Mechanics

Science 1.1

Topic Outline

- Speed
- Acceleration
- Distance-Time Graphs
- Speed-Time Graphs
- Balanced Forces
- Unbalanced Forces
- Mass and Weight
- Pressure
- Kinetic Energy
- Gravitational Potential Energy
- Conservation of Energy
- Work
- Power

Equations

$$v = \frac{\Delta d}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t}$$

$$F_{net} = ma$$

$$P = \frac{F}{A}$$

$$\Delta E_P = mg\Delta h$$

$$E_K = \frac{1}{2} mv^2$$

$$W = Fd$$

$$P = \frac{W}{t}$$

g = 10 ms^{-2}

g = 10 Nkg^{-1}

Speed

- **Speed** is the distance covered in a given time.

$$v = d/t$$

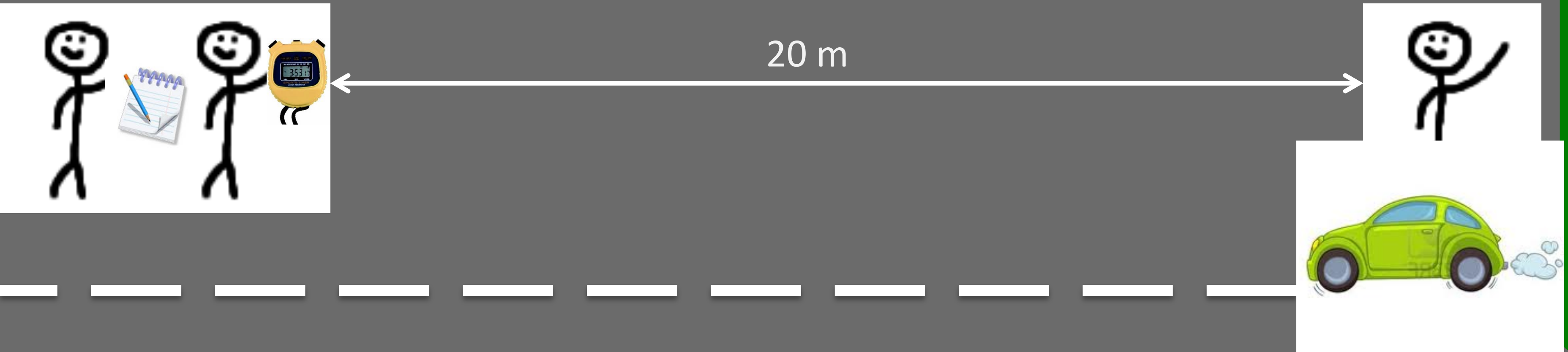
v = speed, $m.s^{-1}$

d = distance, m

t = time, s

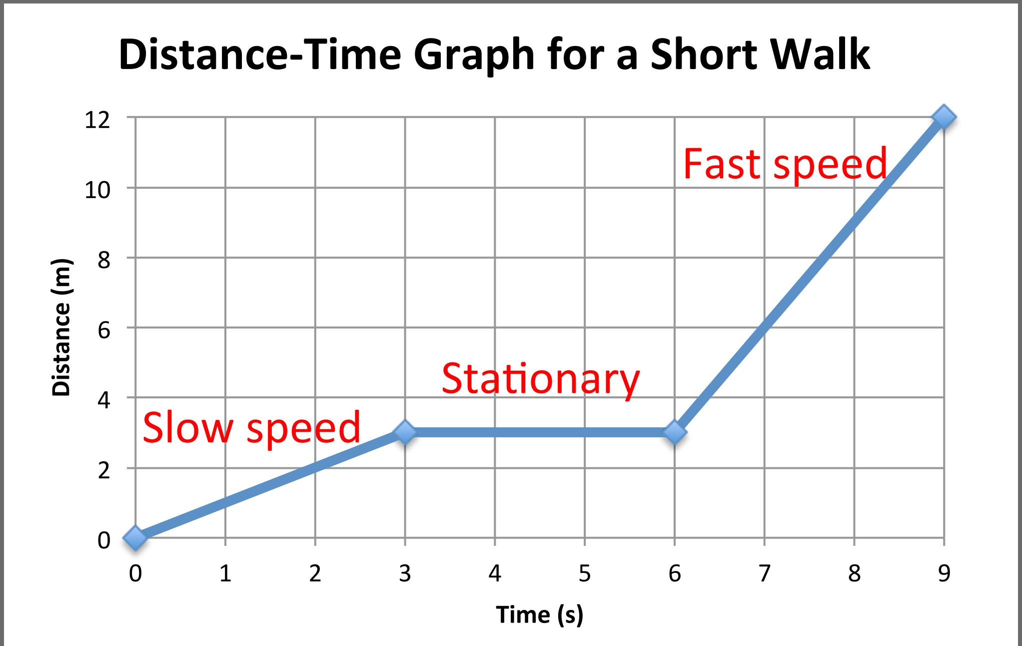
Speed – Practical

Car	Time (s)	Distance (m)	Average Speed ($m.s^{-1}$)	Average Speed ($km.h^{-1}$)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				



