physics

CONTENT CHECKLIST (FROM TEXTBOOK)

GRAVITY & MOTION
- the force due to gravity
- motion in a gravitational field
- equilibrium of forces

ELECTROMAGNETISM
- electric fields
- magnetic field & force
- magnetic field & emf

UNIT 3

WAVE-PARTICLE DUALITY & THE QUANTUM THEORY
- wave-particle duality & the quantum theory

SPECIAL RELATIVITY
- special relativity

THE STANDARD MODEL
- the standard model

UNIT 4

TIPS FOR SOLVING PROJECTILE MOTION QUESTIONS

pg. 47 pearson

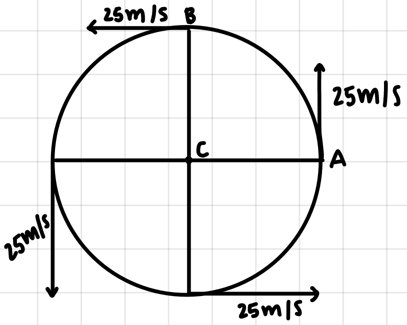
1. construct a diagram showing the projectile's motion to set the problem out clearly. write out the information supplied for the horizontal and vertical components separately
2. in the horizontal direction, the velocity, v, of the projectile is constant, so the only formula needed is $v_{av} = \frac{s}{t}$
3. in the vertical direction, the projectile is moving with a constant acceleration ($9.8 m/s^2$ down), and so the equations of motion for uniform acceleration must be used. These include:

   $v = u + at$

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

   $v^2 = u^2 + 2as$
4. in the vertical direction, it is important to clearly specify whether up or down is the positive or negative direction. Either choice will work just as effectively. The same convention needs to be used consistently throughout each problem
5. if a projectile is launched horizontally, its horizontal velocity throughout the flight is the same as its initial velocity
6. Pythagoras' theorem can be used to determine the actual speed of the projectile at any point
7. if the velocity of the projectile is required, it is necessary to provide a direction with respect to the horizontal plane as well as the speed of the projectile

TEXTBOOK NOTES - CIRCULAR MOTION IN A HORIZONTAL PLANE



← hammer throw event
w/ constant speed of 25m/s
as it travels in the circular path:
↳ speed is constant
↳ velocity is constantly changing (vector)
velocity @ any instant = tangential to the path

PERIOD + FREQUENCY

$f = \frac{1}{T}$ ← Hz $T = \frac{1}{f}$ ← s

SPEED

circumference = $2\pi r$ per revolution

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{period}}$$

$$v = \frac{2\pi r}{T}$$

(v in m/s, r in m, T in s)

WORKED EXAMPLE 1

wind turbine, 55m long, f=20 revolutions/minute
find v of tips of blades answer in km/h

① calculate period (T)

$\frac{20}{60} = 0.33\text{ Hz}$

$T = \frac{1}{f} = \frac{1}{0.33} = 3s$

② sub r + T into the formula for speed, solve for v

$$v = \frac{2\pi r}{T} = \frac{2\pi(55)}{3} = 115.2\text{ m/s}$$

③ convert m/s → km/h

115.2×3.6
$= 415\text{ km/h}$

CENTRIPETAL ACCELERATION

since velocity is changing, it is accelerating
- the object is continually deviating inwards from its straight-line direction & so has an acceleration towards the centre
  ↳ this is centripetal acceleration

$a = \frac{v^2}{r}$ $v = \frac{2\pi r}{T}$

$$a = \frac{v^2}{r} = \frac{2\pi r^2}{T} \times \frac{1}{r} = \frac{4\pi^2 r}{T^2}$$

$$F_{net} = ma = \frac{mv^2}{r} = \frac{4\pi^2 rm}{T^2}$$

F_{net} = centripetal force (N)

WORKED EXAMPLE 2

mass = 7kg, ball is moving at 20m/s, radius = 1.6m
a) calculate the magnitude of the acceleration of the ball

① write variables given
$v = 20\text{ m/s}$
$r = 1.6\text{ m}$
$a = ?$

② find centripetal acceleration w/ the variables you have

$$a = \frac{v^2}{r} = \frac{20^2}{1.6} = 250\text{ m/s}^2$$

b) calculate magnitude of tensile (tension) force in the wire

① identify unbalanced force that is causing the object to move in a circular path

$m = 7kg$

$a = 250 m/s^2$

$F_{net} = ?$

② equation for centripetal force & sub variables

$F_{net} = ma$

$= 7 \times 250$

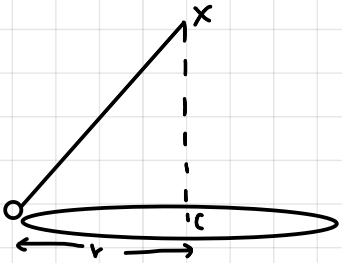
$= 1.75 \times 10^3 N$

③ calculate the magnitude only

- the force of tension in the wire is the unbalanced force that is causing the ball to accelerate

$F_T = 1.75 \times 10^3 N$

BALL ON A STRING



WORKED EXAMPLE

mass 150g, cord = 1.5m, $\theta = 60°$

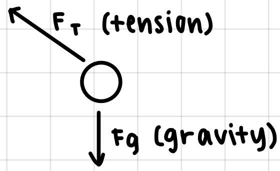
a) calculate radius of the circular path

① centre is not @ the top end but is where the pole is level w/ the ball, use trig to find r

$r = 1.5 \sin(60)$

$= 1.3m$

b) draw & identify the forces that are acting on the ball at the instant shown in the diagram



c) determine the net force that is acting on the ball @ this time

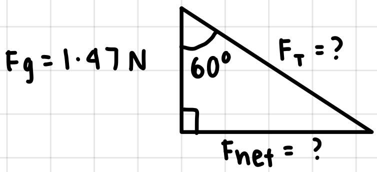
① calculate weight force (F_g)

$= mg$

$= 0.15 \times 9.8$

$= 1.47N$

② the ball has an acceleration that is towards the centre, net force also lies in this direction



$F_{net} = 1.47 \tan(60)$

$= 2.55N$ left

d) find the size of the tensile force

$$F_T = \frac{1.47}{\cos(60)}$$

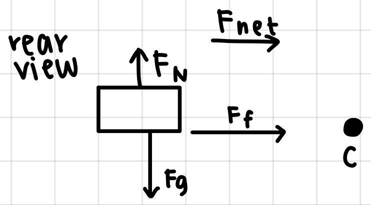
$= 2.94N$

TEXTBOOK NOTES – CIRCULAR MOTION ON BANKED TRACKS

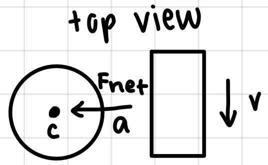
- enables vehicles to travel at higher speeds without skidding

