AP Physics Formula Sheet

Data

Scientific Method
Observation
Define the Problem
Test/Experiment
Hypothesis
Collect Data/Manipulate
Conclusion

Uncertainty
*units (metrics)
* measuring
* sig. figs
* Data
Manipulation

Accuracy vs. Precision
Accuracy – closeness of results to a standard
Precision – closeness of results to each other
use same piece of equipment to collect data

Qualitative vs. Quantitative
Qualitative – more on precision than accuracy
Quantitative – numbers count and are important

Sig. Figs
Addition and Subtraction:
*least # places after decimal

Multiplication
*places after decimal count as sig. figs
2. 5 cm = 1 in

Vectors
Vectors (velocity) – has BOTH *magnitude* and ***direction***
Scalars (speed) – has *magnitude* ONLY
*time, mass, volume

Metric System Abbr.
Mm - km - hm - dkm – m
dm - cm - mm - Mm(E-6) - nm(E-9)

Mult. Component Vectors

1. 18m due S
2. 22m, 47deg. S of W
3. 10 m, 78deg. N of W
4. 30 m due E

*(W&E) Sum of the
$V\chi$= (0) + (-22 cos47) + (-10 cos78) + (30) =12. 9m
*(N&S) Sum of the

$V\chi$= (-18) + (-22 sin47) + (10 sin78) +(0) =-24. 3m

*Resultant υ =
$((12.9)^2 + (24.3)^2)^{1/2} = 27.5\text{m}$
$* \theta = \tan^{-1}(24.3)$
(12.9) = 62.0deg

(12.9) = 62.0deg
R= 28m, 62deg S of E

Kinematics
Displacement
If + it's AWAY
If – it's TOWARD

Velocity (m/s)
Use ONLY when *SPEED* is *CONSTANT*

1. does not include acceleration
2. does not include starting and stopping in the same place
$$v = \frac{\chi}{t}$$

Acceleration (m/s/s)
*speeding up or slowing down
$$\text{a} = \frac{v}{t}$$

Kinematic Formulas

X Direction	***Y Direction***
$\text{v} = \text{v}_0 + \text{at}$	$-\text{gt}$
$\chi = \chi_0 + \text{V}_0\text{t} + \frac{1}{2}\text{at}^2$	$-\frac{1}{2}\text{gt}^2$
$\chi = \chi_0 + \frac{1}{2}(\text{v} + \text{v}_0)\text{t}$	…….
$\text{v}^2 = \text{v}_0{}^2 + 2\text{a}(\chi - \chi_0)$	-2 g(Change $\chi(0 = \text{Y}(0)$

Projectial Motion Half

* Y determines time in air
*compliment angles of 45deg have same range

X	**Y**
$\chi = V\chi t$	$Y = \frac{1}{2}gt^2$
$T = \chi$	
V_χ	

Full

* 45deg has max. range
Steps:

1. $v_0 \cos\theta_0 / v_0 \sin\ \theta_0$
2. Find the TIME (check Y)
3. Find the height / range

X
$\chi = V\chi t$
$(V_X = v_0 \cos\theta_0)$

Y
$t = 2v_0/g$
$(V_0 = v_0 \sin\theta_0$

$$Y = \max = \frac{v_0^2}{2g}$$

Force (N)

-Causes a change in motion (causes acceleration)
-Is a VECTOR quantity

Equilibrium – no acceleration, forces cancel, "at rest"

Newton's Laws of Motion

1. An object at rest will remain at rest until acted upon by an outside force
   INERTIA – directly related to mass
2. Acceleration is *directly* related to *Force indirectly* related to *mass*
   F = m a (1 kg m / s^2 = 1 Newton)
3. Action = equal and opposite reaction -can't have only one force
   F a, b = - F b, a

Normal Force

- able to change until breaking point of whatever it's holding
- acts perpendicularly to "holding" object
- comes from ground (except water)

Newtons

1 N = 0. 225 lbs   Mass is constant

F= ma ------ Fw = mg   N → kg (/ 9. 8)

Kg → N (x 9. 8)

Friction (Ff)

1. two or more things must be touching
2. energy is transferred (heat, sound, etc) .
3. texture matters… NOT SURFACE AREA

   μ = coefficient of friction (Ratio of parallel force to perp. Force)

   $\mu = \frac{\mathrm{F_f}}{\mathrm{F_N}}$

   $\mathrm{F_f} = \mu \mathrm{mg}$ $\mathrm{Ff} = \mathrm{Fw}$ ((on flat surface)