Distance-Time Graphs

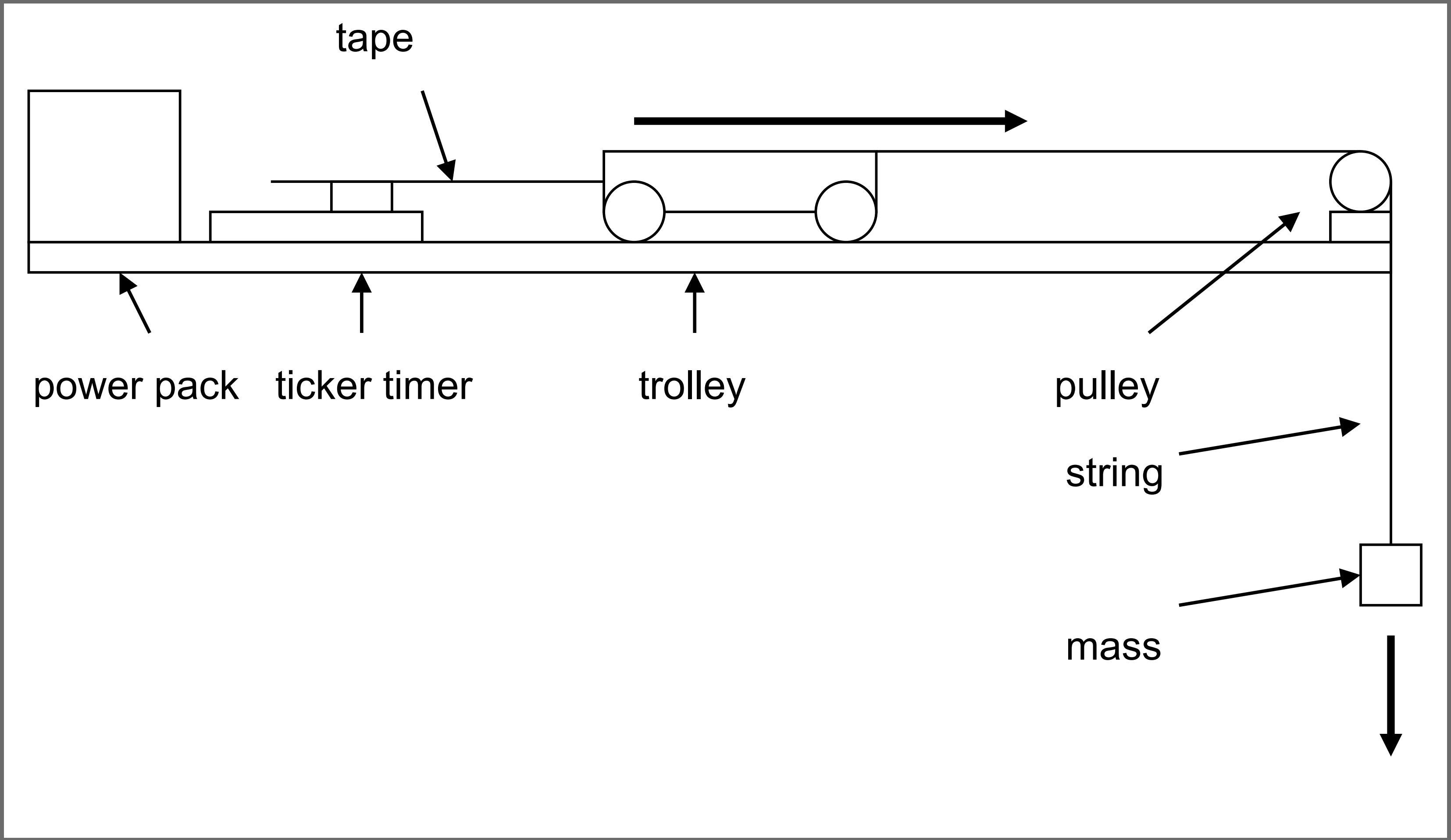
- **Distance-time graphs** have distance travelled on the y-axis and time along the x-axis.
- The slope of the graph gives the speed at that time.



Distance-Time Graphs

- In a distance-time graph, the slope indicates the speed:
  - a steep slope indicates a fast speed
  - a gradual slope indicates a slow speed
  - a flat (horizontal) slope indicates the object has stopped moving

Ticker-Trolley Practical



Ticker-Trolley Practical

- **Aim:** To plot a distance-time graph for the journey of a ticker trolley
- **Hypothesis:** I think that as the trolley is pulled off the table the speed will <*increase / stay the same / decrease*>
- **Method:** *Outline steps and draw a diagram*