BANKED CORNERS

when cars travel in circular paths on horizontal roads, they are relying on the force of friction between the tyres and the road to provide the sideways force that keeps the car turning in the circular path

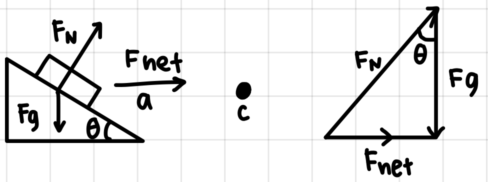


acceleration towards the centre (c)



v = constant speed

normal + reaction forces = balanced
gravity

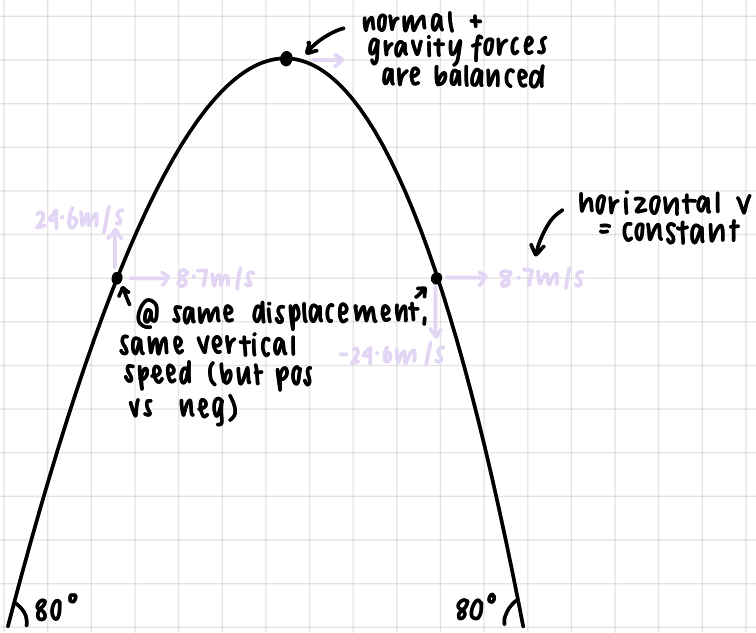


design speed:
the θ @ which the car can travel at a speed so that there is no sideways frictional force
↳ i.e no tendency to drift higher or lower on the track

projectile motion

the horizontal motion of the launched projectile has **NO EFFECT** on its vertical motion (and vice versa)

vertical + horizontal are separate and time is what links them



PROJECTILE MOTION

- if air res is ignored, $\boxed{Fg}$ is the only acting force during flight

vertical component 9·8m/s downwards

can be used to find:
- time of flight
- max height

horizontal component uniform

can be used to find:
- range (horizontal s)
- angle of projection
- initial velocity
- time of flight

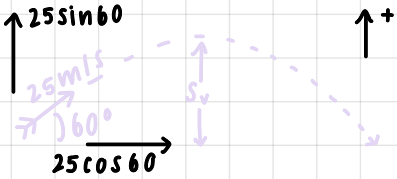
vector components

- horizontal and vertical components must be at right angles ∟
- horizontal = vector $\cos\theta$
- vertical = vector $\sin\theta$
  (θ must be the angle adjacent to the horizontal component

projectile motion examples

TYPE 1 - VERTICAL

$u = 25 m/s$ @ $60°$ to the horizontal



a) VERTICALLY

$v_V^2 = u_V^2 + 2aS_V$

$S_V = \frac{0-(25\sin 60)^2}{2 \times (-9.8)}$

$= 23.9m$

b) $t = 3s$

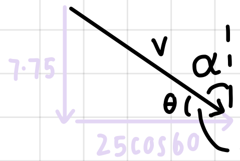
$v_H = 25\cos 60$

$v_V = ?$

VERTICALLY

$v_V = u_V + at$

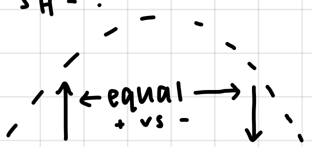
$= -7.75 m/s$



$v = 14.7m/s$

to the horizontal

c) $S_H = ?$



$v_H = 25\cos 60$ $\quad S_V = 0$

VERTICALLY (for t)

$v_V = -25\sin 60$

$v_V = u_V + at$

$t = 4.42s$

HORIZONTALLY

$S = ut$

$= 55.2m$

HORIZONTALLY

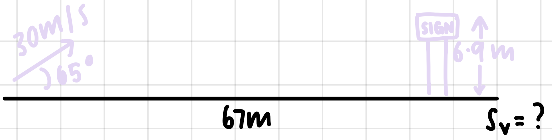
$S = ut + \cancel{\frac{1}{2}at^2}$ — no acceleration horizontally

$\therefore S = ut$

TYPE 2 - HORIZONTAL

$S_H = 67m$ $\quad S_V$ (aiming for) $= 6.9m$

$u = 30m/s$ $\quad \theta = 65°$

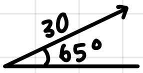


$u_H = 30\cos(65)$

$S_H = u_H t$

$t = \frac{67}{30\cos 65}$

$= 5.28s$



VERTICALLY

$S_V = ?$ $\quad a = -9.8$

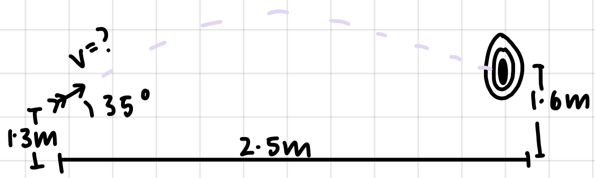
$u_V = 30\sin 65$ $\quad t = 5.28s$

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

$= 6.95m$

(misses by 5cm)

TYPE 3 - COMBINED



$a = -9.8 m/s^2$ $\quad u_H = u\cos 35$

$u = ?$ $\quad u_V = u\sin 35$

$S_H = 2.5m$

$S_V = 0.3m$

HORIZONTALLY

$S_H = u_H t$

$t = \frac{2.5}{u\cos(35)}$

sub into

VERTICALLY

$S_V = u_V t + \frac{1}{2}at^2$

$0.3 = u\sin 35 \times t + \frac{1}{2}(-9.8)t^2$

= combined

$0.3 = u\sin 35 \times \frac{2.5}{u\cos 35} - 4.9\left[\frac{2.5}{u\cos 35}\right]^2$

$\frac{\sin 35}{\cos 35} = \tan 35$

$0.3 = 2.5\tan 35 - 4.9 \times \frac{2.5^2}{u^2\cos^2 35}$

$\underbrace{4.9 \times \frac{2.5^2}{u^2\cos^2 35}}_{30.625} = \underbrace{2.5\tan 35 - 0.3}_{1.451}$

