Forces

Sunday, September 13, 2020 12:37 PM

1.5:
Forces

1.5.1:
Effect of Forces

What is force?

Force is an external factor exerted which may cause a change in the motion of an object.

Effects of force:
1) Change shape
2) Change motion
3) Change size
4) Change direction

Does not change mass.

Hooke's Law:
Hooke's law states that the extension of a spring is directly proportional to the force exerted on it. Hence, we have an equation:

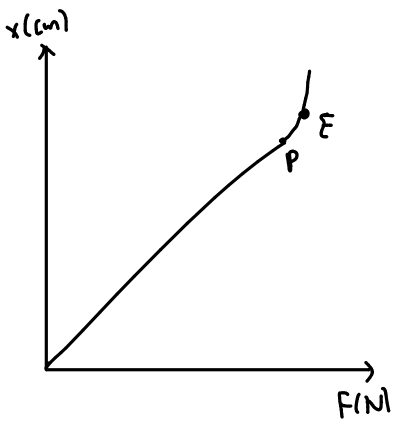
$$F \propto x$$

$$F = kx$$

↳ Spring Constant

$$k = \frac{F}{x} \ (Nm^{-1})$$

The greater the spring constant, the smaller the extension, with the condition that force remains constant.



P: limit of proportionality where F is not equal to kx

Elastic limit: Spring is deformed and will not be able to return to its original shape. A small amount of force will drastically increase its extension.

Newtons' 3 Laws of Motion
1) An object will remain at its state of motion unless an external force acts upon it. An example would be if a car were to travel in constant speed where it is not affected by friction, it will continue moving in constant speed. In real life, the car will slow down due to friction between the surface and the tires. It is also called the Law of Inertia (Inertia is a property an object of mass posses in which it will resist a change in its state of motion. The higher the mass, the larger the effect of inertia)
2) The resultant force of an object is equal to the product of its mass as well as its acceleration. If mass remains constant. Force is also equal to the rate of change in momentum

$$\Sigma F = m \times a$$

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

$$\Sigma F = m\left(\frac{v-u}{\Delta t}\right)$$

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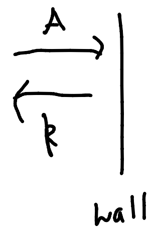
1. Action is equal to negative reaction. (Just like when you are standing, just as Earth is pulling you towards the center of the Earth towards the center, you are also pulling the Earth towards you in equal magnitude but opposite direction

$\Sigma F = m\left(\frac{v-u}{\Delta t}\right)$

$\Sigma F = \frac{m\Delta v}{\Delta t}$

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

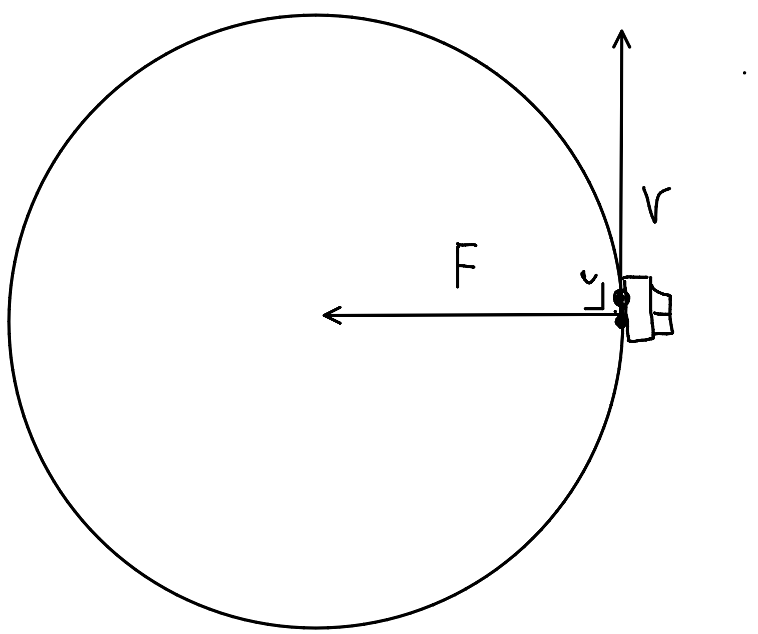


$\Sigma F = 500 - 100$
$= 400$

$acc = \frac{\Sigma F}{m} = \frac{400}{100} = 4 m/s^2$

Forces acting on a body when it is travelling around a circle.

