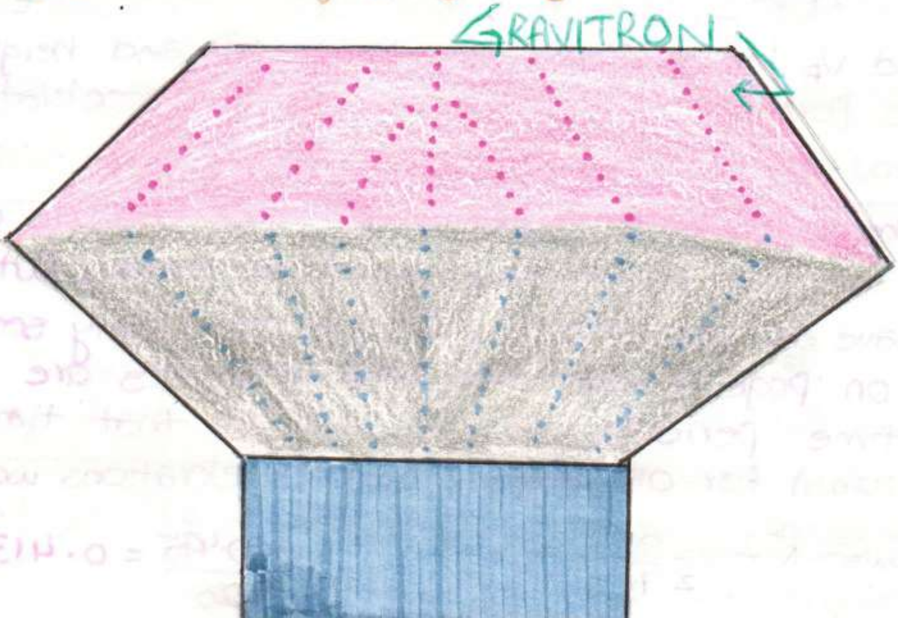
UNIT 2 FORCE

TASK INTRODUCTION

- To be able to understand how a force works and use this to come up with an amusement park ride that defies gravity.



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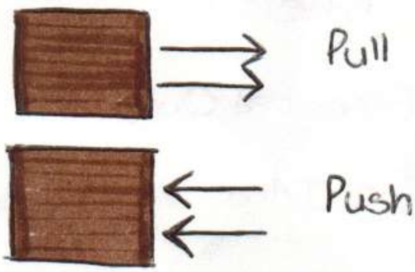
ESSENTIAL

FIRST THOUGHTS

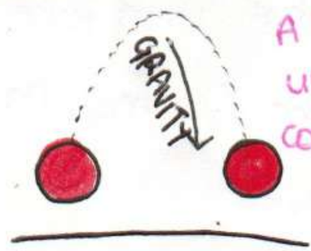
I think

Force is a phenomenon that can be experienced but it cannot be seen.

The effect of a force, however, can be seen. In simple terms it can be a push or pull.



Examples The force of gravity that the earth exerts on every object that is present on it.

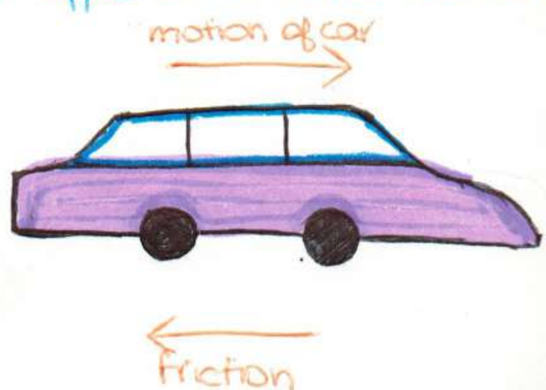


A ball thro[wn] up, eventua[lly] comes down

The core of the earth attracts everything towards itself.

When two cars crash with each other, a force is exerted by first car onto the second, and by second car onto the first.

Both cars have an impact and they go in opposite directions due to the effect of collision.



The force of friction comes into play when surfaces of any 2 objects are in contact with each other.

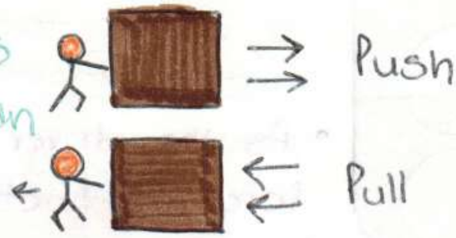
Friction is always in the opposite direction to the original motion.

QUESTION

Q What do you think a force is?

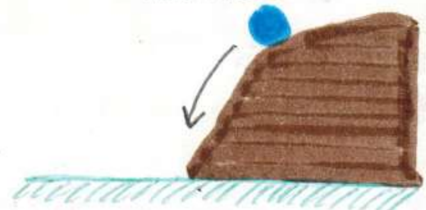
LAST THOUGHTS

- A force is a push or pull that acts on an object. The effect of a force can be seen.



- Force is what causes motion in all types of objects. Zero net force means no motion.

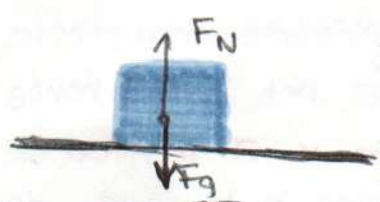
<u>Examples</u> Force due to gravity of the earth.
It pulls everything towards the earth.

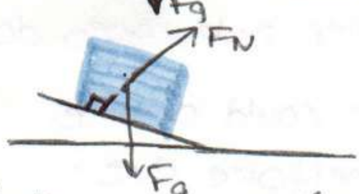


Friction is a force that comes into play when two objects are in contact.
It opposes motion.

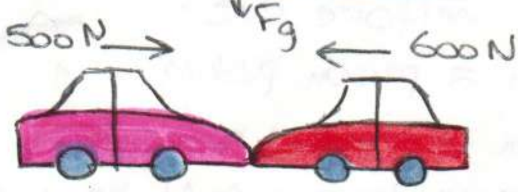
Applied force is the force exerted on an object by another body, for example a push applied to a box.

Normal force is the reaction to the gravitational force.
- It is always perpendicular to the surface.
- It may or may not be directly opposite to the gravitational force.





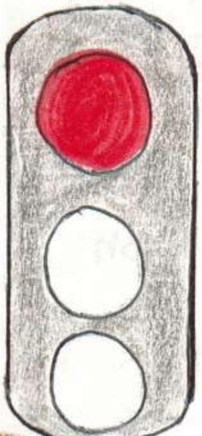
Net force is the sum of all forces acting on a single object



<u>Net force</u> ← 100 N

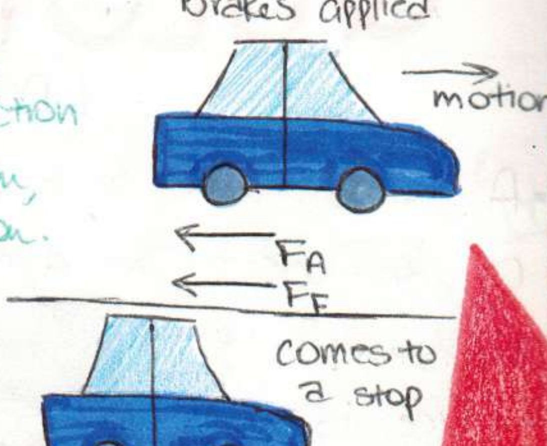
Q What role does force play at traffic light

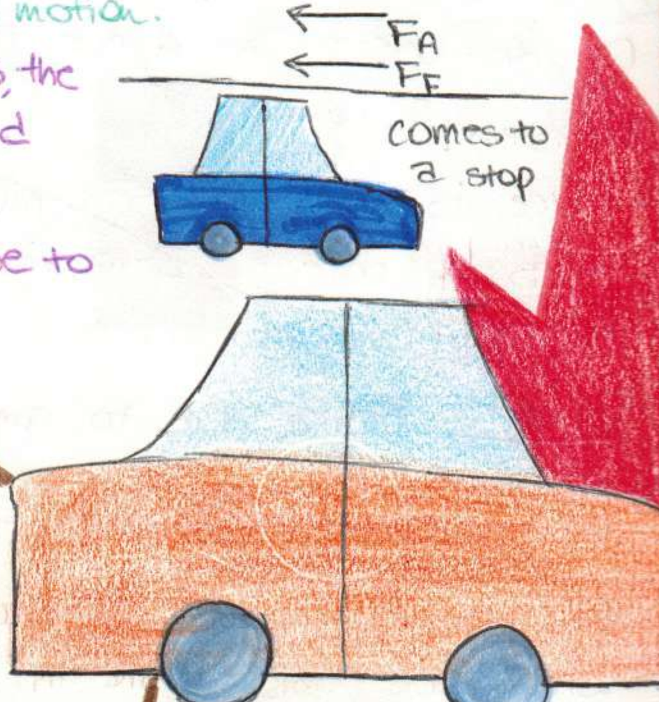
When color of traffic light changes to red, cars are supposed to slow down & stop.