$\frac{30.625}{u^2\cos^2 35} = 1.451$

$21.106 = u^2\cos^2 35$

$u = \sqrt{\frac{21.106}{0.671}}$

$u = 5.6m/s$

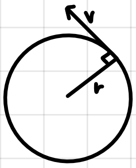
horizontal circular motion

i.e. HCM

3 TYPES

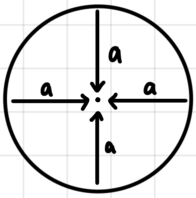
- pendulum
- banked track
- leaning into a bend

$v = \frac{\text{distance}}{\text{time period}} = \frac{2\pi r}{T}$



CENTRIPETAL FORCE

(center-seeking force)



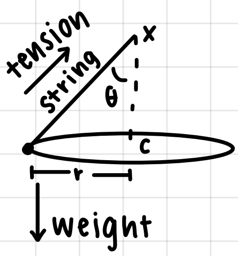
$a_c = \frac{v^2}{r}$

$F_c = ma_c = \frac{mv^2}{r} = \frac{m4\pi^2 r}{T^2}$

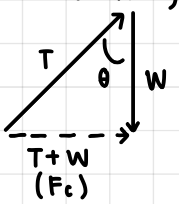
what causes the centripetal force ?

ball on a string - T in string
moon in orbit - gravitational F
electron in orbit - electrostatic F
circling ice skater - N reaction force of ice
racing car turning on banked track - N force of track

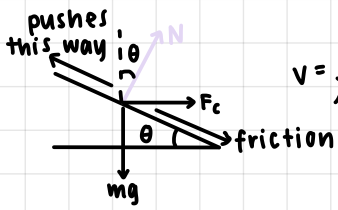
TYPE 1 - PENDULUM

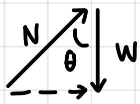


usually given θ to the vertical



TYPE 2 - BANKED TRACK

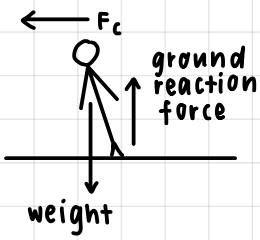




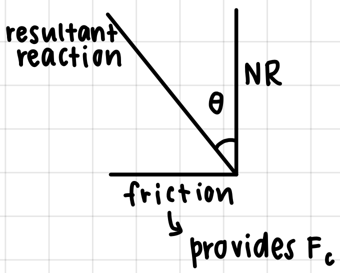
$v = \sqrt{rg\tan\theta}$

↳ get rid of reliance on friction

TYPE 3 - LEANING INTO A BEND



$F_c = F_F$



general steps for solving:

① draw vector diagram

② solve w/ trig
(or can use pythag)

derivations & examples - HCM

$F_c = ma_c$
$= m \times \frac{v^2}{r}$

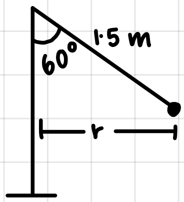
$v = \frac{s}{t}$
$= \frac{2\pi r}{T}$

$v^2 = \frac{4\pi^2 r^2}{T^2}$

$F = m \times \frac{\left(\frac{4\pi^2 r^{\cancel{2}}}{T^2}\right)}{\cancel{r}}$

$F = \frac{4\pi^2 r}{T^2}$

PENDULUM



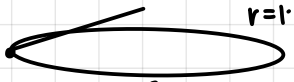
a) $r = 1.5 \sin 60$
$= 1.3\text{m}$

c) $F_c = ?$
$\tan(60) = \frac{F_c}{W}$
$F_c = W \times \tan(60)$
$= mg \tan(60)$
$= 57 \times 10^{-3} \times 9.8 \tan(60)$
$= 0.968\text{N}$ towards centre

d) $T = ?$
$\frac{W}{T} = \cos(60)$
$T = \frac{mg}{\cos(60)}$
$= 1.12\text{N}$

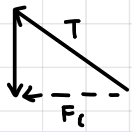
e) $v = ?$
$F_c = \frac{mv^2}{r}$ $F_c r = mv^2$
$v = \sqrt{\frac{F_c r}{m}}$
$v = 4.7\text{m/s}$

PENDULUM EX 2



$r = 1.2\text{m}$
$m = 250 \times 10^{-3}$ $T = 2\text{s}$

a) $v = \frac{2\pi r}{T}$
$= 3.77\text{m/s}$

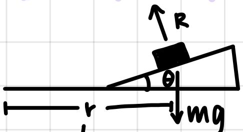
b)


$F_c = \frac{mv^2}{r}$
$= 3\text{N}$

c) $a_c = \frac{v^2}{r}$
$= 12.03\text{m/s}^2$

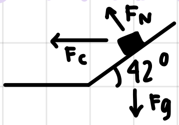
$\tan\theta = \frac{F_c}{W}$
$F_c = W \tan\theta$
$\frac{\cancel{m}v^2}{r} = \cancel{m}g\tan\theta$
$\frac{v^2}{r} = g\tan\theta$
$v^2 = rg\tan\theta$

BANKED TRACK

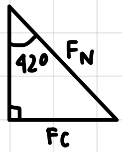


$r = 60\text{m}$
$v = 40\text{km/h}$
$v^2 = rg\tan\theta$
$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$
$= 11.86°$

BANKED TRACK EX 2



$-F_g$

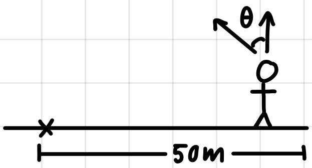


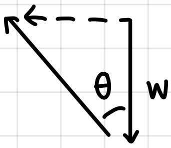
$m = 75\text{kg}$
$r = 50\text{m}$
a) $F_c = W\tan\theta$
$= 75(9.8)\tan(42)$
$= 662\text{N}$

b) $v = \sqrt{rg\tan\theta}$
$= 21\text{m/s}$

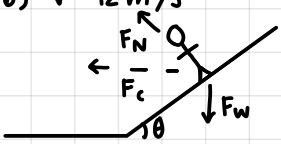
LEANING INTO A BEND

$m = 110\text{kg}$
$r = 50\text{m}$
$F_F = 600\text{N} = F_c$
if F_F, find θ

a)




$\tan\theta = \frac{F_c}{W}$
$\theta = \tan^{-1}\left(\frac{F_c}{W}\right)$
$= 29°$

b) $v = 12\text{m/s}$


design speed

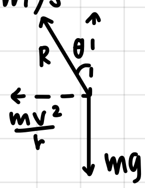
$\theta = ?$
$\tan\theta = \frac{F_c}{W}$
$= \frac{\cancel{m}v^2}{\cancel{m}g}$
$= \frac{v^2}{g}$