When an object travels round a circle in constant speed, it will still accelerate. This is due to the fact that it is constantly changing direction and acceleration is a vector quantity.



An object will travel in a circular motion if the force of the object is perpendicular to its velocity. The acceleration is towards the center of the circle. The force which keeps the object in circular motion is called centripetal force and it acts towards the center of the circle. If an unbalanced force causes the object to leave its circular motion, they will leave in a direction tangent to the circle.

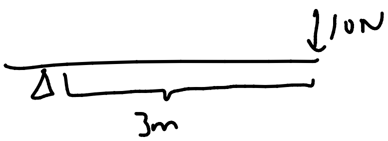
Friction
Two types of Friction:
1) Between surfaces: The frictional force that acts between two surfaces is n~~ot affected by spe~~ed but by the asperity of the surface (how rough/smooth). The friction will always oppose the direction of motion.
2) Air resistance: Proportional to the velocity of the object

1.5.2:

Turning effect

The moment of a force is the measure of its turning effect. Take an example of your door knob or a see saw.

Moment of force is equal to the product of force and **perpendicular distance** to the pivot.



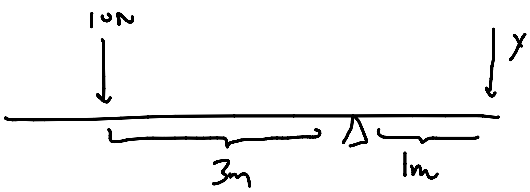
$= 10 \times 3$

$= 30\,Nm$ (Clockwise)

1.5.3:
Conditions for Equilibrium
If the distance or the force increases, moment of force increases. For a body to be in equilibrium, its resultant force and resultant moment of force must be equal to zero.

Principle of Moments:
If resultant moment is equal to 0:

Clockwise moment = Anti - clockwise moment



$10 \times 3 = x \cdot 1$

$x = 30N$

1.5.4:
Centre of Mass

It is the point of an object where its mass seems to be concentrated at. Hence, center of mass affects stability. The larger the base area and the shorter the height, the more stability. This is why NBA players widen their stance and lower their height when defending.

Center of mass of lamina:
1) Push pin through point on edge of lamina and allow the swing freely.
2) Mark vertical line
3) Repeat for a second time with another pin on another edge point
4) Mark where both vertical lines intersect

1.6:
Momentum

Momentum is the product of mass and its velocity.

$p = m \times v$

$p = kgm/s$

Law of conservation of momentum:

Momentum before collision is equal to momentum after collision.

Eg:
If a car, mass 1250kg, travels at a speed of 35m/s towards East collides with a car with same mass but travelling at the opposite direction with speed of 15m/s, what is the final velocity.

1250 x 35 + 1250 x (-15) = (1250 x 2) x V

V = 10m/s towards the East

Impulse:
Impulse can be defined as a large force acting on a body for a short period of time or small force acting on a body for a small period of time.

Impulse is equal to the change in momentum.

Since mass cannot change, change in momentum is equal to mass x change in velocity.

$$I = \Delta p$$

$$\left(\Sigma F = m \times \frac{\Delta v}{\Delta t} \right) \times \Delta t$$

$$\Delta p = m \times \Delta v$$

$$\Sigma F = m \times a$$

$$\Sigma F \times \Delta t = \underbrace{m \times \Delta v}_{\Delta p}$$

$$\text{Impulse} = F \times \Delta t$$

1.7:
Energy, Work and Power

1.7.1:
Energy

Energy is defined as the ability to do work. There are different forms of energy.

Law of Conservation of Energy:
Energy cannot be destroyed or created but only converted to one form or another.

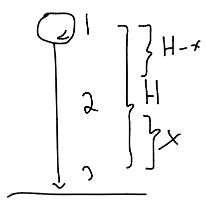
Energy due to Motion is called Kinetic energy and energy due to position of an object is Potential Energy.