- As the driver applies brakes, the applied force changes from in direction of motion to the opposite direction, that is, against the current motion.
- As the driver applies brakes, the force of friction and applied force are in same direction.

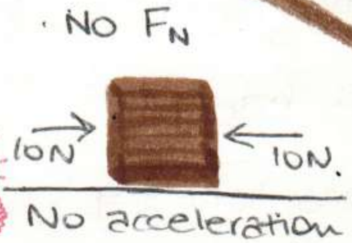
Friction helps the car come to a stop.



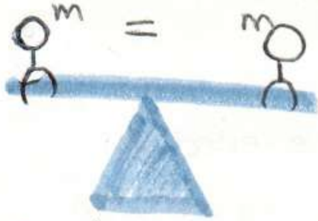


1st Law

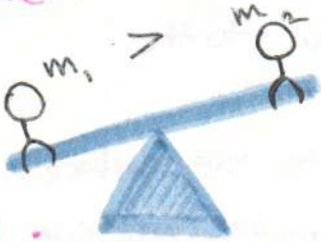
Newton's first law states that acceleration occurs only when there is a net force



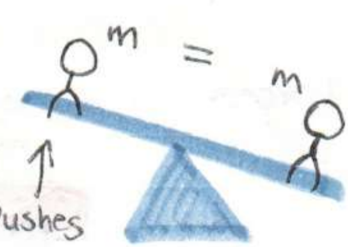
When forces on both sides of a seesaw are equal (this happens when mass is same) then there is no acceleration & hence no motion.



When there is a difference in masses, then there is a net force & hence there is a motion. Heavier side goes down.



There could also be a netforce due to a person pushing on the ground and hence there would be motion.

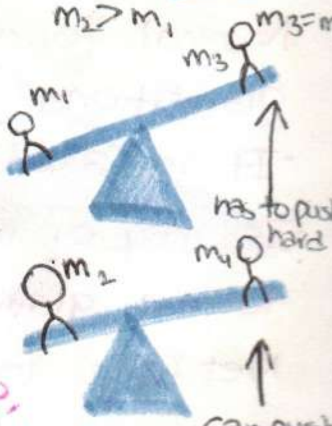


FOR

2nd

This law establishes that $a \propto$ Net force & $a \propto \frac{1}{\text{mass}}$.

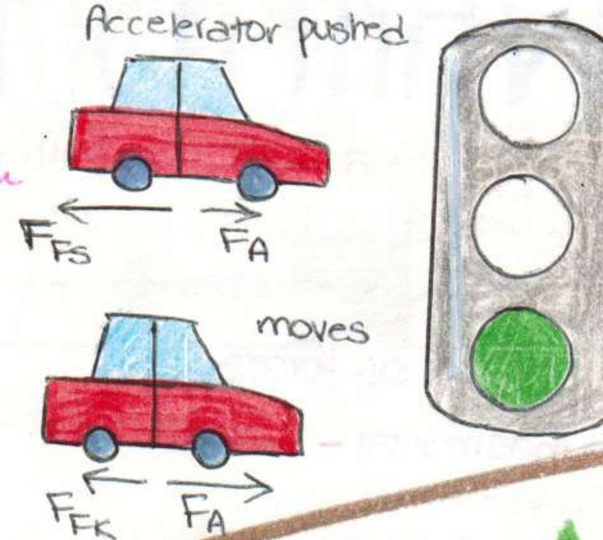
When mass of the person infront of you is er, then it is easier to work the seesaw (go up), that is, the acceleration will be higher than when person weighs

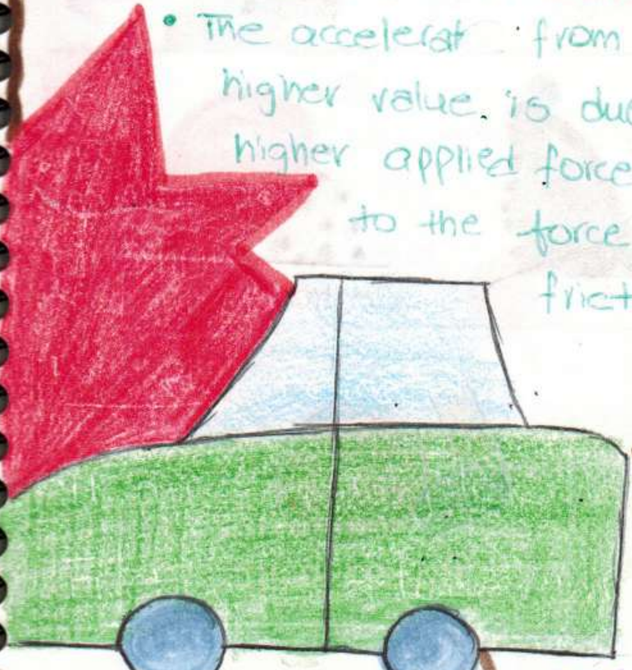


that is red and green

When color of traffic light changes to green, the cars at stop are supposed to start moving.

- As the driver pushes accelerator, the applied force keeps increasing in direction opposite of the friction until it goes over max static friction.
  - The accelerat from 0 to a higher value is due to constantly higher applied force as compared to the force of kinetic friction.

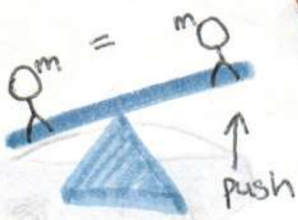




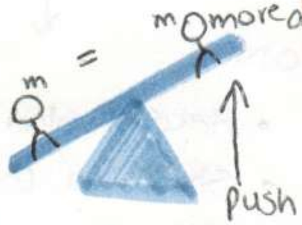
CE

Law

Say there are two people playing on a seesaw.



Acceleration will be higher when the person pushes the ground harder and it will be lower when push is not as hard



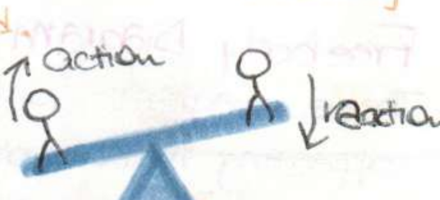
3rd Law

The third law states that every action has an equal & opposite reaction.

When a person pushes against the ground, he himself gets pushed as well and he rises & the other person goes down.

Without this law, seesaw's working cannot be explained.

When a person comes down from a higher position that is the action and as a result the other person comes down (reaction)



WHAT IS A FORCE

- Force is a push or pull acting on some object.
- The effect of force can be seen.
- Force is what causes all types of motion

Types of forces

Fundamental -

Gravity

Electromagnetic force

Weak and strong nuclear forces

GRAVITY

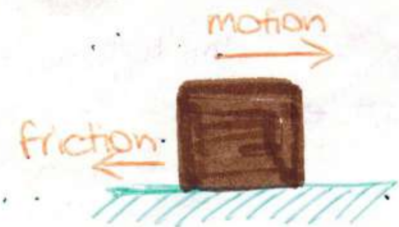
Electromagnetic force

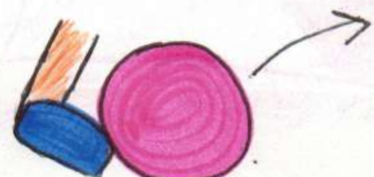
Everyday -

Gravity

Friction

Applied force

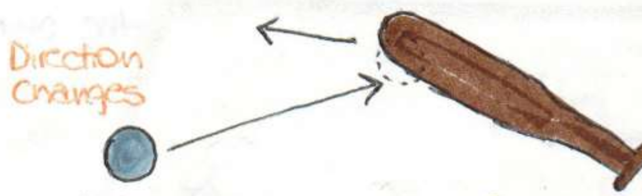




Applied force

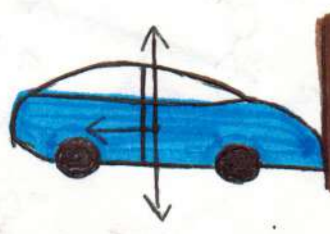
- A Force is vector and it can cause a stationary object to move, a moving object to stop, and cause an object to change its direction and/or speed.
- It's SI unit is Newton ($kg\,m/s^2$)

  Force = mass x accelration



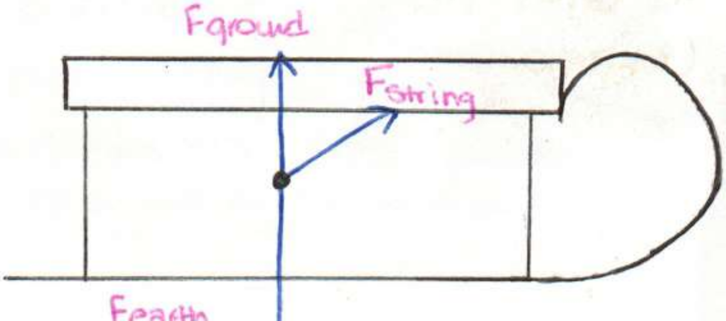
Freebody Diagram

These diagrams only analyze forces affecting motion of 1 object.
(Always represented at center of the object)



Effect of wall on motion of car.