   $\mu = \tan\theta \quad (When\ v\ is\ constant\ )$

   Pressure: P = Force/area

4. opposes motion which causes deceleration
5. static – "starting Ff" not moving (rolling) greater force than kinetic

   kinetic – moving (rolling, sliding, fluid)

Equilibrium

Translational: the sum of forces equal zero

Rotational: the sum of torques equals zero

Complete: must have BOTH

Center of Gravity: center of distribution of mass

Torque

Force with leverage causes rotation

Leverage: distance from fulcrum to for

*Directly related to torque

τ = F (perp.) l

Circular Motion

Moving at a constant speed while accelerating

A = v → speed: constant

dxn: constantly changing

Centripetal Acceleration

Inward seeking $Ac = \frac{v^2}{r}$

Centripetal Force

Causes centripetal acceleration

Fc = m Ac (F = m a)

Fc = $\frac{mv^2}{r}$.(N)

You MUST have cent. F to keep something moving in a circle

Centrifugal: body's interpretation of cent. F

DOES NOT EXIST → feels inertia

Rotation: spinning on axis within object

Revolution: spinning on axis outside of object

Linear / Angular

Linear : speed = distance / time → radius matters

57. 3deg = 1 RADIAN

1 rotation = 2 π Radians = 360 degrees

Angular: speed = # rotations or revolutions / time

→ radius does NOT matter

* by doubling the angular speed

you double the # of rotations

Linear		**Angular**
χ (m)	χ = r θ	θ (RAD)
υ (m/s)	υ = r ω	ω (RAD / s)
a (m/s/s)	a = r α	α (RAD / s / s)
F (N)	Ft = τ	τ (Nm)
Mass (m)		I (mr)
F = m a		τ = I α

For linear

See other corner

$$\omega = \omega_0 + at$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}at^2$$

$$\theta = \theta_0 + \frac{1}{2}(\omega + \omega_0)$$

$$\omega^2 = \omega_0^2 + 2a(\theta - \theta_0)$$

Rotational Inertia

Resistance to begin or stop rotation

- Depends on amount of mass AND where it is placed
  Solid Sphere → 2/5 mr^2 Solid Disk → ½ mr^2
  Hollow Sphere → 2/3 mr^2 Hollow Disk → 1 mr^2
- Velocity is indirectly related to Inertia
- Shape of object spinning makes the difference while spinning

3 Forces acting upon an object in circular motion

1. Centripetal Acceleration (Ac)
2. Angular Acceleration (α)
3. Linear Acceleration (a)

Conservation Laws

Momentum (N s)

Moving inertia (Newton's 2nd law)
Momentum IS inertia…Inertia is NOT momentum
Momentum is DIRECTLY related to mass and speed
p= mv (N s)

Causes body to want to fly off tangent

Impulse

A change in momentum (how you feel p change)
Force : F = m a → $F = \frac{m\Delta v}{\Delta t}$
Time : * hidden variable*
$F\Delta t = m\Delta v = \Delta p$

Conservation of Momentum

In the absence of an external force, the total momentum of a system is constant
$m_1v_1 + m_2v_2 = m_1v_1 + m_2v_2$

Work (J)

*Need to apply force W = Fd
* implies motion

Power (watt -- w)

$$P = \frac{w}{t} = \frac{fd}{t}$$

$$\frac{J}{s} = 1w = \frac{Nm}{s} = \frac{1kgm^2}{s^2}$$

1 horse power = 746 w

Energy

Ability to do work

Mechanical: energy of motion or position

Kinetic (K): motion

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

Potential (U): position

$\mathrm{U = mgh\ (J)\ (W = FD)}$

When not given distance…(or force)

When not given distance…(or force)

$W = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 (W = \Delta K)$

(K final) − (K initial)

Conservation of Energy

Energy change from one to the other w/o any net loss

$\mathrm{U_{TOP} = K_{BOT}\ (mgh = \frac{1}{2}mv^2)}$

Wave Motion

Simple Harmonic Motion

A repeating motion in which the acceleration is directly related to the displacement (distance away from the equilibrium) and always directed towards equilibrium.