Types of Energy:
1) Kinetic energy = $\frac{1}{2}mv^2$
2) Gravitational Potential = $mg\Delta h$
3) Chemical Potential energy -- Energy stored which can be released during a chemical reaction
4) Sound energy -- Energy that travels in the form of waves
5) Light energy -- Energy carried by electromagnetic radiation (discussed further in Waves chapter)
6) Electrical energy -- Energy carried by electrical current
7) Strain energy -- Energy stored in an object that is being stretched
8) Nuclear energy -- stored energy released by nuclear reaction of radioactive substances
9) Internal energy -- Sum of potential energy and kinetic energy

Mechanical energy of a system remains constant throughout.

Mechanical energy is the sum of potential and kinetic energy.

Take an example of a ball dropped from rest.



At 1, $E_k = \frac{1}{2}(m)(0)^2 = 0$

$E_p = mgH$

$T = 10mH$

At 2, $E_k = \frac{1}{2}mv^2$

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

$v^2 = 2(10)(H-x)$

$= 20(H-x)$

$E_k = \frac{1}{2}m(20(H-x))$

$= 10m(H-x)$

$E_p = mg\Delta y$

$= m(10)x$

$= 10mx$

At 3

$E_p = 0$

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

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

$v^2 = 2(10)(H)$

$= 20H$

$E_k = \frac{1}{2}m(20H)$

$10mH$

$T = 10m(H-x) + 10mx$

$T = 10mH$

1.7.2:
Energy Resources

Energy Resource	Description	Energy Transfer
Wind	Wind turbines can be used to produce electricity	KE (wind) → KE (turbine) → Electrical
Water	Hydroelectric and Tidal power use the GPE of water to turn turbines which generate electricity	GPE → KE(water) → KE (turbines) → Electrical
Geothermal	Heat from underground can be used to create steam, which spins turbines producing electricity.	Heat → KE → Electrical
Solar Heating	Light from the sun can be used to warm water passing through black pipes.	Light → Heat
Solar Cells	Photovoltaic cells can use light to create electricity	Light → electrical
Fossil fuels	Burning fossil fuels produces steam, which can turn turbines	Chemical → Heat → KE → Electrical
Nuclear	Nuclear fuel is reacted, producing heat which creates steam	Nuclear → Heat → KE → Electrical

https://www.savemyexams.co.uk/igcse-physics-edexcel-new/revision-notes/energy-resources-electricity-generation/energy-resources/

Energy Resource	Renewable?	Advantages	Disadvantages
Wind	Yes	Produces no greenhouse gases or pollution. Land can still be used for farming.	Not reliable. Can be noisy and ugly. Not everywhere is suitable.
Water	Yes	Hydro is reliable and can produce large amount of energy at short notice. Produces no pollution of greenhouse gases.	Tidal is not reliable (but is predictable). Can involve flooding large area, destroying important wildlife habitats. Very few suitable sites.
Geothermal	Yes	Reliable. Geothermal stations are usually small.	Can result in the release of harmful gases from underground. Not many places are suitable.
Solar Heating	Yes	Produces no greenhouse gases or pollution.	Not reliable (only works when sunny).
Solar Cells	Yes	Produces no greenhouse gases or pollution. Good for producing energy in remote places.	Not reliable (only works when sunny). Solar farms can use up lots of farmland.
Fossil fuels	No	Reliable. Can produce large amounts of energy at fairly short notice.	Produces significant greenhouse gases and pollution.
Nuclear	No	Reliable. Produces no greenhouse gases or pollution. A large amount of energy is produced from a small amount of fuel.	Produces dangerous radioactive waste that can take thousands of years to decay.

Useful Energy:

It is the percentage at which the amount of input energy is converted to useful energy. The higher the percentage, the more efficient the system is.

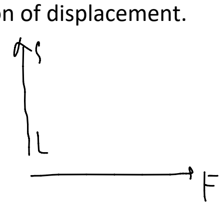
$$\text{Efficiency}(\%) = \frac{\text{Useful Energy}}{\text{Total Input Energy}}$$

Energy can be replaced with Power

1.7.3:
Work done

Work done is the product of force along the direction of displacement.