$F_{ground} = 90N$ $F_{string} = 60N$ $F_{Earth} = 90N$

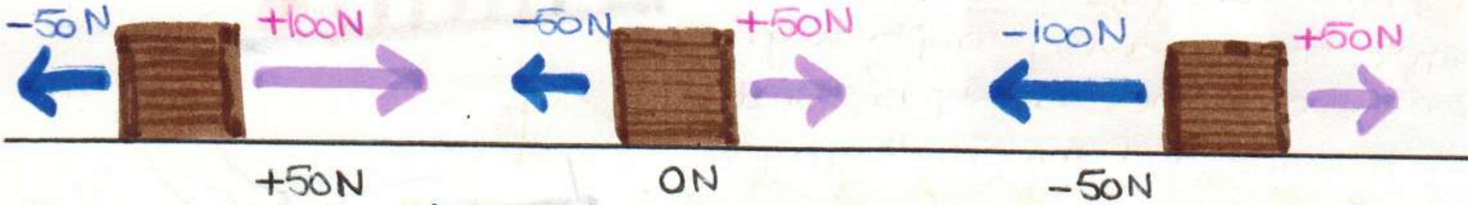


- Make a Sled.
- Show all forces acting at the center.
- Length of arrows must be proportional to magnitude of forces.

FORCE SIMULATIONS

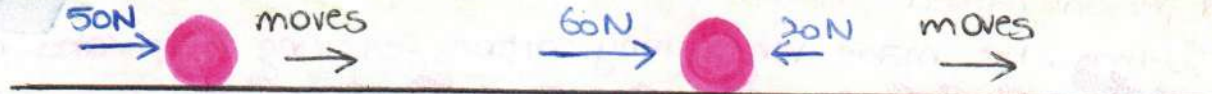
NET FORCE

Net force is sum of all forces acting on an object (can be +ve , 0 , or −ve)



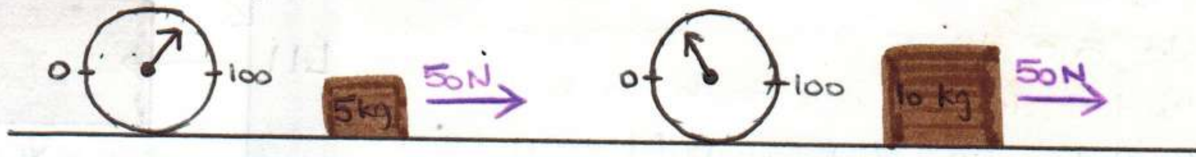
When force has been applied to something & it starts moving then an equal & opposite force will not be able to stop it. you need greater force

MOTION



When an imbalanced net force is applied to an object, it moves in direction of force. When this force is constantly applied, object keeps accelerating. An opposite force decelerats the object.

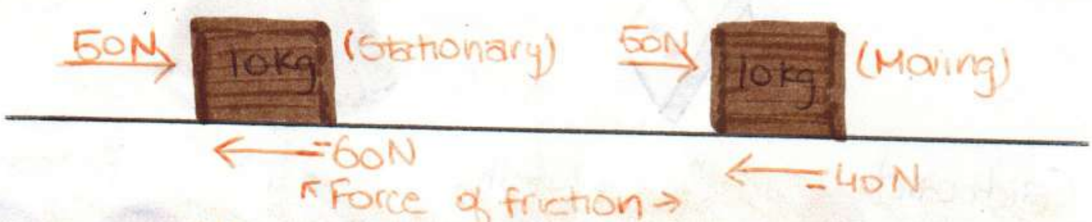
Speed after 5 seconds.



FRICTION

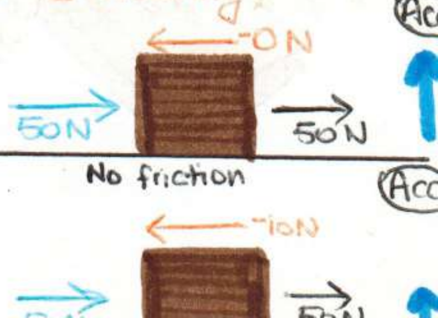
Friction comes into play everytime 2 objects are in contact. You need to overcome force of friction to move an object. The more the mass and roughness of surfaces more is the friction.

ACCELERATION



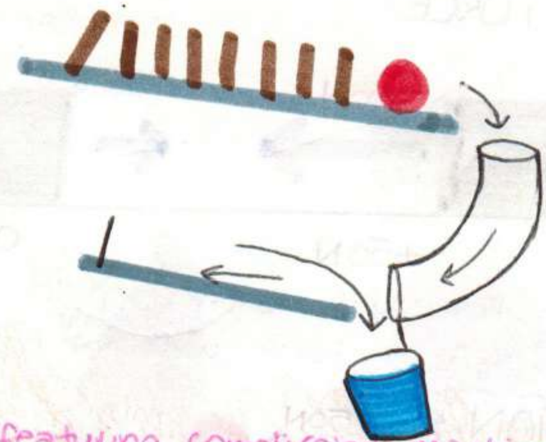
Force of friction is more difficult to overcome when object is stationary than to negate force of friction when the object is moving.

When force of friction is 0, the acceleration that object experiences for a certain amount of force applied is the highest.



RUBE GOLDBERG DAY-1

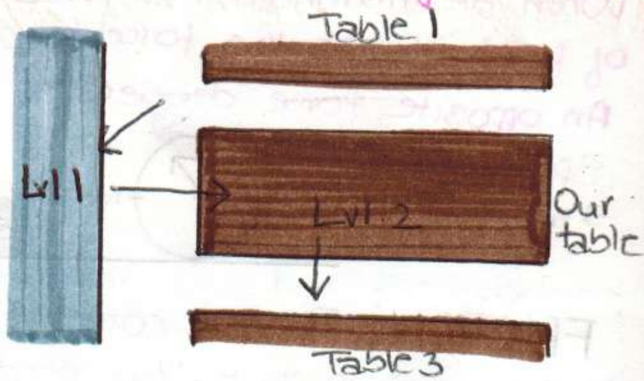
A Rube Goldberg machine uses a chain reaction to complete a simple task in a very complex way! Usually only the first step is started by a human and then everything begins to happen.



The name 'Rube Goldberg' comes from a peson named 'Reuben Lucius Rube Goldberg. He made very funny cartoons featuring complicated machines for 'Evening Mail'. These became a hit and people started building their own complicated machines - Rube Goldbergs.

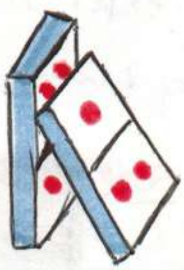
DESIGN

We are think about the shelf to the left of our table to be level 1. The table would then be level 2 and would connect to the table behind us.