$\theta = \tan^{-1}\left(\frac{v^2}{g}\right)$
$= 16.4°$

EXAMPLE

$m = 160\text{t}$, $r = 350\text{m}$, $v = 18\text{m/s}$

a) $a = ?$
$a = \frac{v^2}{r}$
$= 0.926\text{m/s}^2$

b)


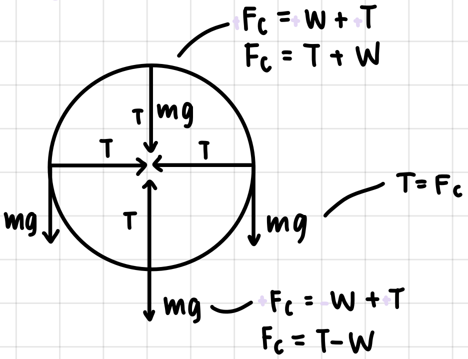
$R = ?$
$\tan\theta = \frac{v^2}{mg}$
$\theta = 5.4°$

$R\cos\theta = mg$
$R = 1.57 \times 10^6\text{N}$

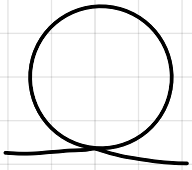
vertical circular motion

i.e. VCM

BALL ON A STRING

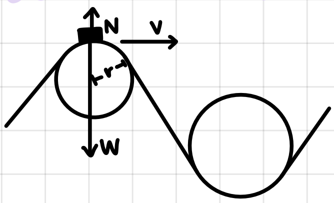


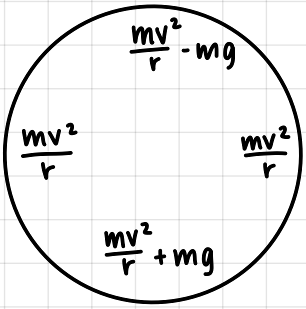
ROLLER COASTER



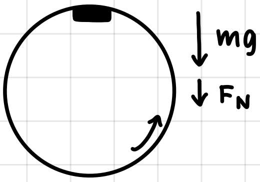
in place of T(tension), R (reaction force from the ground)

ABOVE THE TRACK





WHY YOU DON'T FALL OUT - ROLLERCOASTER LOOPS



normal force = F_c - weight
if $F_c = W$ then you feel weightless
if F_c was a tiny bit less, the cart would be falling off the rail

at this point,
$N = 0$
∴ the rails are no longer pushing on the rollercoaster cart

only by maintaining a high speed can the cart successfully negotiate the loop
↳ go too slow and the cart falls

G - FORCES

$$g_F = \frac{R}{F_g} \quad \text{i.e.} \quad g_F = \frac{N}{T}$$

derivations & examples - VCM

EXAMPLE 1

$m = 0{\cdot}2kg,\ r = 0{\cdot}6m,\ v = 3m/s$

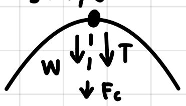
a) $T = ?$

$F_c = W + T$

$T = F_c - W$

$\frac{mv^2}{r} + mg$

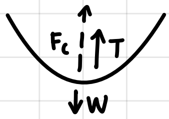
$= 1{\cdot}74N$



$\downarrow +$

$a = \frac{F_c}{m}$

b)



$\uparrow +$

$T = ?$

$F_c = T + (-W)$

$F_c = T - W$

$T = \frac{mv^2}{r} + mg$

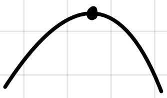
$= 4{\cdot}96N$

EXAMPLE 2

$m = 100g,\ r = 80cm$

a) $f = 2$, find T

$\downarrow +$



T @ top = ?

T @ bottom = ?

$v = \frac{s}{t}$

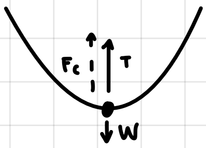
$v = \frac{2\pi r}{T}$ plug into $\frac{mv^2}{r} - mg$

$T = \frac{4m\pi^2 r^{\cancel{2}}}{T^2 \cancel{r}} - mg$

$= \frac{4m\pi^2 r}{T^2} - mg$

$T = 11{\cdot}6N$

b)



max T = 18N

bottom = max tension

$18 = 4\pi^2 mrf^2 + mg$

$= 4\pi^2 \times (0{\cdot}1)(0{\cdot}8) f^2 + 0{\cdot}98$

$f = \sqrt{\frac{18 - 0{\cdot}98}{4\pi^2 \times 0{\cdot}1 \times 0{\cdot}8}}$

$= 2{\cdot}32Hz$ (rotations per second)

EXAMPLE 3

$r = 7{\cdot}5m,\ T = 10s,\ m = 65kg$

a) @ top, find N

$F_c = W + N$

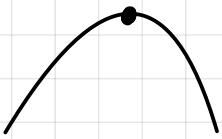
$N = F_c - W$

$= \frac{mv^2}{r} - mg$

$= -444{\cdot}74N$

∴ 444 N up

(down = pos @ top)



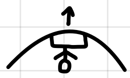
b) $N = F_c + W$

$\frac{mv^2}{r} + mg$

@ bottom find N

$N = 829{\cdot}26N$ up

$F_n = \frac{mv^2}{r} - mg$



$0 = \frac{mv^2}{r} - mg$

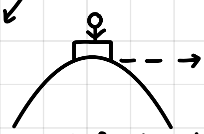
to solve for max. speed

$\frac{\cancel{m}v^2}{r} = \cancel{m}g$

$v^2 = rg$

$v = \sqrt{rg}$

weightlessness



any faster & you would fly off

max to not become a projectile

min to clear upside-down section

EXAMPLE 4

$r = 22m$, find min. v as it enters the loop

@ top:

$v^2 = rg$

$v = \sqrt{22 \times 9{\cdot}8}$

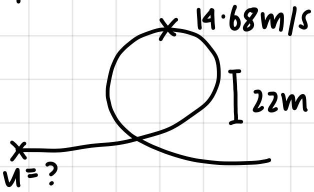
$= 14{\cdot}68$

$KE = KE + PE$

$\frac{1}{2}\cancel{m}u^2 = \frac{1}{2}\cancel{m}v^2 + \cancel{m}gh$

$u = \sqrt{\frac{0{\cdot}5 \times 14{\cdot}68^2 + 9{\cdot}8 \times 44}{0{\cdot}5}}$

