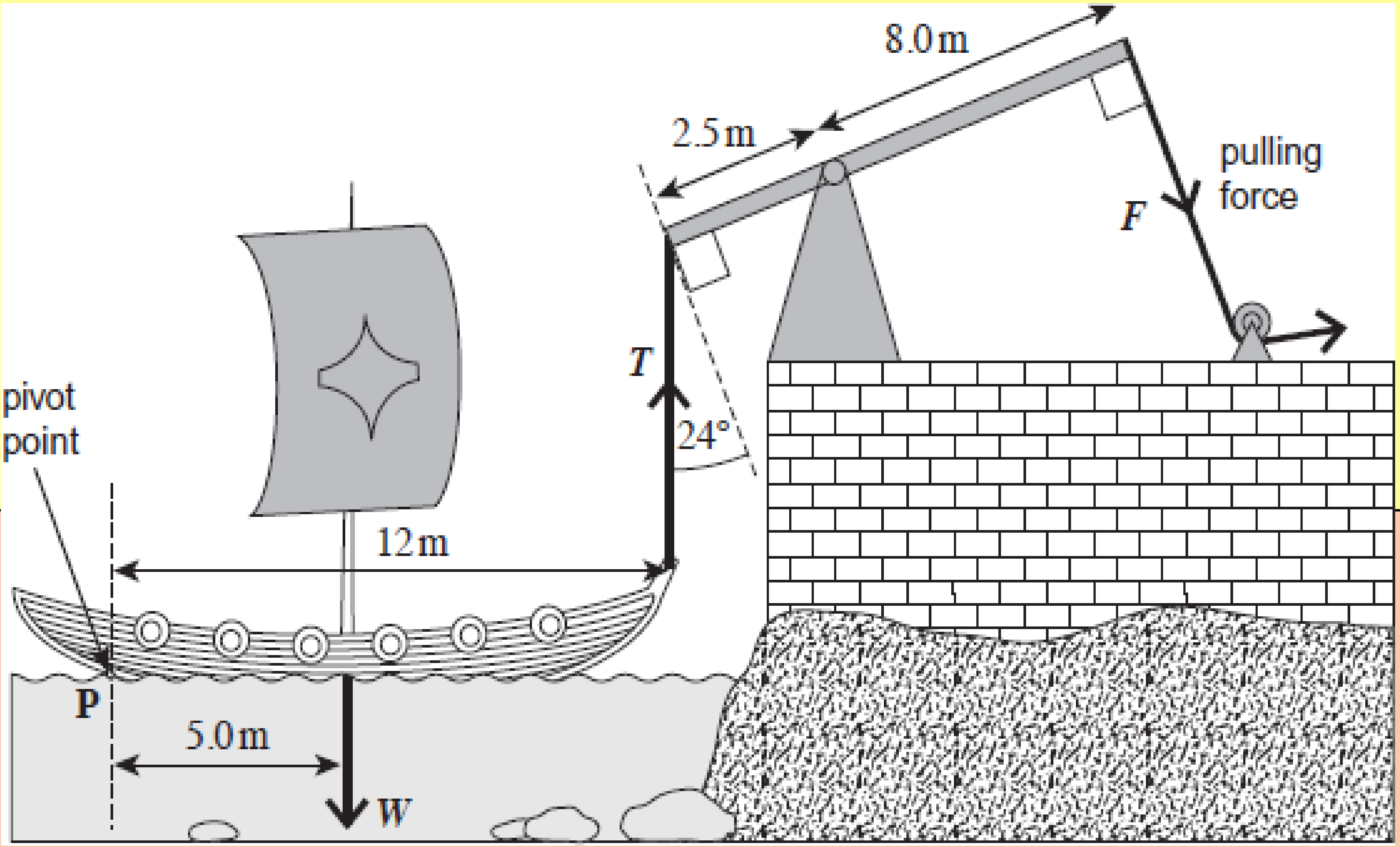
Torque (Nm) = Force (N) x distance between (m)
= F x d

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Making Moments Harder…

All these examples so far have been easy.