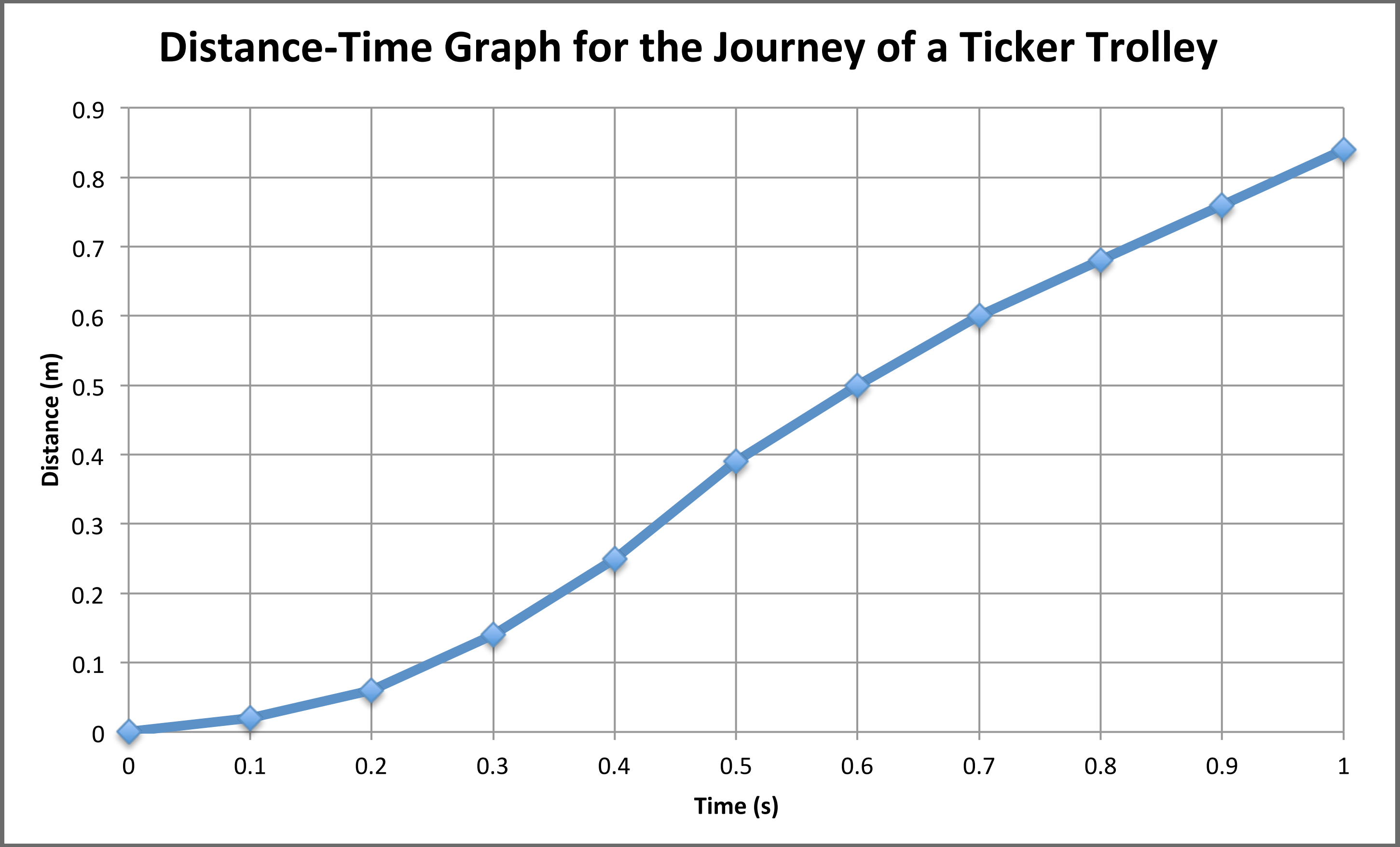
Ticker-Trolley Practical

- **Results**

Interval Number	Time (s)	Distance (cm)	Distance (m)	Summative Distance (m)	Average Speed (ms^{-1})
1	0.1				
2	0.1				
3	0.1				
4	0.1				
5	0.1				
6	0.1				
7	0.1				
8	0.1				
9	0.1				
10	0.1				

Once you have filled out the table, draw a distance-time graph for your results

Ticker-Trolley Practical



Ticker-Trolley Practical

- **Conclusion**
  - *Agree or disagree with your hypothesis*
  - *Explain your results*
  - *Suggest three reasonable Improvements*

Acceleration

- **Acceleration** is the change in speed over time.