$= 32{\cdot}8m/s$



$h = 44m$

GRAVITATIONAL FIELDS + SATELLITE MOTION

fundamental forces
- strong
- weak
- electromagnetic
- gravitational

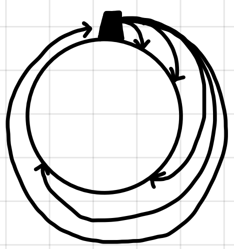
$$F_g = \frac{GMm}{r^2}$$

- gravitational force (N)
- mass of 1 object (kg)
- mass of other object (kg)
- distance between centres of mass (m)
- gravitational constant ($6 \cdot 67 \times 10^{-11}$ $N \cdot m^2 \cdot kg^{-2}$)

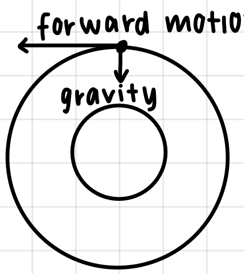
or $\boxed{F_g = G\frac{m_1 m_2}{r^2}}$

GRAVITATIONAL FORCE $= \frac{1}{d^2}$ (inverse square law)

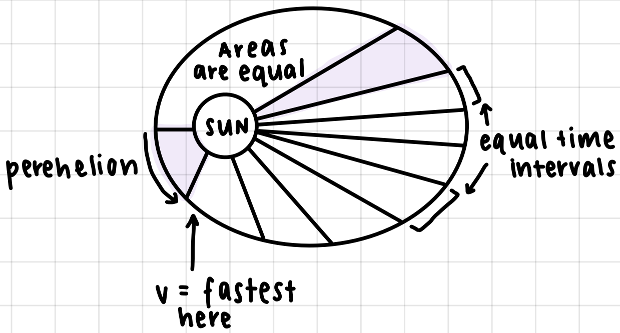
SATELLITE MOTION



$F_c = F_g$



geosynchronous satellite
over the same place always
(T of 24 hours)



KEPLER'S 3rd LAW

$$\frac{\cancel{m}v^2}{r} = \frac{G\cancel{m}M}{r^2}$$

$$\frac{4\pi^2 r^{\cancel{2}} \cancel{m}}{T^2 \cancel{r}} = \frac{G\cancel{m}M}{r^2}$$

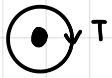
$$\frac{4\pi^2}{T^2} = \frac{GM}{r^3}$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$ constant value

orbital r

O---O

orbital T



$v^2 = \frac{GM}{r}$

$$\boxed{\frac{r^3}{T^2} = \frac{r^3}{T^2}}$$

how fast must a satellite be travelling in order to remain orbiting @ a particular height?

$$\frac{mv^2}{r} = G\frac{Mm}{r^2}$$

$$v^2 = \frac{GM}{r}$$

derivations - satellites/ gravitational fields

$$F = \frac{GMm}{r^2}$$

$$ma = \frac{GMm}{r^2}$$

$$g = a = \frac{GM}{r^2}$$

$$F_c = F_g$$

$$\frac{\cancel{m}v^2}{\cancel{r}} = G\frac{M\cancel{m}}{r^{\cancel{2}}}$$

$$v^2 = \frac{GM}{r}$$

$$v = \sqrt{\frac{GM}{r}}$$

$$\frac{mv^2}{r} = \frac{GmM}{r^2}$$

$$\frac{4\pi^2 r^2 m}{T^2 \cancel{r}} = \frac{GmM}{r^2}$$

$$\frac{4\pi^2}{T^2} = \frac{GM}{r^3}$$

orbital r

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

constant value

orbital T

torque

τ

WHAT IS TORQUE?
- turning force
- a 'moment of force' (M)

$\tau = 40 \times 0{\cdot}06$
$= 2{\cdot}4N$

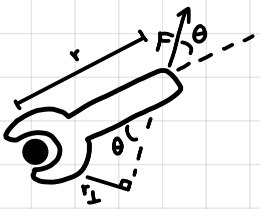
$\Sigma\tau_{cw} = \Sigma\tau_{ccw}$
$F_A \cdot r_\perp = F_m \cdot r_\perp$
$\Sigma F_\uparrow = \Sigma F_\downarrow$
$\Sigma F_\leftarrow = \Sigma F_\rightarrow$

HOW IS IT MEASURED
- magnitude
- direction
- location

$\tau = r_\perp F$ ← perpendicular

greater torque at ↑r

NON-PERPENDICULAR TORQUE

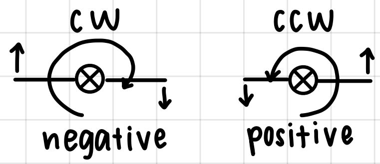


$\boxed{\tau = r\,T\sin\theta}$

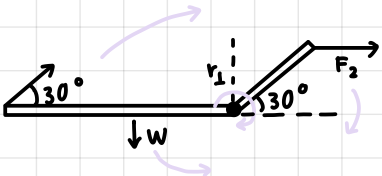
$\sin\theta = \frac{r_\perp}{r}$

$r_\perp = r\sin\theta$

SIGN CONVENTIONS

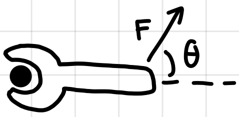


RESULTANT TORQUE

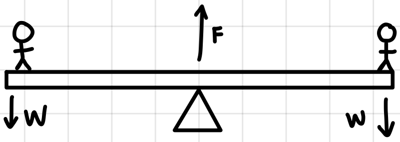


Σ torques = resultant
* make sure + and − are labelled *
ccw cw

DISEQUILIBRIUM vs EQUILIBRIUM

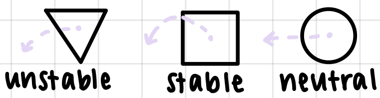


$\Sigma F \neq 0$
$\Sigma\tau \neq 0$

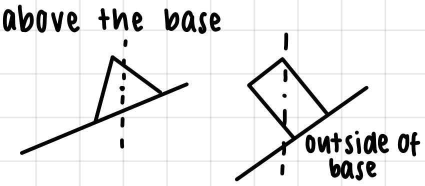


$\Sigma F = 0$
$\Sigma\tau = 0 \ (\Sigma\tau_{cw} = \Sigma\tau_{ccw})$

STABILITY

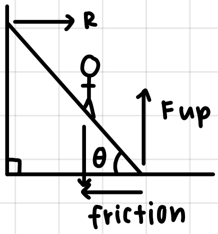


stable = centre of mass is above the base

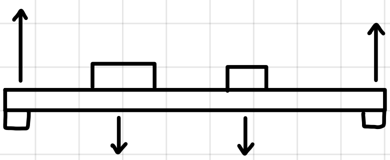


translational equilibrium: $\Sigma F = 0$
rotational equilibrium: $\Sigma\tau = 0$
static equilibrium: $\Sigma\tau = 0$ & $\Sigma F = 0$