You will get questions where the forces are not perpendicular and you will need to use your resolving skills



Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Practice:

10 minutes, this time to practice moments

Tips:

- Draw a diagram to show all the forces
- Choose where you take your moments so you reduce the number of unknown forces
- There are two conditions for equilibrium: Resultant force = zero AND sum of moments = zero
- Remember to resolve any forces at an angle, so you have the component perpendicular to the pivot.

Newton's Laws of Motion

Newton's Third Law

Can you define an interaction pair?

What have they got to do with the third law of motion?

When two objects interact, they exert equal and opposite forces on each other.

When two objects interact, the pair of forces produced will always be **equal and opposite**. The forces acting on the interacting objects are always of the **same type**.

Types of Forces

How do we group forces at GCSE?

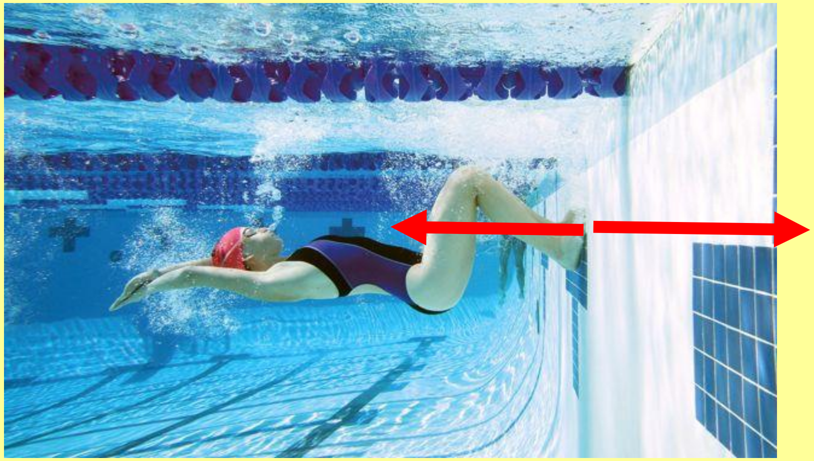
Contact and non-contact

At A-level we learn that there are four fundamental forces

Gravitational
Electromagnetic
Strong nuclear
Weak nuclear

Interaction Pairs

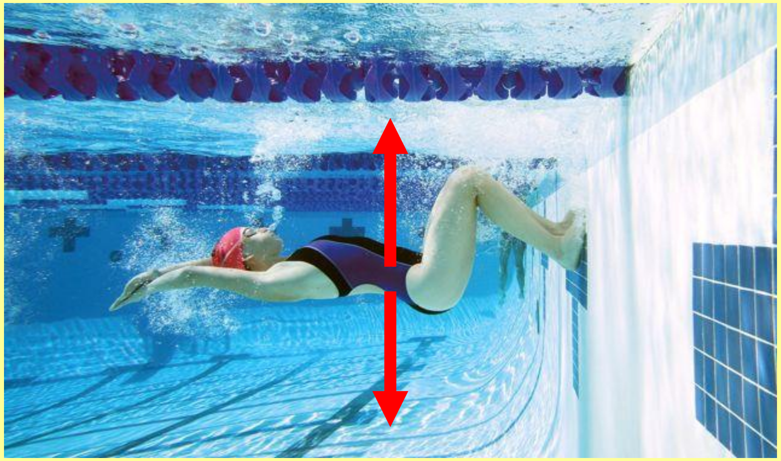
When identifying an interaction pair, the forces must be of the same type – and acting on different objects



The **swimmer** exerts a force on the **wall**.
The **wall** exerts an equal and opposite force on the **swimmer**.
Both forces are contact (support) forces

Interaction Pairs

The swimmer stays at a constant depth. The upthrust is equal to their weight. Is this a N3L interaction pair?