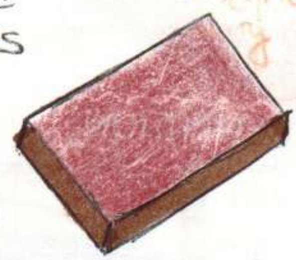
MATERIALS WE ARE CONSIDERING

Dominos



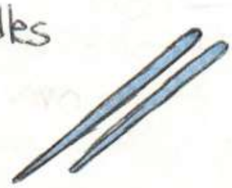
Cardboard Tubes

Wood pieces



Cardboard

Needles

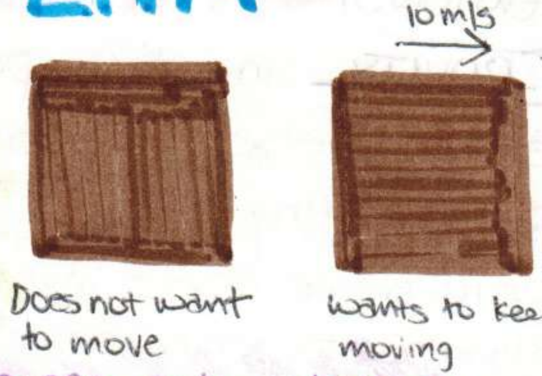


Balloons

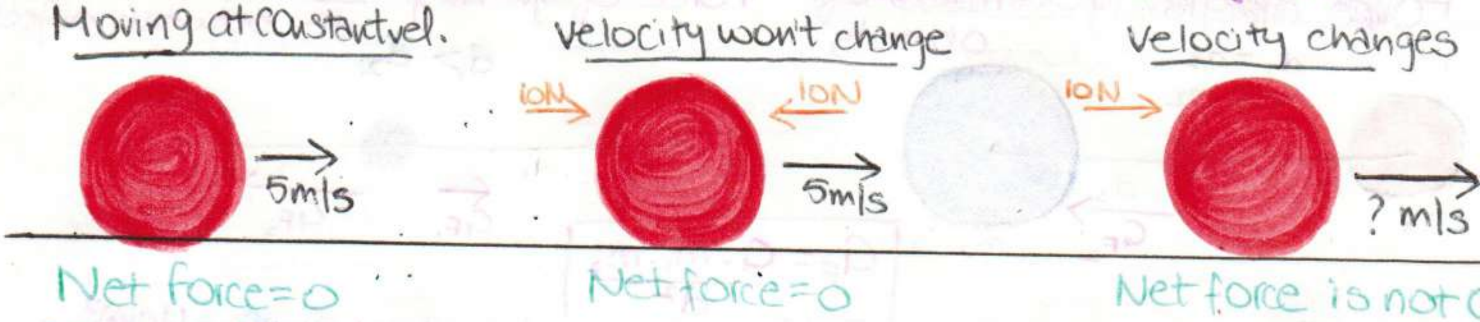
Confetti

NEWTON'S 1st LAW

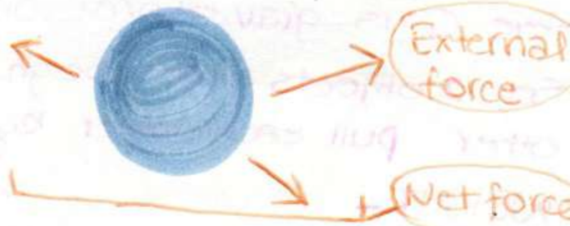
Inertia - An object at rest wants to be at rest, and an object in motion wants to keep going in the same direction and at same speed.

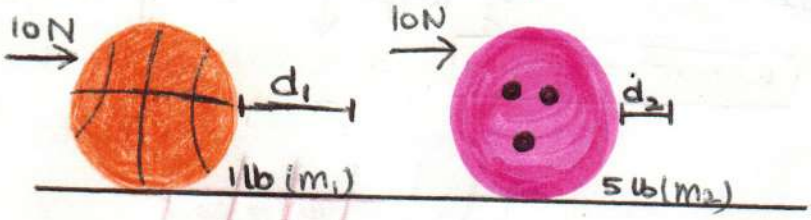


First Law - Velocity of an object changes only when an imbalanced net force is applied to the object.

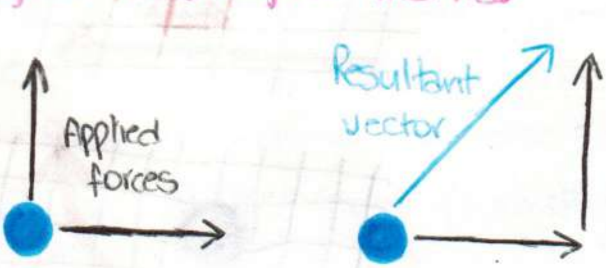


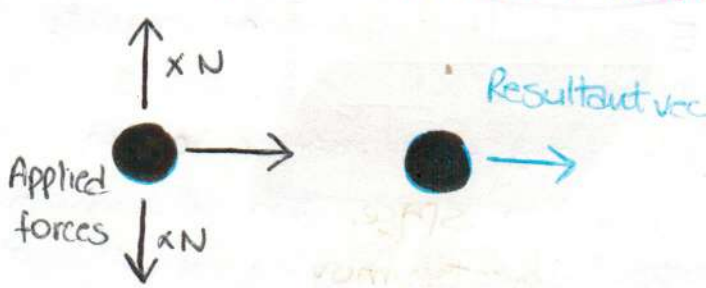
- External force is a single force acting on the object.
- Net force is sum of all forces.

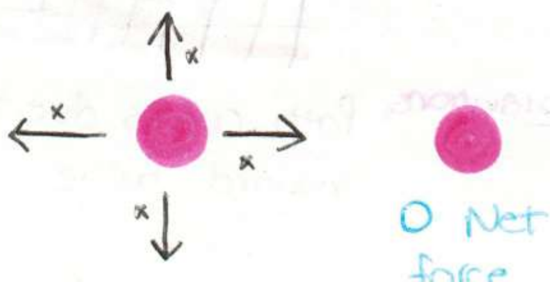




More is the mass, less is effect of similar force on the object. A lighter object accelerates faster thus it has lower inertia. A heavier object has higher inertia.







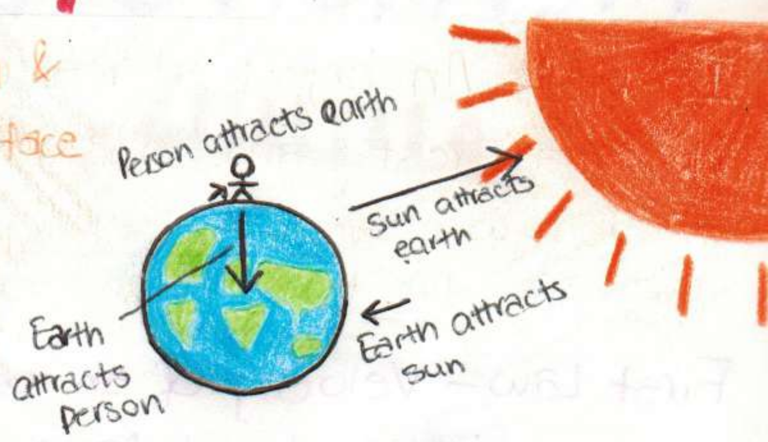
When the object is under 0 net force - it is said to be in equilibrium.

GRAVITY

NEWTON'S

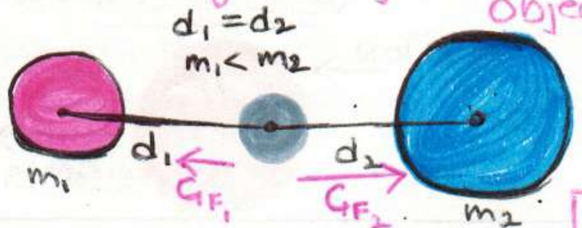
GRAVITY – This force pulls you & everything else down to the surface of the earth

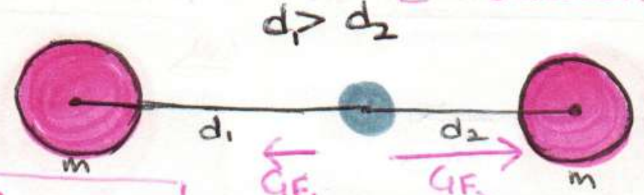
Every single object in space is attracted to every other object. This is called gravity



Force of gravity $\propto$ mass of objects

Force of gravity $\propto \frac{1}{d^2}$ (d is distance between objects)





$$\boxed{G_F = \frac{G \cdot m_1 \cdot m_2}{d^2}}$$

Here G is gravitational constant ($6.67 \cdot 10^{-8}$ dyne) 1 dyne $= \frac{(1cm)^2}{(1gm)^2}$

So, 2 objects that weigh 1g each when kept 1cm from each-other pull each-other by 1 dyne (0.001g)

WEIGHT – Heaviness of an object when gravity acts on its mass. $\boxed{\text{weight} = m \cdot g}$

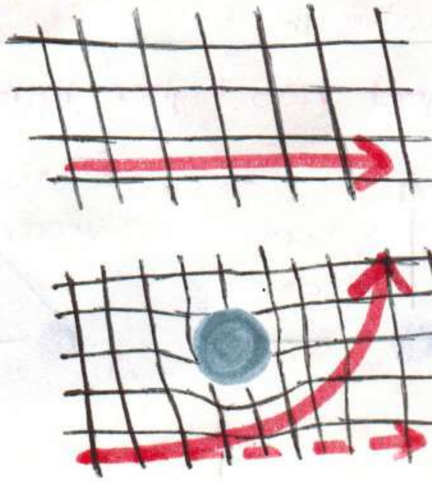
g is acceleration due to gravity

- On earth $g = 9.8\ m/s^2$

EINSTEIN'S GRAVITY

Einstein believed that gravity is not a force.