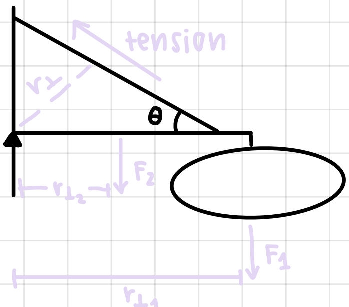
LADDERS
$\Sigma F = 0$, $\Sigma\tau = 0$



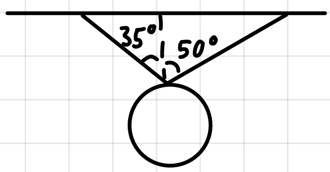
BRIDGES/PLATFORMS



STRUTS + TIES

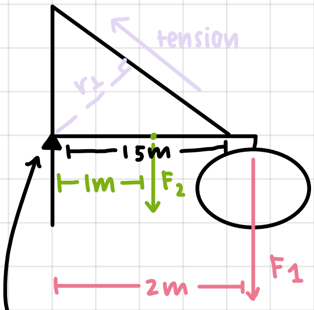


CABLES W/ A LOAD
① $F_\uparrow = F_\downarrow$, $F_\leftarrow = F_\rightarrow$
② sin rule then NFT



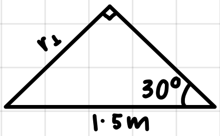
torque examples

STRUTS + TIES



to ignore reaction force

find tension in wire



$\sin(30) = \frac{r_\perp}{1.5}$

$r_\perp = 0.75m$

not rotating

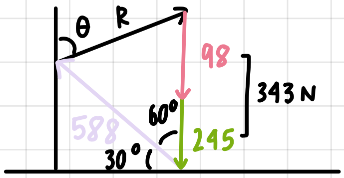
$\therefore \Sigma \tau_{cw} = \Sigma_{ccw}$

$F_1 r_\perp + F_2 r_\perp = T r_\perp$

$T = \frac{(10\times9.8)(2) + (25\times9.8)(1)}{0.75}$

$T = 588N$

reaction force from the wall



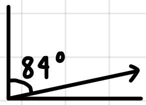
cos rule:

$R = \sqrt{588^2 + 343^2 - 2(588)(343)\cos(60)}$

$= 512\,N$

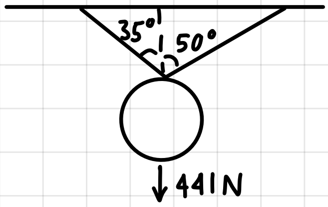
sin rule:

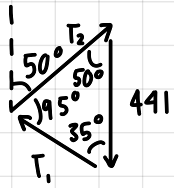
$\frac{\sin A}{588} = \frac{\sin(60)}{512}$



$A = 84°$ from wall

CABLES SUPPORTING A LOAD





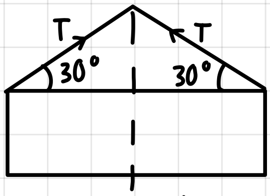
sin rule:

$\frac{\sin(50)}{T_1} = \frac{\sin(95)}{441}$

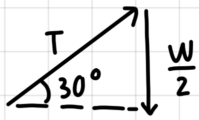
$T_1 = 339\,N$

$\frac{\sin(35)}{T_2} = \frac{\sin(95)}{441}$

$T_2 = 254N$



symmetrical



$T = \frac{w \div 2}{\sin 30}$

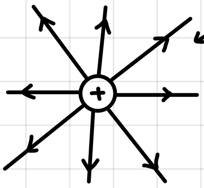
$= 34.3N$

ELECTRIC FIELDS + FORCES

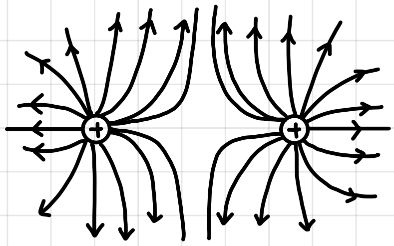
any charged object has a REGION around it - an ELECTRIC FIELD
↳ exerts repulsion or attraction forces

↑ is a vector quantity

FIELD DIAGRAMS

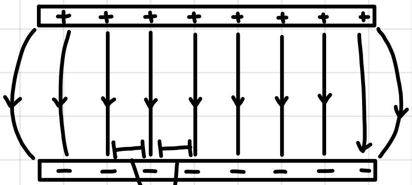


moves in the direction a positive charge would

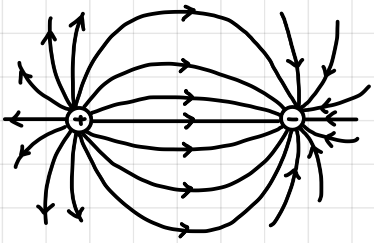


repulsion

charged plates



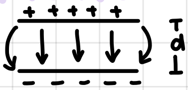
equidistant lines



attraction

EQUATIONS

plates:



electric field strength (NC^{-1})

$$\boxed{E = \frac{F}{q}}$$

Force (N)

electric charge (C)

also expressed as:

$$\boxed{E = \frac{\Delta V}{d}}$$

also through combining:

$$F = \frac{q \Delta V}{d}$$

and to find work:

$$W_d = q \Delta V$$

and since $W = \Delta E$:

$$\Delta E_K = q \Delta V$$

kinetic energy

coulomb's law

$$\boxed{F = \underbrace{\frac{1}{4\pi \varepsilon_0}}_{k} \cdot \frac{q_1 q_2}{r^2}}$$

electric charge (C)

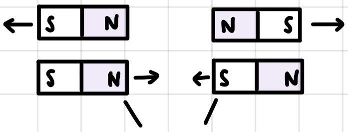
k = coulomb's constant ($9 \times 10^9 \, Nm^2C^{-2}$)

electronic constant/ permeability of free space (see formula sheet)

magnetic fields + forces

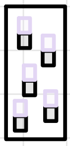
MAGNETISM
- weak force
- from motion of electric charges
- a spinning electron causes a magnetic field around it
- if electrons spin in the same direction (or aren't cancelled by another e⁻) = magnetism

magnets are DIPOLAR (north/south poles)