$T = 2\pi\sqrt{\frac{l}{g}}$ $\qquad f = 1/T$

Cosine Curves

Y = A cos B (x – C) + D

A = amplitude (0): how much energy it has

Cos B = period (2 PIE / t) : time, 1 oscillation

C = horz. Shift : human error

D = vert. Shift : distance, to x-axis

Waves

* Graphed SHM, transfer of energy

Vibration: WORK to get energy

Propagates : what energy moves through

Mechanical (light)	Electromagnetic (sound)
Needs a medium	does NOT need a medium
More dense – better	less dense – better

<u>Mechanical Waves</u>

<u>Transverse:</u> medium vibrates perp. to energy Most common ex. Guitar string, slinky
<u>Longitudinal</u>: medium vibrates para. to energy Has compressions ex: sound
Surface: both para. and perp. to energy "physics bob" ex: earthquakes, waves

<u>Principle of Superposition</u>

Constructive Interference: added
Deconstructive: subtracting (adding negatives)

$V = \frac{\lambda}{T}$ $\quad\quad$ $V = \lambda f$

<u>Standing Wave</u>

A continuous wave train of equal amplitude (RAD), wavelength (m), and frequ. (Hz) (/sec) in the same medium creating nodes and antinodes.

<u>Boundary:</u> change in medium
(part of energy gets reflected, part gets absorbed)

rigidity: how much energy gets ABSORBED
close rigidity → more absorbed
different rigidity → more reflected

<u>Interference in Diffraction</u>

Crest + crest = antinode Crest + troph = node

<u>Sound</u>

A range of longitudinal wave frequ. to which the human ear is sensitive

Infra sonic	sonic spectrum	ultra sonic
(Below 20 Hz.)	(20 Hz – 20,000 Hz)	(20,000 Hz +)

1. **production** : needs vibration
2. **transition** : needs a medium → air
3. **reception** : must be heard

V sound = 340 m/s
V sound = 331 + . 6 (Temp.)

Intensity: measurable

How loud a sound is * the time of flow of energy per unit area

$I = \frac{\text{Pow}}{\text{Amp}^{-}}$ **P** = W/t

Intensity is DIRECTLY related to *amplitude*

Damping: further you get from the center → quieter it will be

Inverse Square Law: $I_1 r_1^2 = I_2 {r_2}^2$

Volume (B) : subjective (**decibels**)

Relative Intensity Level → loudness level

Volume is DIRECTLY related to *Intensity*

Volume is DIRECTLY related to *Frequency*

f standard = 1,000 Hz

Intensity Range

Threshold of hearing $(I_0) = 1 \times 10^{-12} \text{w/m}^2$

Threshold of sound $= 1 \text{ w/m}^2$

$$\beta = 10 \ \log \frac{I}{1 \times 10^{-12} \text{w/m}^2}$$

"How many powers of 10 are in that number?"

Decibel $= \frac{\text{w/m}^2}{\text{w/m}^2}$

Pitch and Tone

I → volume *f* → pitch

Notes and tones: pitch with recognizable frequencies Laws of Pitch:

1. *f* is INDIRECTLY related to *length*
2. *f* is **DIRECTLY** related to *tension* (Ft)
3. *f* is INDIRECTLY related to *diameter* (d)
4. *f* is INDIRECTLY related to *density* (D)

Beats: the resultant interference pattern of 2 notes

close in frequency but not exact

Creat nodes (sharps and flats)

Doppler Effect: the apparent change in frequency of a sound due to the relative motion of either the observer or the source of both

Resonate: when you cause something to vibrate at its natural frequency

Music → repeating wave pattern

Noise → no repeating wave pattern

Consonance → sounds GOOD

Dissonance → sounds BAD

Decibel:

I	**B**
1×10^{-12}	**0 db**
1×10^{-11}	**10 db**
1×10^{-10}	20 db
……	**……**
1×10^{-2}	100 db
1×10^{-1}	110 db
1	120 db

Natural Frequencies l = 170 / Hz

Brass/String n	name	synm	wavl (λ)	1	f
f	Fund	1st har.	$2l$	½ λ	$v/2l$
$f2$	1st ov.	2nd har.	l	λ	v/l
$f3$	2nd ov.	3rd har.	$2/3l$	3/2 λ	$3v/2l$
$f4$	3rd ov.	4th har.	$1/2l$	2λ	$2v/l$
$f_n = \frac{nv}{2l}$		$hn = \frac{2l}{n}$		$f_n = Nf_1$	