$$a = \frac{\Delta v}{\Delta t}$$

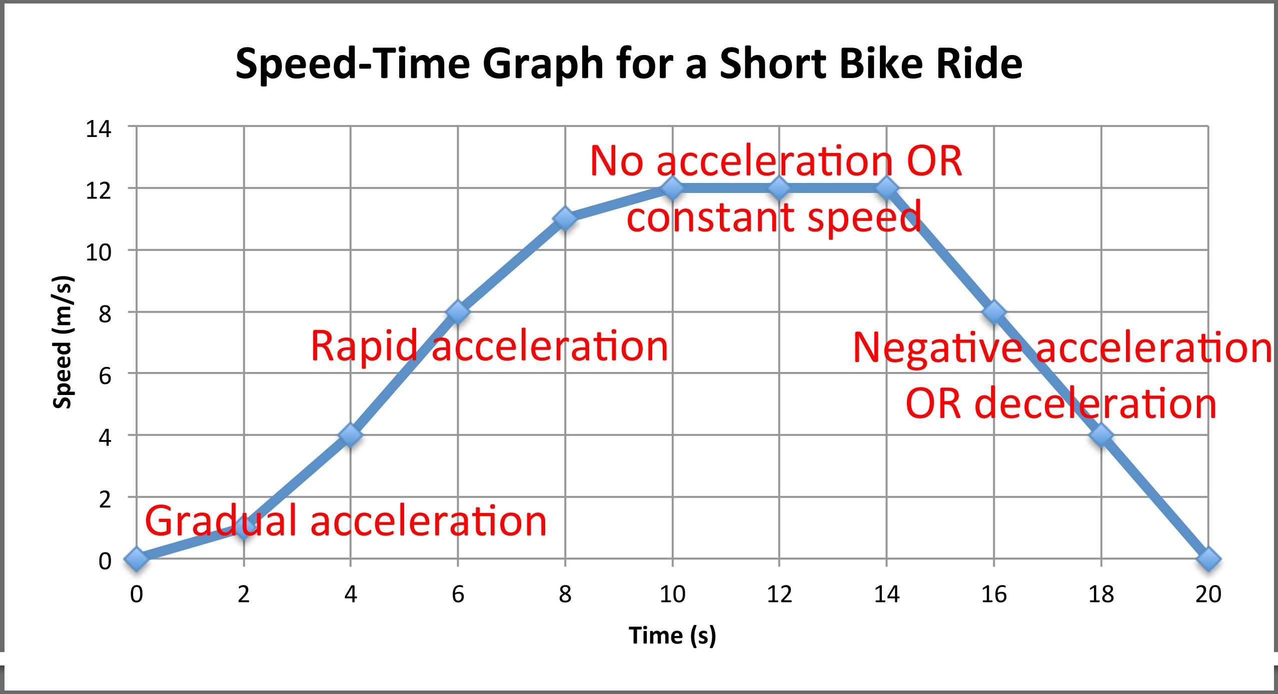
a = acceleration, $m.s^{-2}$

Δv = change in speed, $m.s^{-1}$

Δt = change in time, s

Speed-Time Graphs

- **Speed-time graphs** have the speed on the y-axis and time along the x-axis.
- The slope of the graph gives the acceleration at that time.



Speed-Time Graphs

- In a speed-time graph:
  - an upward slope indicates acceleration
  - a downward slope indicates deceleration
  - a flat line indicates no acceleration
  - a steep slope indicates a fast acceleration/ deceleration
  - a gentle slope indicates a slow acceleration/ deceleration
  - The area under the graph gives the distance travelled

Reaction Time – Practical

Activity:

1. Set up a chair so one group member can push their foot against a wall
2. Drop a meter ruler between the person's foot and the wall
3. Record the distance the ruler falls
4. Repeat three times for each group member
5. Use the chart to work out the average reaction time for each person
6. Time permitting, repeat using a different condition, e.g. having a conversation, listening to music, texting… (check with teacher first)

Reaction Time – Practical

Distance on ruler (cm)	Reaction time (s)
5	0.10
10	0.14
15	0.18
20	0.20
25	0.23
30	0.25
35	0.26
40	0.28
45	0.30
50	0.32

Once you have calculated your average reaction time, calculate how far you would travel in this time in a car travelling at 50 km/h.

How does this compare to statistics that people travel an average of 11 m before starting to break?

Force

- A **force** is a push, pull or twist
- **Contact forces** require physical contact between the two objects, e.g. kicking a ball; **non-contact forces** do not, e.g. gravity and magnetism
- All forces have a **direction**
- When a force is applied to an object, the object will: speed up, slow down, change direction or change shape
- When two forces of the same size are acting against each other, they will cancel out (or '**balance**')
- Force is measured in **Newtons**. 1 N = the force required to accelerate a 1 kg object at 1 $m.s^{-2}$