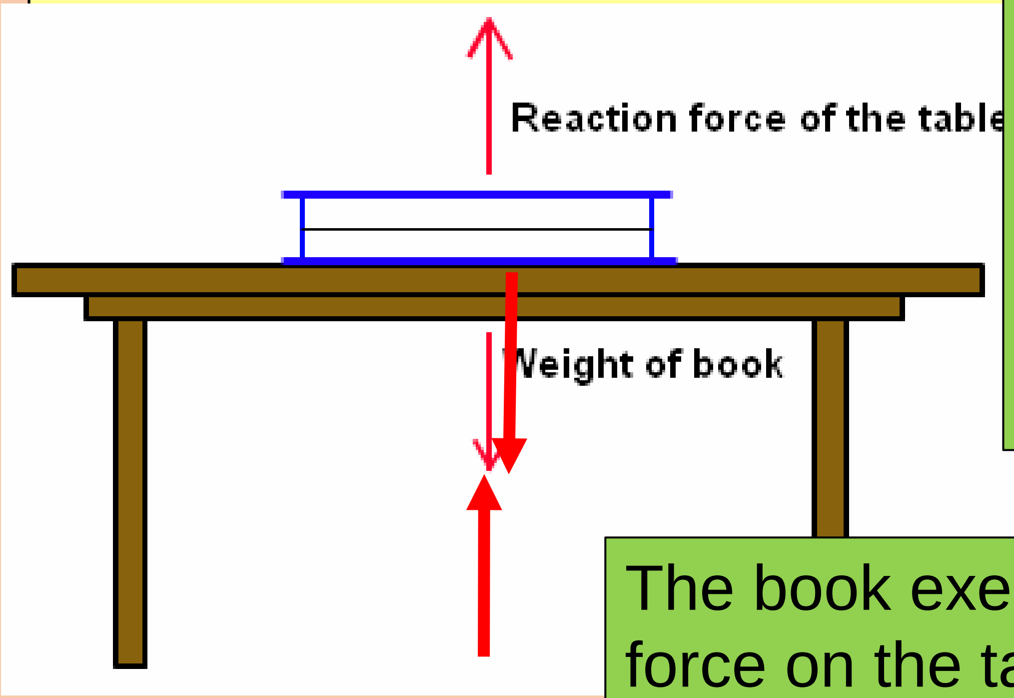
No

- The forces are both acting on the swimmer.
- They are not the same type of force (upthrust = contact force, weight = gravitational force)

Interaction Pairs

Can you identify a N3L interaction pair in this example?

(Hint: other forces are involved)



The Earth exerts a gravitational force on the book. The book exerts an equal and opposite gravitational force on the Earth.

The book exerts a reaction force on the table. The table exerts an equal and opposite reaction force on the book.

Newton's Second Law:

At GCSE we learn this simply as F=ma

But more precisely, the law states that the net resultant force acting on an object is directly proportional to the rate of change of its momentum, and is in the same direction.

Net force α rate of change of momentum

$$F = \frac{\Delta p}{\Delta t}$$

One **newton** is the force required to give a 1kg mass an acceleration of $1ms^{-2}$

Example:

In a crash test at $14ms^{-1}$, a 4.5 kg dummy head hits the steering wheel and comes to rest in 9.1ms. Calculate the net force acting on the head on the impact.

Find the change in momentum, then use Force = rate of change of momentum i.e. $\Delta p / \Delta t$

$\Delta p = mv - mu = 4.5 \times 0 - 4.5 \times 14$

$$F = \frac{\Delta p}{\Delta t} = \frac{-(4.5 \times 14)}{9.1 \times 10^{-3}} = -6.9 \times 10^{3}\ N$$

F = ma is a special case of N2L

If the mass of the object remains constant during the period of acceleration then the equation can be rewritten as F = ma

$$F = \frac{\Delta p}{\Delta t} = \frac{mv - mu}{t} = \frac{m(v-u)}{t} = ma$$

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Collisions:

There are two main types of collision:

What is the difference between them?

Type of collision	Momentum	Total Energy	Total kinetic energy
Perfectly elastic	Conserved	Conserved	Conserved
Inelastic	Conserved	Conserved	Not conserved

Impulse

The impulse of a force is defined as the product of force and the time for which this force acts on an object

Impulse of a force = F x Δt

The impulse of a force is equal to the change in momentum.