He said that matter could cause a curve in space and this was gravity. The objects moving in straight line get attracted to this inward bulge



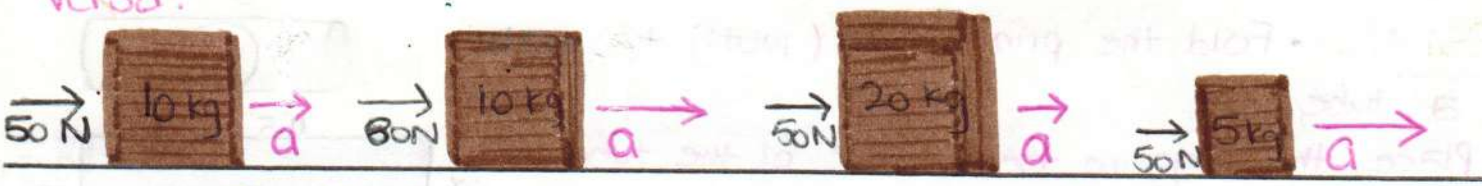
Path curves due to the inward bulge

- Some theories say that matter has gravitrons, and these attract & cause gravity.
- Some look at gravity as waves.

2ND & 3RD LAWS

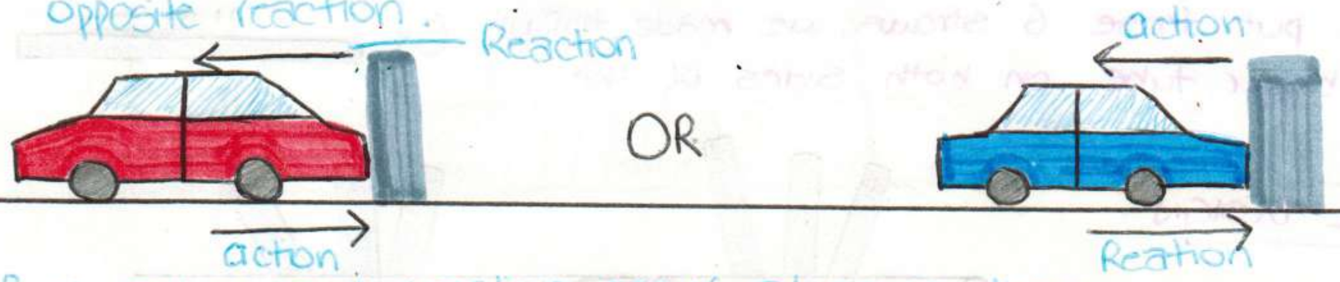
Second Law – For an applied force, heavier object has lower acceleration and vice-versa. Also, higher net force gives higher acceleration and vice-versa.

$F = m \cdot a$



$a \propto$ Net force $\qquad \boxed{\Sigma F = ma} \qquad a \propto \frac{1}{\text{mass}}$

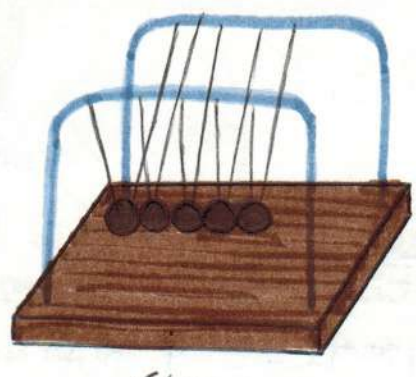
Third Law – For every action, there is an equal and opposite reaction.



Both action and reaction occur at same time.

$\boxed{F_1 = F_2}$

Newton's Cradle shows all 3 laws of motion.

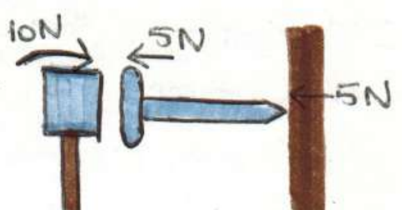


First law – when one ball is lifted a net force is applied and this causes acceleration

Second law – When ball is lifted higher, more net force is applied and other ball rises higher

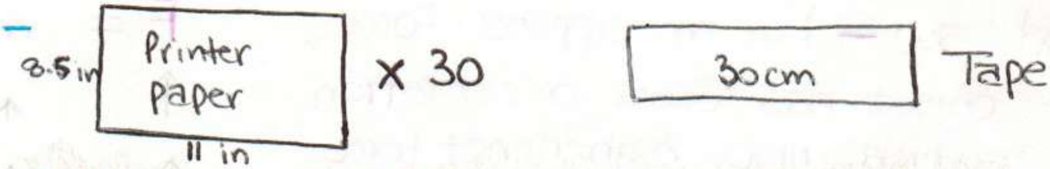
Third law – when 1 ball from right is lifted & it comes down and hits a ball, it comes to rest. This is due to equal & opposite reaction.

* Force applied has equal and opposite reaction but because net force on nail is not 0, it penetrates into wood.



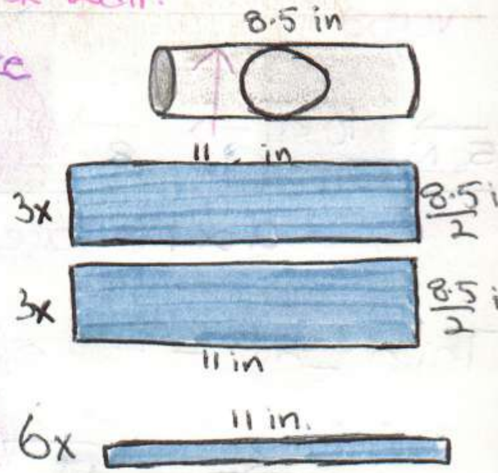
EGG LAUNCH

MATERIALS -



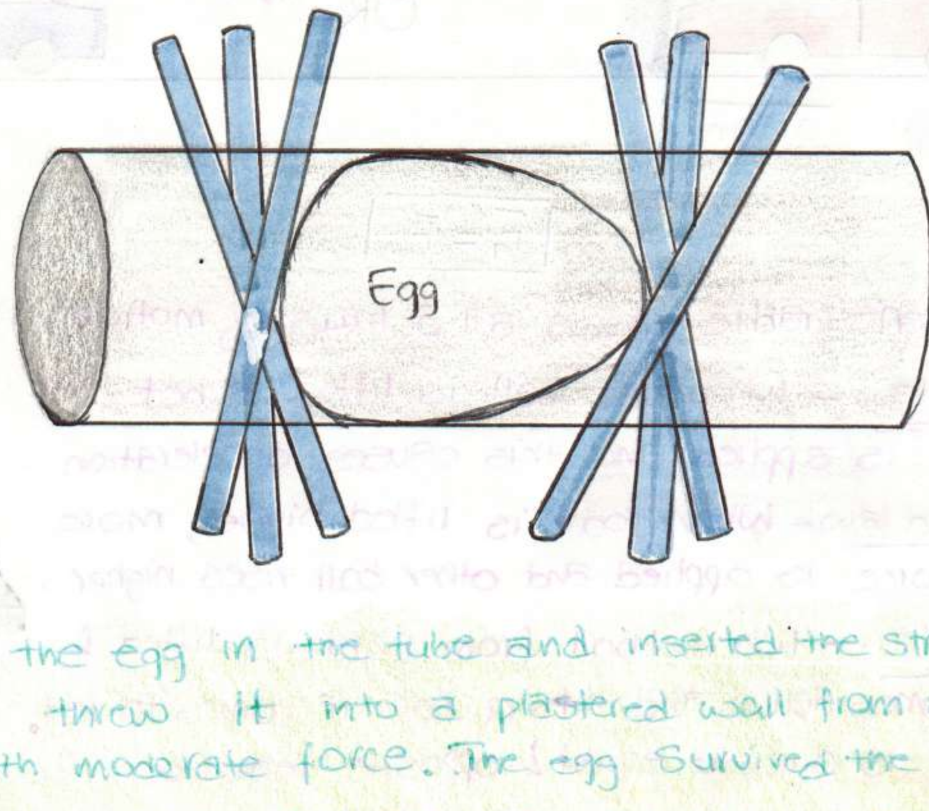
GOAL - Make a structure that holds an egg and prevents it from breaking when launched into a brick wall.