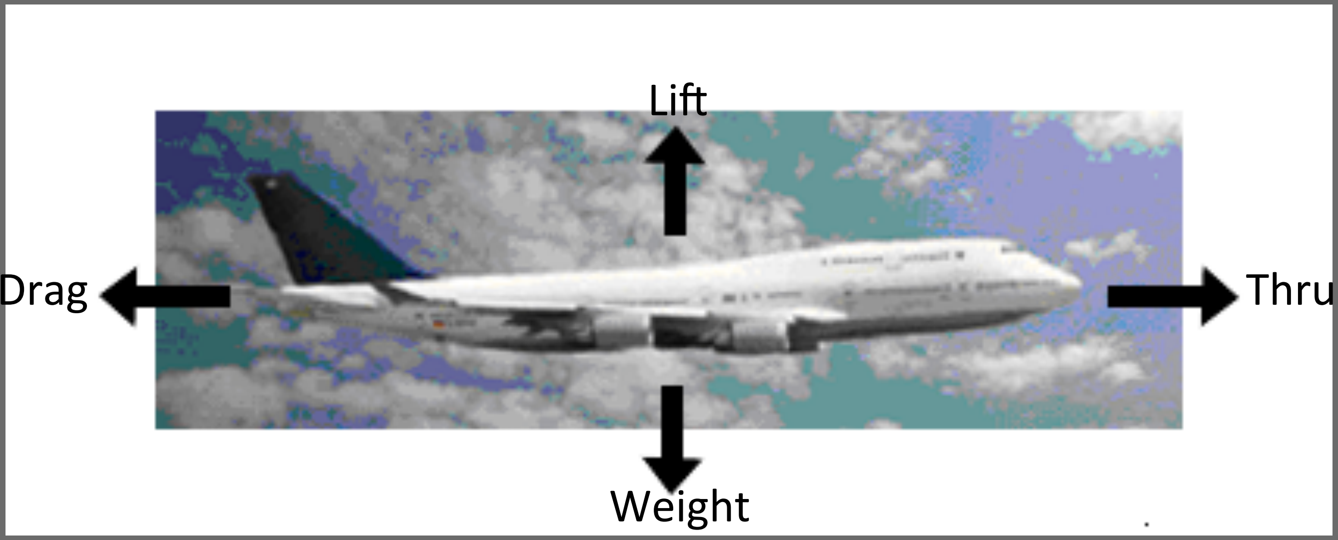
Worksheet: Types of Force

Newton's First Law of Motion

- **Newton's First Law of Motion**: An object will continue to travel in the same speed and in the same direction unless it is acted on by an unbalanced force
- All forces have a **size** and a **direction**
- The forces in a given direction (e.g. horizontal direction or vertical direction) can be added to work out the net (overall) force in that direction
  - **Thrust** is the force that is intended to make the object move
  - **Friction** is a force that opposes the movement of an object
  - **Weight** is the downward force of gravity on an object
  - **Support** is the force holding up the weight of an object

Free-Body Force Diagrams

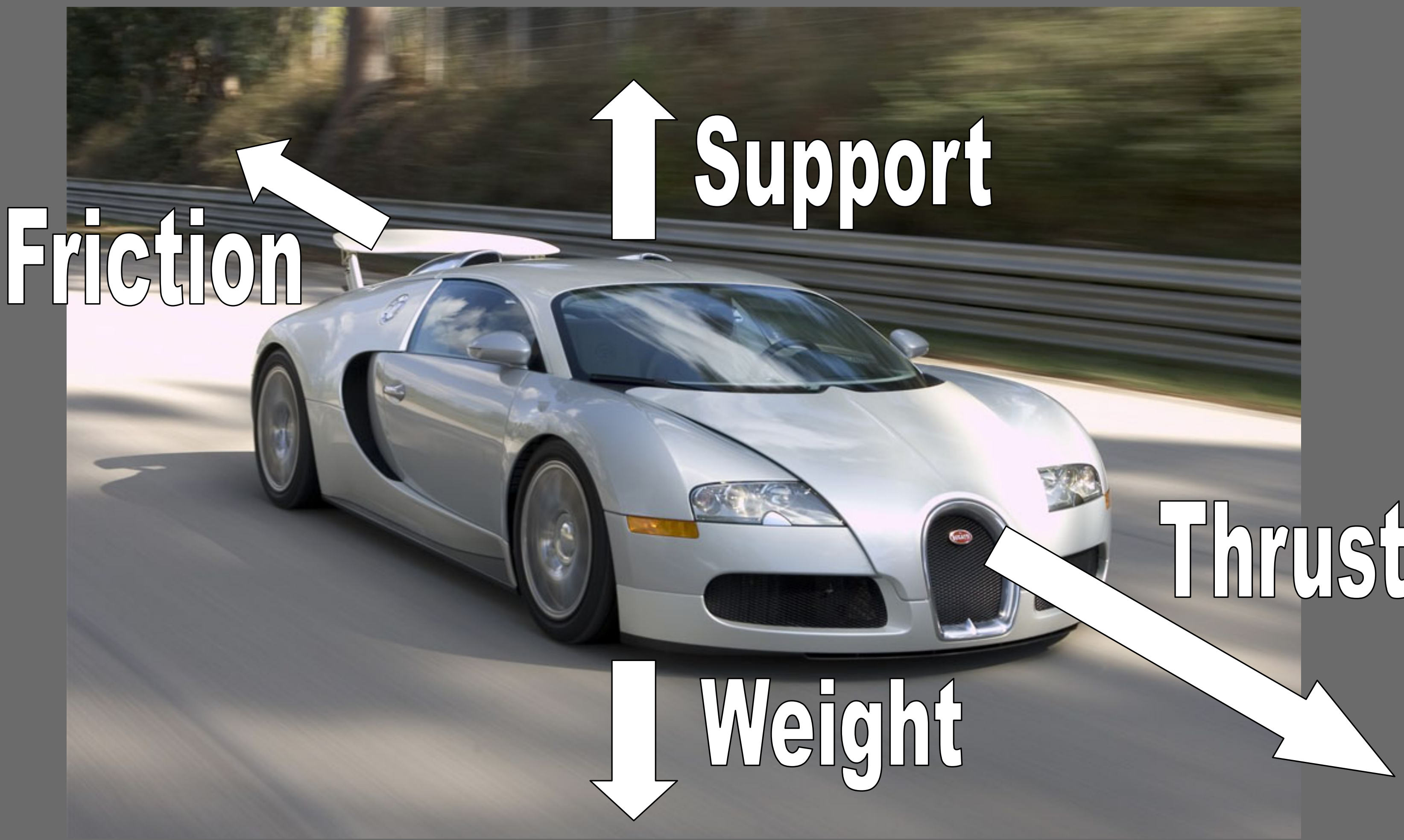
- We can draw **free-body force diagrams** to show the forces on an object