$Ft = mv - mu$

Units of impulse = Ns or $kgms^{-1}$

Example:

A ball of mass 1.5kg is travelling towards a wall at $3ms^{-1}$. It hits the wall and bounces back with a speed of $2ms^{-1}$. The ball is in contact with the wall for 0.2s. Calculate:

a) The change in momentum
b) The impulse
c) The force exerted on the wall

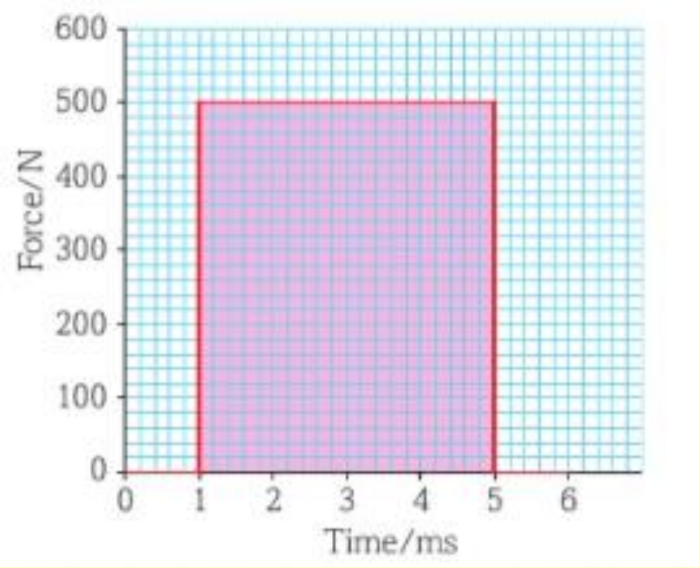
Tip: Always remember that momentum and velocity are vectors, so you MUST take account of direction

a) $7.5kgms^{-1}$
b) $7.5kgms^{-1}$
c) 37.5N

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Force-time graphs

The area under a force-time graph is always equal to the change in momentum, when the force is constant.