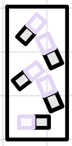


opposites attract

MAGNETIC DOMAINS



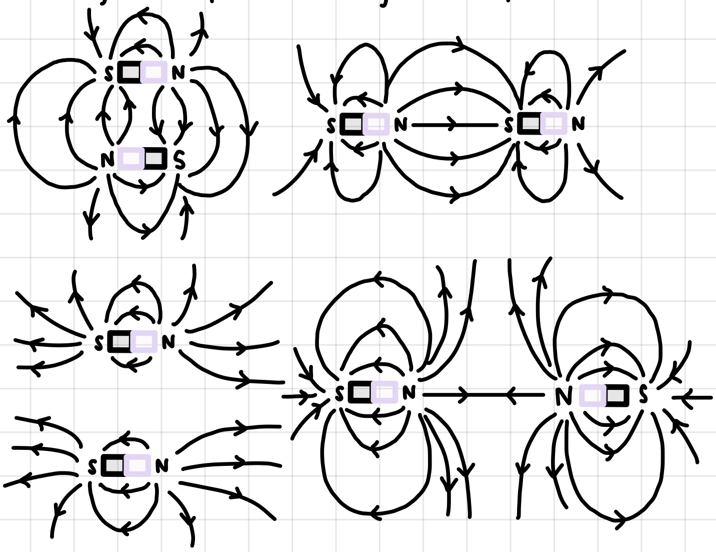
magnet: alignment of magnetic domains



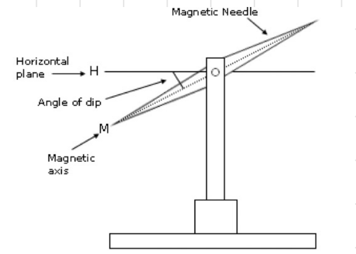
non-magnet: random arrangement of magnetic domains

MAGNETIC FIELD LINES exit north and enter south

magnetic field strength = B , unit = T (Tesla)

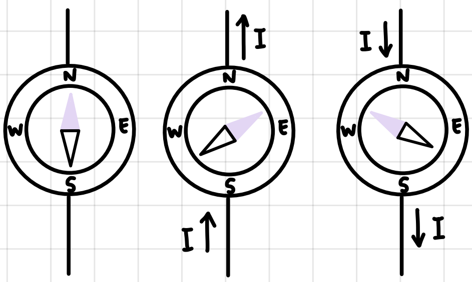


THE EFFECT OF THE EARTH'S MAGNETIC FIELD ON MAGNETS



The angle HOM betw een the horizontal plane HO and the axis of freely suspended magnetic needle MO is Angle of Dip or Inclination.

ELECTRIC CURRENT AND MAGNETS



there is a connection between moving charge + magnetism

MAGNETIC FIELDS DUE TO ELECTRIC CURRENTS

- the wire must be magnetic (must have its own internal magnetic field - attracted or repulsed by the external field)

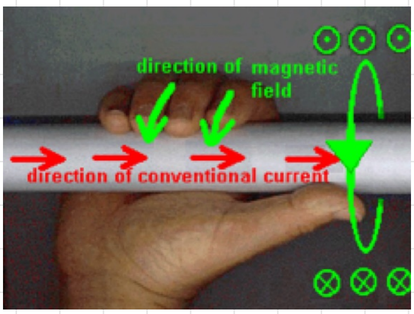
MAGNETIC FIELD CAUSED BY A STRAIGHT CURRENT-CARRYING WIRE

$$B = \frac{\mu_0 I}{2\pi r}$$

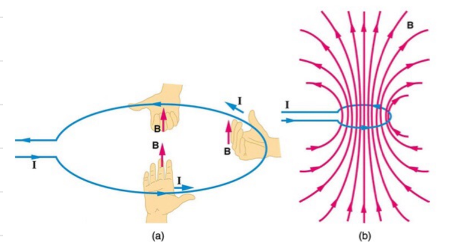
I ← current

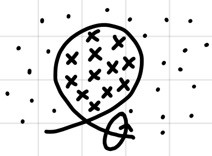
r ← distance from the wire

RIGHT-HAND GRIP RULE

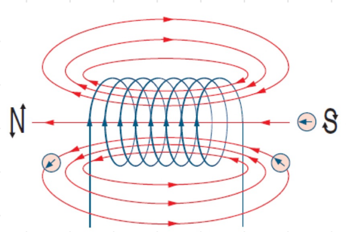


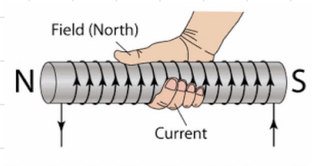
MAGNETIC FIELD IN LOOPS

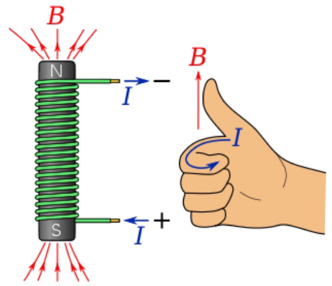




SOLENOIDS AS ELECTROMAGNETS





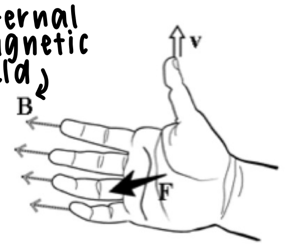


RIGHT HAND RULE

⊙ out of page ⊗ into page

only for positive charges

external magnetic field



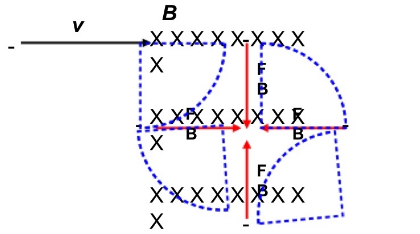
for NEGATIVE CHARGES use left hand

MAGNETIC FORCE ON A MOVING CHARGE

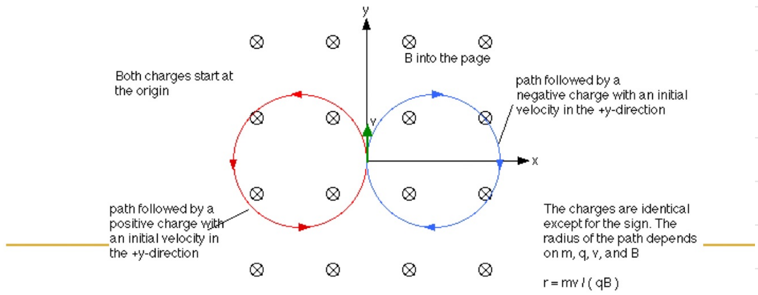
F_B on a moving charge q is ∝ to:
- velocity
- magnetic field

$F = qvB_\perp$ (absolute value)

MAGNETIC FORCE + CIRCULAR MOTION



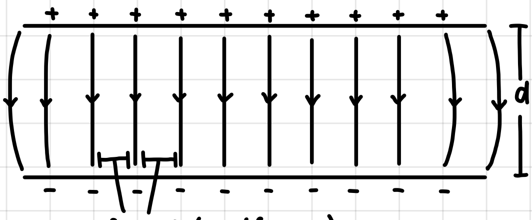
Suppose we have an electron traveling at a velocity , ***v***, entering a magnetic field, ***B***, directed into the page. What happens after the initial force acts on the charge?