Newton's Second Law of Motion

- **Newton's Second Law of Motion**: If an unbalanced force acts on an object, the object will accelerate in the direction of that force
- Another way to think of this is that the object will move in the direction of the **net** force
- The net force is the 'overall' force, which is calculated by adding all the forces together (remember: forces have **direction**)

Newton’s Second Law of Motion



Newton's Second Law of Motion

Force = mass x acceleration

F = ma

F = force, N

m = mass, kg

a = acceleration, $m.s^{-2}$

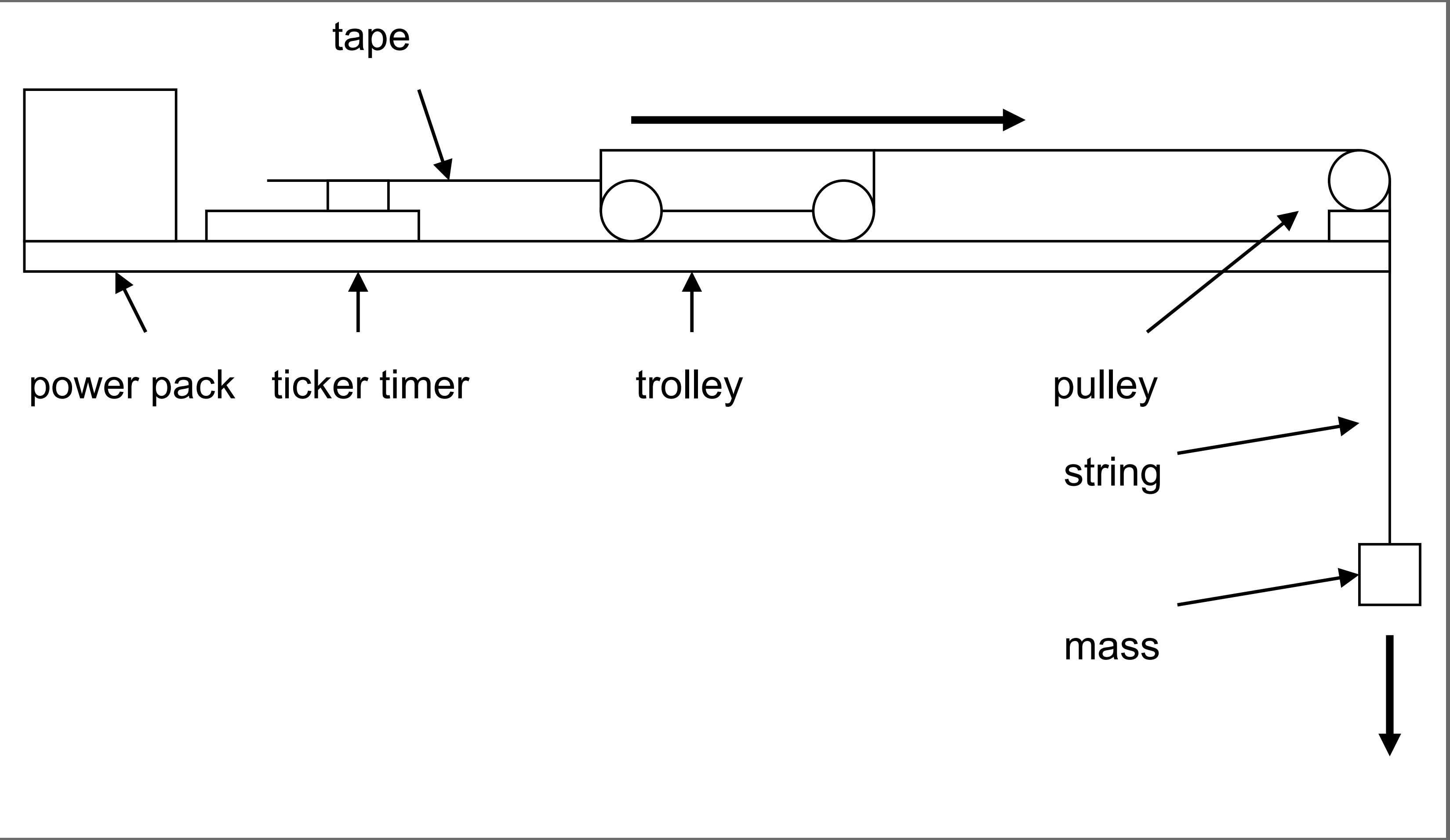
Worksheet: Newton's Laws

Worksheet: Warbirds over Wanaka

Force – Practical

- **Aim:** To determine the relationship between force and acceleration for a ticker trolley
- **Hypothesis:** I think that as force increases, acceleration will <*increase / decrease / stay the same*>
- **Method:** *Set up ticker trolley as for previous experiment; accelerate the trolley using 100 g, 200 g, and 300 g masses; analyse the traces as for the previous experiment*