Calculate the impulse

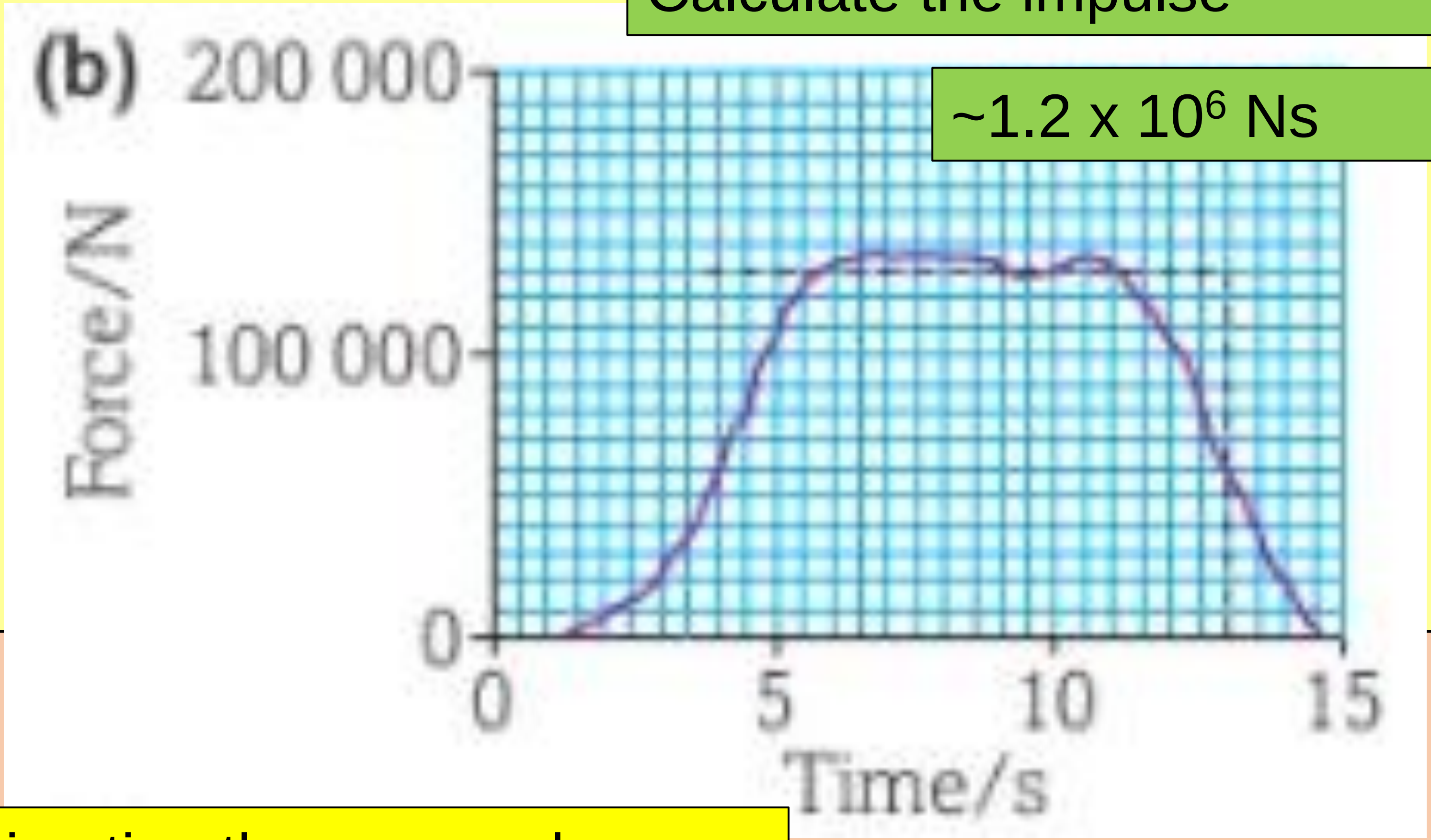
2 Ns

Force-time graphs

The area under the graph is equal to the impulse even when the force is changing.

Calculate the impulse

~1.2 x 10^6 Ns

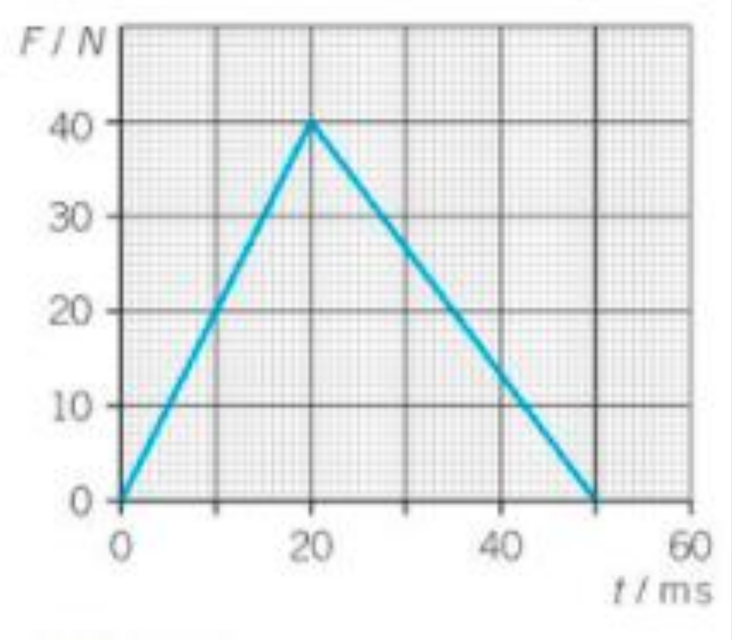


Estimating the area under a graph – counting squares

Learning Objectives: Projectile Motion; Moments & torques (couples); Newton's Laws of motion; momentum, collisions and impulse, 3rd law interactions); Practical Skills

Example:

A stationary squash ball of mass 0.025kg is hit with a racket. Use the force-time graph for the ball to determine the final velocity of the ball.



The area under the graph = impulse of the force.
Area = 1.0Ns

Impulse = change in momentum

1.0 = mv – mu
1.0 = 0.025 x v
v = 40ms^{-1}

Newton's Laws of Motion:

10 minutes to practice some questions where you will need to use Newton's three laws of motion to explain the forces in a situation.

Remember:

N1L - When resultant force = zero, object remains at rest or steady speed
When resultant force is not zero, object changes speed or direction

N2L - A resultant force will cause an acceleration. The force is directly proportional to the rate of change of momentum

N3L - An interaction pair requires two separate objects and the two forces will be of the same type