DESIGN - • Fold the printer paper (just 1) to make a tube.



- Place the egg in the middle of the tube.
- Make each of the other 3 printer papers into very thin tubes (just like straws) along the long side after cutting each paper into half.
- Now put these 6 straws we made through the bigger tube on both sides of the egg.

FINAL DESIGN

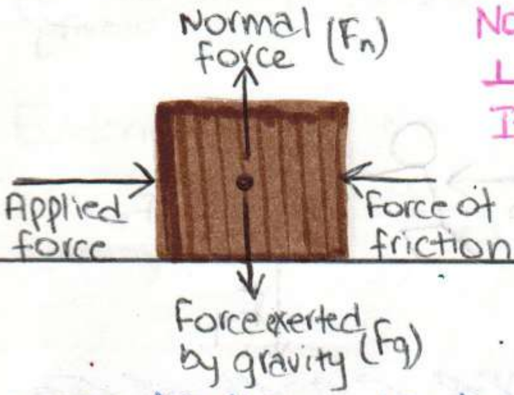


TEST

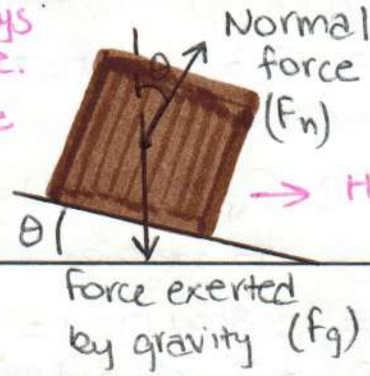
1st Test - I put the egg in the tube and inserted the straws into it. Then I threw it into a plastered wall from about 5 feet away with moderate force. The egg survived the test

2nd Test - I threw it again and the egg did not survive this time.

FRICTION FORCE



Normal force is always ⊥ to contact surface. It may or may not be at 180° with force of gravity



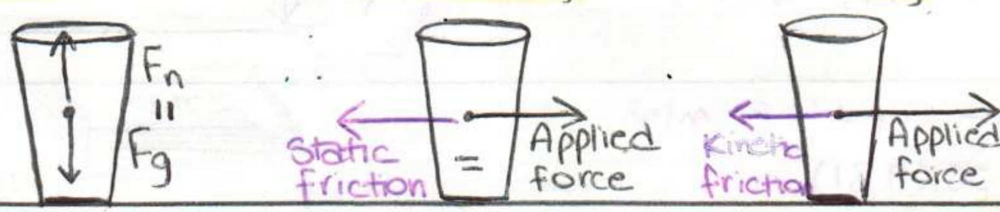
in absen[ce] of net forc[e] $F_n = F_g$

→ Here $F_n = mg\,co$[s]

Static friction – the force that stops the object (stationary) from moving when in contact with a surface.

Kinetic friction – the force that opposes motion of a moving objec[t] that is in contact with a surface.

Equilibrium Stationary Moving

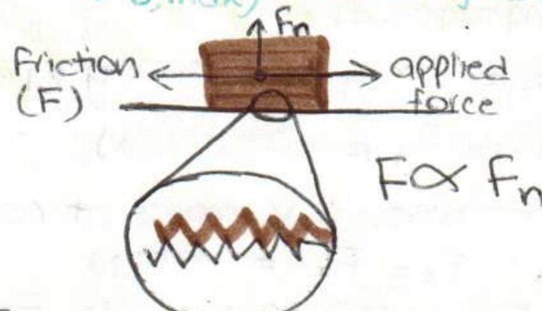


Net force = applied force – kinetic frictio[n]

The highest value of Applied force, for which applied force = stat[ic] friction is called maximum static friction ($F_{s,max}$). Force great[er] than $F_{s,max}$ can accelerate an object.

Static friction ≥ Kinetic friction.

Because when not moving, surfaces of 2 objects stick together at microscopic level due to electrostatic forces.

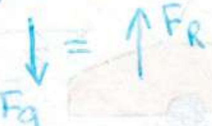


$F \propto F_n$

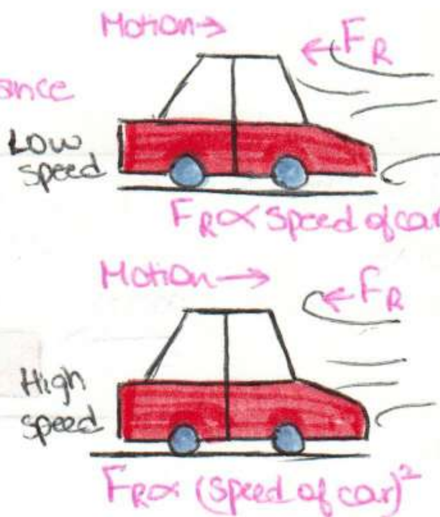
AIR RESISTANCE

F_R – force of air resistance

This also occurs when a object falls to ground.



Then object reaches constant max speed



Force of friction also depen[ds] on type of surfaces in contact when F_n is same, rougher surface provides more frictio[n]

Coefficient of friction (μ) exp[resses] this relation between 2 surfaces in contact.

$$\mu = \frac{\text{Force of friction } (F_F)}{\text{normal force } (F_N)}$$

FORCE WORKSHEET

F_A = applied force, F_N = normal force, F_F = force of friction, F_g = force due to gravity

Mass(m) = 17.3 kg F_A = 127 N

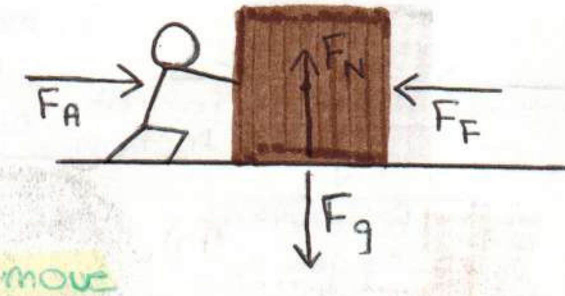
μ = 0.569

$F_F = \mu F_N$ & $F_N = F_g = W = ma_g$

$F_N = ma_g = 17.3 \times 9.81 = 170.\text{ N}$

$F_F = \mu F_N = 0.569(170.) = 96.7\text{ N}$

Because $F_A > F_F$, box will start to move



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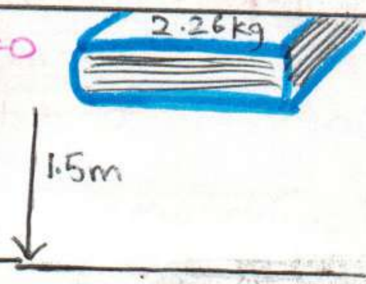
m = 2.26 kg distance(d) = 1.5 m $V_f = ?$ $V_i = 0$

$V_f^2 = V_i^2 + 2ad$ $a = a_g = 9.81\text{ m/s}^2$

$V_f^2 = 0^2 + 2(9.81)(1.5)$

$V_f^2 = 29 \Rightarrow \sqrt{V_f^2} = \sqrt{29}$

$V_f = 5.4\text{ m/s}$



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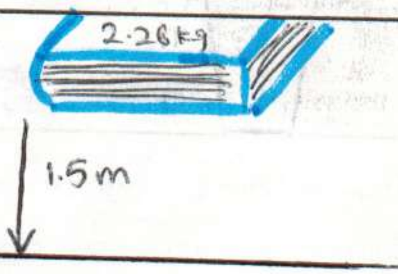
m = 2.26 kg $a = a_g = 9.81\text{ m/s}^2$