Force – Practical



Force – Practical

- **Data Analysis**
  - *Mark off intervals by putting a line through every 5th dot on the trace*
  - *Measure the **length** of the **longest** interval on the trace*
  - *Calculate the **speed** for this interval (s = d/t)*
  - *Work out the **change in speed** from the start (0 ms^{-1}) to the maximum speed (which you have just calculated)*
  - *Count the number of intervals and work out the **change in time** to reach the maximum speed*
  - *Calculate **acceleration** using a = Δv/Δt*

Mass (g)	Force (N)	Acceleration (m.s^{-2})
100	1	
200	2	
300	3	

Force – Practical

- **Results:**
  - *Fill in the table*
  - *Draw a graph of acceleration (y-axis) vs. force (x-axis)*
- **Conclusion:**
  - *Agree or disagree with your hypothesis*
  - *Explain your results*
  - *Suggest three reasonable Improvements*

Mass and Density

- **Mass** is a measure of the amount of matter in an object
- Mass is measured in kilograms (kg)
- **Density** is the amount of matter in a given volume
- Density is measured in kg/l ($kg.l^{-1}$) or g/ml ($g.ml^{-1}$)

$$\textbf{Density} = \frac{\textbf{mass}}{\textbf{volume}}$$

- One kilogram of water has a volume of one litre, so the density of water is 1 kg/l

Density – Practical

- **Aim:** To calculate the density of at least 5 small objects
- **Method:**
  - *Measure the* ***mass*** *(g) of an object on the electronic scales*
  - *Measure the* ***volume*** *(ml) of the object using water displacement in a measuring cylinder*
  - *Calculate* ***density*** *= mass/volume*
- **Results:**
  - *Make a table of your results*

Density – Practical

1. Which object had the highest density?
2. Which object had the lowest density?
3. Which objects had a density greater than 1 g/ml?
4. Which objects had a density less than 1 g/ml?
5. What can you say about an object if its density is less than 1 g/ml?

Mass and Weight

- **Mass** is the amount of matter in an object, kg
- **Weight** is the force of gravity acting on a mass, Newtons, N

Weight force = mass x acceleration due to gravity

$$\mathbf{F_W = mg}$$

F_W = weight force, N

m = mass, kg

g = acceleration due to gravity, 10 $m.s^{-2}$

Worksheet: Planet Gravity

Measuring Mass in Space - Practical

- **Aim:** To measure *mass* without measuring *weight*
- **Method:**
  - Tape a ruler to the edge of a desk, with most of the ruler hanging over the edge
  - Tape a 50 g mass onto the end of the ruler
  - Time 10 oscillations of the mass on the ruler
  - Repeat for 100 g, 150 g and 200 g masses
  - Plot a graph of time for 10 oscillations (y-axis) vs. mass (x-axis)
  - Attach an unknown mass to the end of the ruler and time 10 oscillations
  - Use your graph (a calibration curve) to estimate the mass of the unknown

Pressure

- **Pressure** is the force on an object divided by the area over which that force acts

$$P = \frac{F}{A}$$

P = pressure, Pascals (Pa) or Nm^{-2}

F = force, N

A = area, m^2

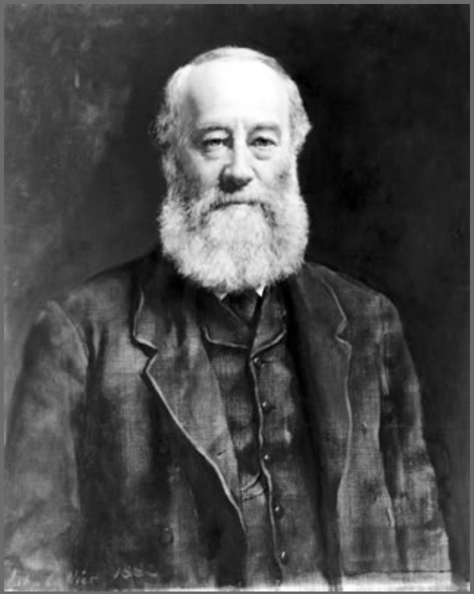
Pressure – Activity

- Trace the sole of your shoe on grid paper with centimetre markings
- Count the number of squares under your shoe, then double this area (for standing on both feet)
- Convert the area from cm^2 to m^2 by dividing by 10 000
- Calculate your weight by multiplying your mass by gravity
- Calculate the pressure you exert on the floor using pressure = force / area
- Repeat using the area of the chair legs