Hence,



$W = Fs$

In Higher level, $W = Fs\,[\cos\theta]$

But in IGSE, $\cos\theta$ is 1

as $\vec{F}$ and $\vec{s}$ is in

$W = Fs\,(\underbrace{\cos 90}_{0})$

$W = 0$

as $\vec{F}$ and $\vec{s}$ is in the same direction

$W = 0$

$\longrightarrow F$ $\quad W = Fs(\cos(180°))$

$\longrightarrow s$ $\quad = Fs(1)$

In $\parallel$, W is $\uparrow$

1.7.4:
Power

Power is defined as the rate of change in work done.

$$P(W) = \frac{W(J)}{t(s)}$$

Take note that W is energy. Do not assume it is always equal to Fs.

Hence →

$P \propto W$

$P \propto \frac{1}{t}$

Take an example where an electronic heater is being switched on. Its power depends on the work done as well as time that has elapsed. Assuming that power is constant, the longer it is being switched on, the more work the heater does.

Another example is a conveyor belt. Assuming time is constant, if the distance of the belt is decreased, work done required will decrease and hence, power consumed by the machine will subsequently decrease.

1.8:
Pressure

Pressure is defined as the force acting per unit area. This is an important concept as it explains very realistic day to day scenarios. You would probably grunt if your feet is stepped by a man with flat shoes. You would not just grunt if it is replaced with heels, would you.

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

$P \propto F$

$P \propto \frac{1}{A}$

Hence, if force is to remain constant, the smaller the area, the larger amount of pressure is exerted. This beautifully explains why a magician can sleep on a bed of nails and not be pierced. The pressure exerted by these nails are all distributed around his body. This would not be the case if there was just one nail.

The equation above is mainly applicable for solids. In order to measure the pressure exerted by a liquid, a different formula is used. The derivation shown below is optional but aids with understanding.

$P = F$ $\quad F = mg$

a different formula is used. The derivation shown below is optional but aids with understanding.

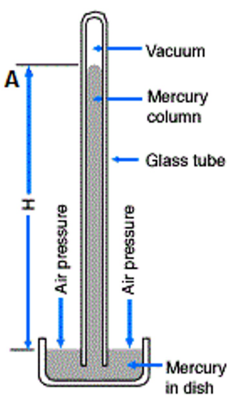
$$P = \frac{F}{A} \qquad F = mg \qquad \rho = \frac{m}{V} \qquad V = A \times h \qquad P_l = \rho g h$$

$$P = \frac{mg}{A} \qquad P = \frac{\rho V g}{A} \qquad P = \frac{\rho A h g}{A}$$

With the formula above, it can be concluded that the pressure exerted by liquids are only affected by the 3 variables shown. This is why the deeper you go down the pool, the more uncomfortable you felt. Take note that the unit is still Pascals or N/m^2.

When larger amounts of pressure is being represented, atp is used. It stands for atmospheric pressure. This is the pressure exerted upon a body of mass right above sea level. This is due to all the fluids above us.

In order to measure atmospheric pressure, a barometer is used.



Height can be found with the equation above.

$P = \rho g h$ density of mercury

$101325\ Pa = 13600(10)(h)$

$h = 0.745m$ Usually its 0.76 m in most TB

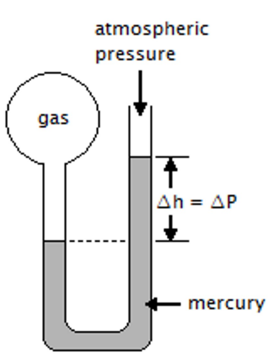
↳ This may change in different parts of the world as g will slightly change as well as atp

https://starguyblog.wordpress.com/2015/08/11/forces-and-pressure/

Important detail:

1) Above mercury is vacuum
2) Take note where the H is measured from and to
3) Mercury is used as it does not stick to the walls of the instrument as well as its very dense. Using water would require a 10m tall instrument.

Another handy instrument is called a manometer. It is used to measure pressure exerted by a gas.



Again, mercury is used with the reasons already listen above. The important thing to understand here is that the mercury is affected by 2 factors. Pressure of the gas as well as atmospheric pressure. Now, a little logic comes into play. The side with atp is taller. This tells that the pressure of the gas is greater compared to atp. Hence, we can say that the change in height of the mercury is equal to the change in pressure. This change in pressure is excess pressure supplied by the gas. To calculate total pressure, add atp.