$W = ma_g = 2.26(9.81)$

W = 22.2 N



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m = 1260 kg

$F_g = ma_g = 1260 \times 9.81 = 124 \times 10^2\text{ N}$

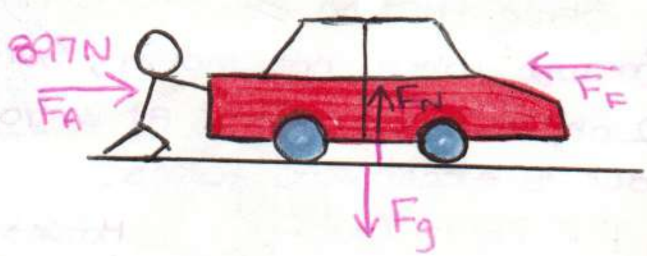
$F_N = F_g = 124 \times 10^2\text{ N}$

Because car moves at contant velocity

$F_A = F_F = 897\text{ N}$

$F_F = \mu F_n$ $\therefore \mu = \frac{F_F}{F_N}$

$\mu = \frac{897}{124 \times 10^2} = 0.0726$



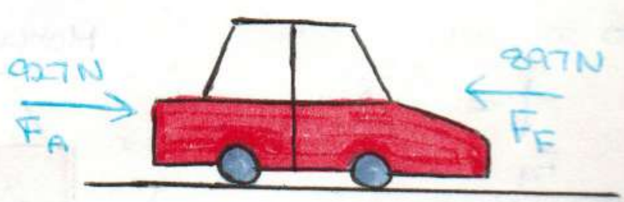
F_A = 927 N F_F = 897 N m = 1260 kg

Net force = 927 − 897 = 30 N

F = ma

30 = 1260 a

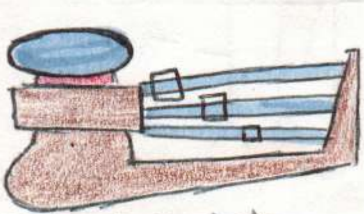
$a = \frac{30}{1260} = 0.02\text{ m/s}^2$



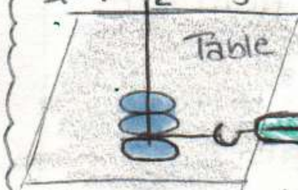
FRICTION LAB

Question – Can you identify and prove some of the factors that increase or decrease friction?

Evidence – We take mass of an object and then pull it using a scale at a constant velocity to get the approximate force of frict



#1 weight hanger on table



$m = 44.95g$

$F_{FS} = 0.55N$

$F_{fk} = 0.48N$

$\mu_s = 0.125$ $\mu_k = 0.109$

#	F_{FK}
1	0.5N
2	0.5N
3	0.5N
4	0.45N
5	0.45N
Avg.	0.48N

#2 Small metal plat on table (rough

$m = 788.4g$

$F_{FS} = 1.70N$

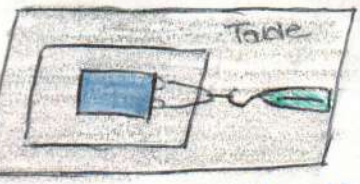
$F_{FK} = 1.48N$

$\mu_s = 0$

$\mu_k = 0$

#	F_{FK}
1	1.50N
2	1.40N
3	1.50N
4	1.50N
5	1.50N
Avg.	1.48N

#3 Small metal plate taped to sheet protector



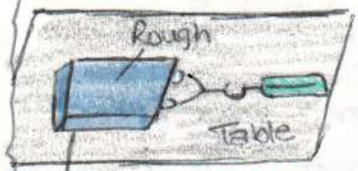
#	F_{FK}
1	1.90N
2	1.80N
3	1.90N
4	1.80N
5	1.90N
Avg.	1.86N

$m = 804g$ $\mu_s = 0.330$

$F_{FS} = 2.6N$ $\mu_k = 0.236$

$F_{FK} = 1.86N$

#4 Small metal plate on table (smooth)



#	F_{FK}
1	1.0N
2	0.95N
3	1.0N
4	1.0N
5	1.05N
Avg	1.0N

$m = 788.4g$

$F_{FS} = 1.1N$ $\mu_s = 0.142$

$F_{FK} = 1.0N$

$\mu_k = 0.130$

#5 White board fa down on table

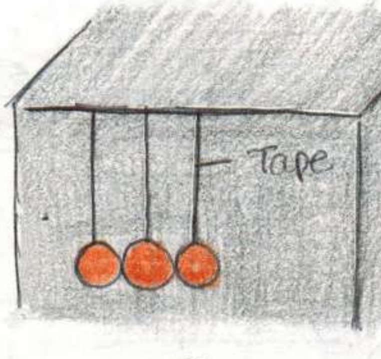
$m = 361.5$

$F_{FS} = 1.3$

CLAIM Based on this lab investigation, I can say that amount of surface area of objects in contact and roughness of objects

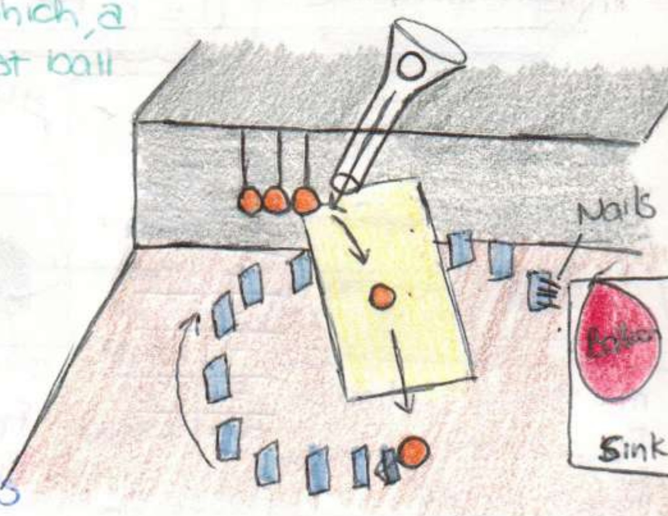
RUBE GOLDBERG DAY-2

Problem – To make a Newton's cradle out of ping pong balls and use a ping pong ball to move it and have this ping pong travel down the ramp.



Evidence – We did not have string, so we used tape to suspend 3 ping pong balls from the side counter.

- These balls act as a Newton's cradle, we actually plan to use 5 balls to make it.
- Then we made a funnel through which a ping pong ball would travel & hit first ball on newton's cradle.
- Then this ball will travel down a ramp to hit dominoes.
- Dominoes fall and the last one has a nail which falls onto a balloon in the sink.



Claim – We were able to set up Newton's cradle and the funnel, also the ball was rerouted onto the ramp.

Reasoning – To make the Newton's cradle work, it is important that all suspended balls are in contact with each other.

- To move the balls in cradle, the ball from funnel must hit the suspended balls with enough force.
- Also, ball from funnel must hit the balls suspend, so that this ball then changes its path and moves down the ramp.

- We will make a path using straws to make sure ball travels down the ramp just the way we want.

Problem for next time – To make sure the ping pong ball travels down the ramp in a way that it hits the dominoes. Then, the last domino must fall with nail hitting the balloon.

PHYSICS TOPICS

MOTION IN 1-DIMENSION

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

Displacement, velocity, & acceleration are important parts of motion.

Moves from rest

All 3 - displacement, vel. & acc are involved

Moving at constant vel.

Displacement & vel. are involved

UNIT 1

NEWTON'S LAWS

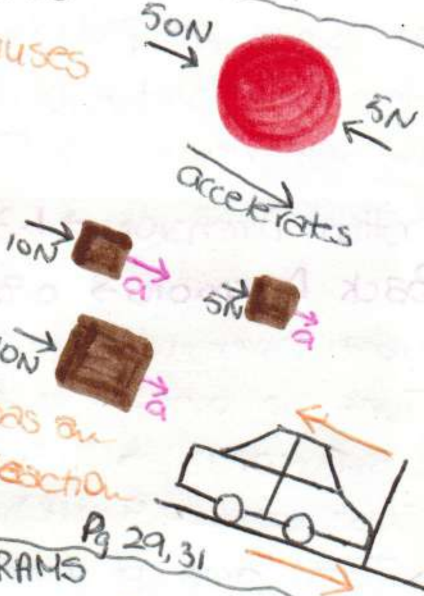
I. A net force causes acceleration

II $a \propto$ Net force

$a \propto \frac{1}{mass}$

$\Rightarrow \Sigma F = ma$

III Every action has an equal & opposite reaction



Pg 29, 31

FORCE SIMULATION

Net Force - sum of forces acting on object

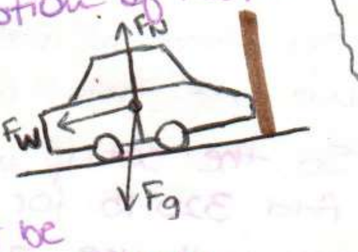
Motion - when an object moves due to net force applied

Friction - a force that opposes motion

Acceleration - change in velocity over time

FORCE DIAGRAMS

These diagrams analyze forces affecting motion of 1 object (Always represented at center of object)



Show all forces

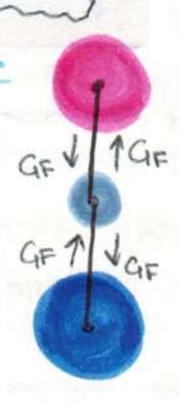
Lengths of arrows must be proportional to magnitude of forces

GRAVITY

NEWTON'S - Every single object in space attracts all other objects.