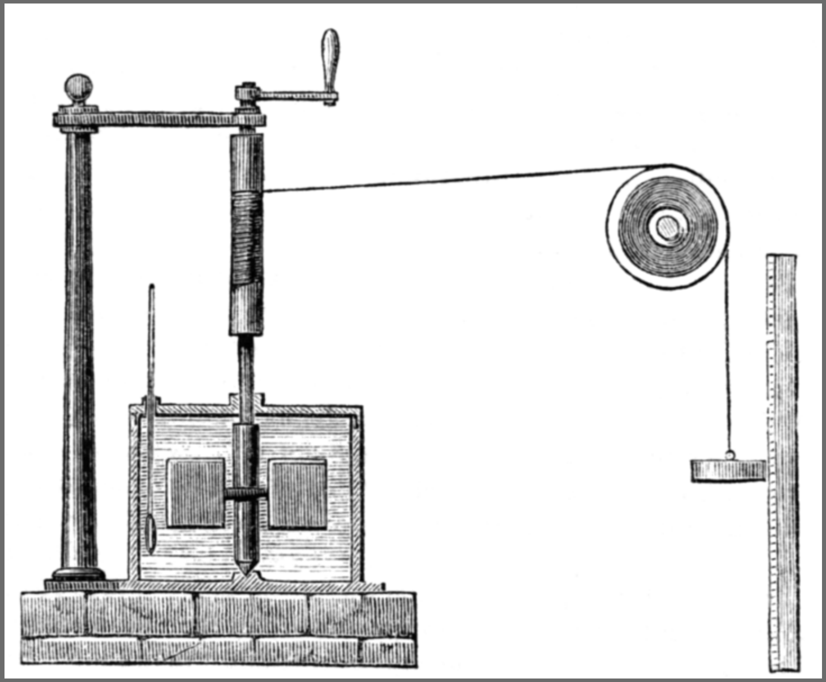
Energy

- **Energy** is the capacity to do work and is measured in Joules (J)
- There are two main categories of energy:
  - **potential energy** is stored energy, e.g. a car battery has chemical potential energy
  - **active energy** is when the energy changes are observable, e.g. fireworks exploding

James Joule



- James Prescott Joule (1818-1889) was an English Physicist
- He demonstrated the equivalence between mechanical work and heat



Energy Transforms

- Energy is neither created nor destroyed, but is transformed from one form to another

Activity: Make an eight-frame cartoon for the energy transforms that result in one of the following situations:

- *– the electric light shining in this room*
- *– you writing on your page*
- *– a person scoring a goal or a try*

Kinetic Energy

- **Kinetic energy** is calculated from the mass of the object and the speed it is going:

$$E_K = \frac{1}{2} mv^2$$

E_K = kinetic energy, J

m = mass, kg

v = velocity (speed), $m.s^{-1}$

Activity: Calculate your average kinetic energy when running 25 m

Worksheet: Kinetic Energy

Gravitational Potential Energy

- **Gravitational potential energy** is the amount of stored energy an object has when it is held at a height
- E.g. water in a dam or a person on a diving board

$$E_{GP} = mgh$$

E_{GP} = gravitational potential energy, J

m = mass, kg

g = acceleration due to gravity, 10 $m.s^{-2}$

h = height of the object

Activity: Calculate the gravitational potential energy you gain by climbing a flight of stairs

Worksheet: Gravitational Potential Energy

Work

- **Work** is the transfer of energy from one form to another, and is measured in Joules (J).
- Work is calculated from the force used to move an object a certain distance

Work = force x distance

W = Fd

W = work done, J

F = force, N

d = distance the object is moved, m

Work - Example

A force of 15 N is applied to lift a school bag 1.2 m from the floor onto a desk

Work done = force x distance

= 15 x 1.2

= 18 J

In this case, chemical potential energy from the person's food is converted into kinetic energy as the muscles and school bag move, and then the kinetic energy is converted into gravitational potential energy of the bag on the desk.

Worksheet: Work

Conservation of Energy

- When an object is in free fall (e.g. a tennis ball dropped from a building), its gravitational potential energy is converted to kinetic energy

Worksheet: Conservation of Energy

Power

- **Power** is a measure of how fast work is done, i.e. how quickly energy is converted from one form to another
- A powerful car is able to turn chemical potential energy (petrol) into kinetic energy (speed) in a short amount of time
- Power is measured in Watts, W

Power = Work / time taken

P = W / t

P = power, W

W = work done, J

t = time, s

Worksheet: Power

Power – Activity

- Calculate your average power when climbing a flight of stairs

Power – Activity

Worked example:

$m = 65$ kg

$F = mg = 65 \times 10 = 650$ N

$h = 3$ m

$W = Fd = 650 \times 3 = 1950$ J

$t = 4$ s

$P = W \div t = 1950 \div 4 = 487.5$ W

Revision

- Summary questions: NZ Cliff Divers
- Glossary
- Past exam papers (Science 1.1)