$F_B = qvB$, $F_c = \frac{mv^2}{r}$, $F_B = F_c$

$qvB = \frac{mv^2}{r}$ $\quad r = \frac{mv}{qB}$

UNIFORM ELECTRIC FIELDS



$E = \frac{F}{q}$

electric field (NC^{-1})

ELECTRIC FIELDS

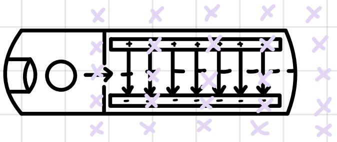
$E = \frac{\Delta V}{d}$

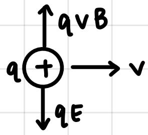
$F = \frac{q\Delta V}{d}$ $\quad W_d = q\Delta V$ (work)

also:

$W = \Delta E \quad \therefore \Delta E = q\Delta V$

MASS SPECTROMETERS





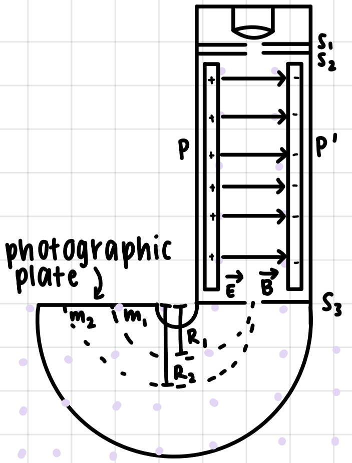
$F_B = F_E$

$E = vB$

$qvB = qE$

$v = \frac{E}{B}$

you want the sample to go STRAIGHT through the plates ∴ need to have an electric field (creating a magnetic field) that CANCELS out the F_E

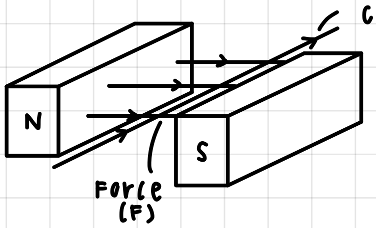


$F_B = F_c$

$qvB' = \frac{mv^2}{r}$

$\frac{q}{m} = \frac{B'v}{r}$

FORCE DUE TO CHARGES MOVING IN A WIRE

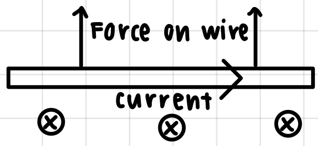


$F_B = qvB\sin\theta \times \frac{t}{t}$

$F_B = \left(\frac{q}{t}\right)(vt)\,B\sin\theta$

$F_B = I\ell B\sin\theta$

note: the MAGNETIC FIELD is produced by some EXTERNAL AGENT



magnetic fields + forces questions

EXAMPLE 1

proton

$v = 1 \times 10^5$ m/s

$B = 55$ mT

when proton moves eastward, magnetic force is a maximum, when moving north, no magnetic force acts upon it

$F_B = ?$

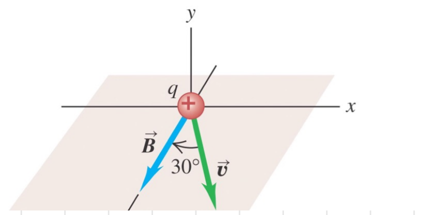
$F_B = qvB$

$F_B = (1.6 \times 10^{-19})(1 \times 10^5)(55 \times 10^{-6})$

$= 8.8 \times 10^{-19}$ N

EXAMPLE 2

Beam of protons (q =+1.6 x 10-19C) moves at 3.0 x 105 m/s through 2.0 Tesla as shown in the diagram below. What is the force on a single proton in the beam?



$= 4.8 \times 10^{-14}$ N

EXAMPLE 3

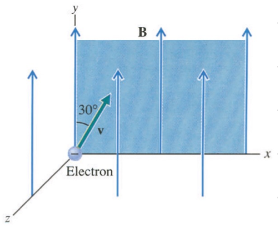
Find the instantaneous acceleration of an electron that is moving at 1.0×10^7 m/s in the *xy* plane, at an angle of 30° with the *y*-axis. A uniform magnetic field of magnitude 10 T is in the positive *y* direction

Solution:
Step 1: Determine Force (F= qvB)
Step 2: Calculate acceleration using F=ma

$F = qvB$
$= 1.602 \times 10^{-19} \times (1.0 \times 10^7 sin30) \times 10$
$= 8.01 \times 10^{-12}\ N$

$a = \frac{F}{m}$
$= \frac{8.01 \times 10^{-12}}{9.11 \times 10^{-31}}$

= 8.8 x 1018 m/s2



EXAMPLE 4

mass $= 2.5 \times 10^{-26}$ kg　　$q = 1.6 \times 10^{-19}$ C

$v = 56,568$ m/s

enters magnetic field 0.5T

$r = ?$

$F_B = F_c$

$qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB}$

$r = \frac{(2.5 \times 10^{-26})(56,568)}{(1.6 \times 10^{-19})(0.5)}$

$= 0.0177$ m

EXAMPLE 5

$I = 100$A

$B = 5 \times 10^{-5}$ T

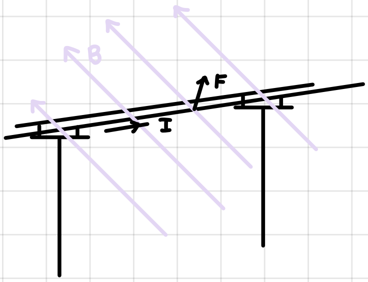
find F/m

$F = nIlB$

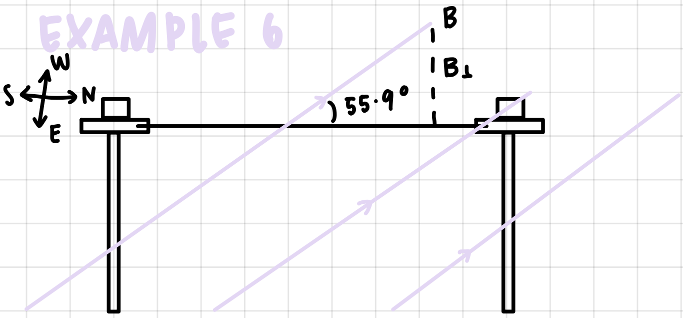
$= 1 \times 100 \times 1 \times 5 \times 10^{-5}$

$= 5 \times 10^{-3}$ N

$\therefore$ $F = 5 \times 10^{-3}$ N per metre of power line



EXAMPLE 6



$I = 3.2$A

$B_\perp = 5 \times 10^{-5} \times \sin 55.9$

$= 4.88 \times 10^{-5}$ T

$F = IlB$

$= 100 \times 1 \times 4.88 \times 10^{-5}$

$= 4.88 \times 10^{-3}$ N

THE MOTOR EFFECT

electrical motors: converts electrical energy to mechanical energy