Gravity $\propto$ mass of obj

Gravity $\propto \frac{1}{d^2}$



EINSTEIN'S GRAVITY

Matter could curve the space time & this is gravity.

FRICTION

Force of friction opposes the applied force.

The objects must be in contact for this force to get involved.

$F_{FS} \geq F_{FK}$

Friction depends on mass of object, roughness of surfaces in contact, & surface area in contact.

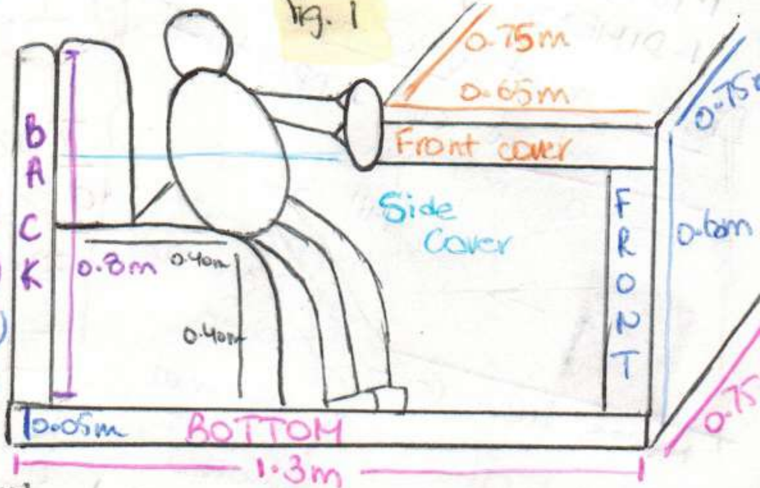
μ represents coefficient of friction

SUMMATIVE TASK

Q– Can you build a ride that hovers in air?

- We would build each cart out of wood and then put rubber on sides as padding
- Here is a sketch of the cart from the side view

Fig. 1



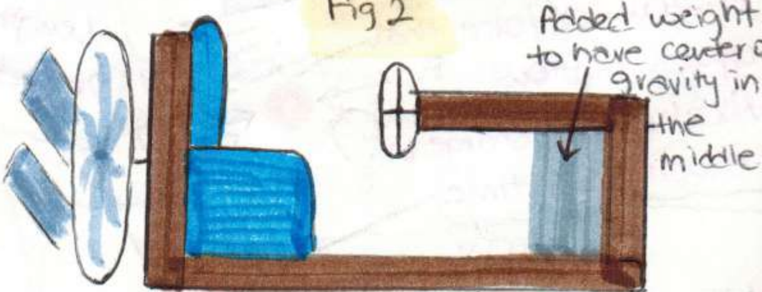
Bottom Dimensions → 1.3 m (l) & 0.75m (w)
Back Dimensions → 0.8m (h) & 0.75 m (w)
Front Dimensions → 0.6m (h) & 0.75m (w)
Front top cover → 0.65m (l) & 0.75m (w)
2 Side covers → 1.3m (l) & 0.60m (h)
Seat → 0.4 m (l), 0.4m (h) & 0.75m (w)

→ Total area of wood required = $4.7 m^2$
We use wood that is 5cm thick.
So volume of wood = $4.7 \times 0.05 = .235 m^3$
we use basil wood which is $170 kg/m^3$

→ So, mass of wood = 0.235×170
= 40 kg
We add another 10 kg for rubber padding, steering wheel & cushions.

So, the set up weighs 50 kg = 110 lb
Add 320 lb for person's mass. Total mass (max) = 430 lb.
We will use a fan and rudder to steer it. That would weigh about 30 lb also we add about 80 lb on front of cart to balance center of gravity (due to person & fan)

Fig 2



We use air boat fan & rudders to steer the boat by using a steering wheel.

So, final mass = 430 lb + 30 + 80
≈ 540 lb ≈ 2400N

Area of bottom of cart = $0.98 m^2$

Pressure = $\frac{2400 N}{0.98 m^2} \approx 2450$ Pa

These pressures can be achieved with pumps available in market.

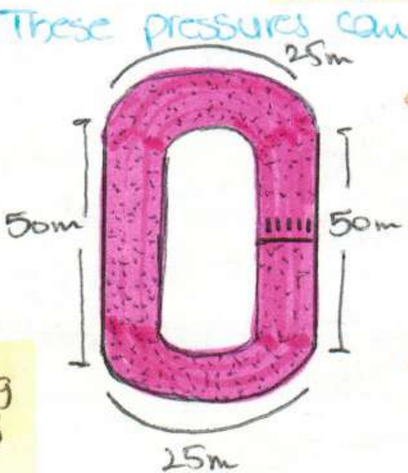


fig 3

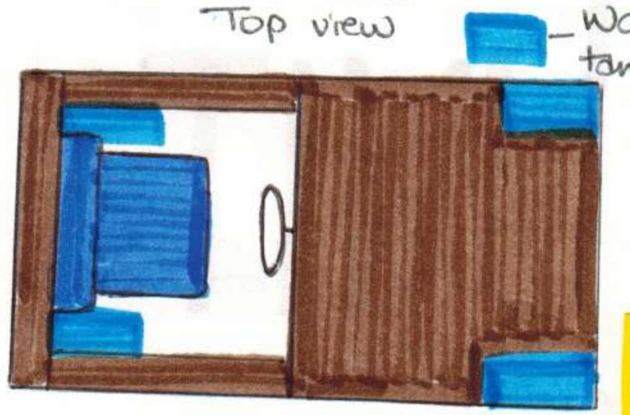
- Next up we will build a race track capable of constantly providing this pressure. It could have upto 5 racers at once.
- Track length would be 150 m & 4 laps (600 m) would be 1 race and on averge it would last 1.5 – 2 mins.
- Pumps under track will give out pressure of 2450 Pa at all times to make cart hover.

TASK REPORT

Q- Can you build a ride that hovers in air?

Claim- I believe that it is possible to build a ride that hovers and can be steered using air boat fan and rudders.

Evidence- On summative task page, we have the design for the carts but there is a flaw. The cart isn't able to have '0' balance. To provide this balance we add 4 water tanks on each corner. When 1 corner gets heavier, it lowers and water is let out to make it lighter.



So, we add to the mass of cart the approximate mass of water used (150 l (at most

Mass of cart = 54.0 lb + 150 lb (water) − 80 lb (static weight we added before)

= 610 lb

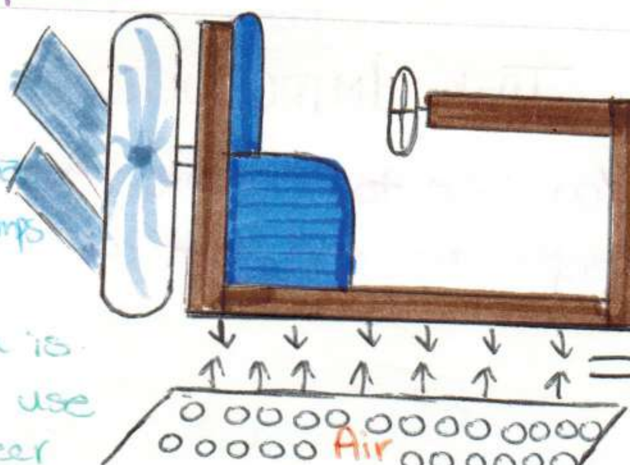
See fig 2 on pg 38

Force = 610 × 4.45 ≈ 2715 N

Pressure (Force / area) = $\frac{2715}{0.98}$ ≈ 2770 pascals

Reasoning- First of all we estimated the pressure required to keep our cart hovering. It comes out to be about 2770 pa. This pressure is achievable using air pumps available in the market.

Next, the cart can be steered as friction is greatly reduced due to air and we can use air boat fan along with rudders to steer the cart. The rudders will be connected to a steering wheel. The fan provides a net force as all other forces have been balanced, which include force due to gravity.



These forces are equal and opposite.

To make the track work, we would place at lot of air pumps under it with a lot of holes which receive uniform air pressure from below (This can be achieved with pipes running under track which have holes at uniform distance and pumps pump air into these pipes)

See fig on pg 3