Woodwind n	name	synm	wavl (λ)	1	f
f	Fund	1st har.	$4l$	¼ λ	$v/4l$
$f2$	…..	…..	…..	…..	…..
$f3$	1st ov.	2nd har.	$4/3l$	3/4 λ	$3v/4l$
$f4$	…..	…..	…..	…..	…..
$f5$	2nd ov.	3rd har.	$4/5l$	$5/4\lambda$	$5v/4l$
$f_n = \frac{nv}{2l}$		$hn = \frac{2l}{n}$			

Instruments

String Produced by: plucking string, bowing
Change pitch : length, diameter, tension, density
Brass Produce by : buzzing mouth piece
Change pitch : length of pipe (valves), buzzing
Woodwind Produced by : reed vibrating
Change pitch : pads, holes
Edge tones: narrow streams of air split by edge
Helmholtz Resonance: edge tone with bottle (open hole)

Light

Particle	**Wave**
+ Newton said so	+ Thomas Young – 2 slit ex
+ Beams / Wave	+ reflection, refraction,
+ travel in straight lines	diffraction, interference
+Hertz – light is energy	
+ Einstein – wave particle duality	

Polarized Light: Light oriented to one plane (calc.)

Liquid Filter Display : lets only one degree of light in

Visible Spectrum: Radio * Micro * Infrared * Ultraviolet * Xrays* Gamma
Big wavelength →→→→→→→ Small wavelength

Red Orange Yellow Green Blue Indigo Violet

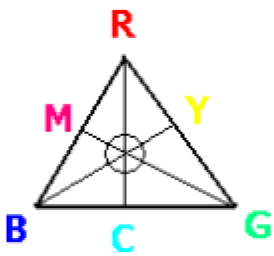
Transparent: see through it and light passes (Windows, glass)
Translucent: can NOT see through it, light passes (frosted glass)
Opaque : can NOT see through it, NO light passes Source: makes and emits light
Luminous: sun
Luminate: moon
Light Year: takes 8. 3 min. to get light from sun Dispersion: breaking up light into colors (prism)

Colors

Cones in eye pick up 3 primary colors of light

Additive

Primary	Secondary
BLUE	YELLOW
RED	CYAN
GREEN	MAGENTA
* More than one light source	



Subtractive

Primary	Secondary
YELLOW	BLUE
CYAN	RED
MAGENTA	GREEN
*only one light source	
* darker colors	

Shades of Colors

Hue: proportion of color

Saturation : amount of white mixed with color

Brightness : amount of black mixed with color

Reflection

Smooth: $\theta_i = \theta_r$

Diffuse: “scatters light” obeys laws still

Refraction

Index of Refraction $n = \frac{3\times10^8}{v}$

(speed in whatever medium)

Air : 1. 00 Water : 1. 33 Glass : 1. 52

Snell's Law

* n is INDIRECTLY related to θ
* n is INDIRECTLY related to speed
* v is DIRECTLY related to θ

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

Lasers

Critical angle(θ_c): the θ_1 that produces the angle that is larger than θ_c.

Total Internal Reflection: no refraction

Optics

Reflection: mirrors

Refraction: lenses

Mirrors

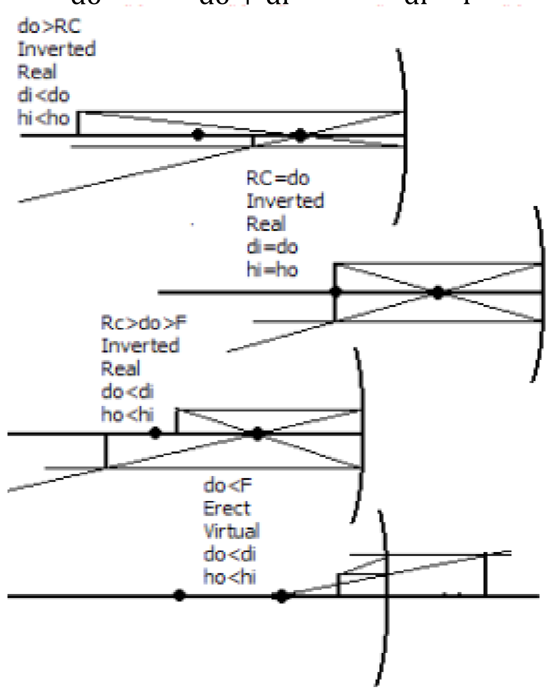
Concave: converging and upside down after foc. Pt

Convex: diverging, upright and smaller

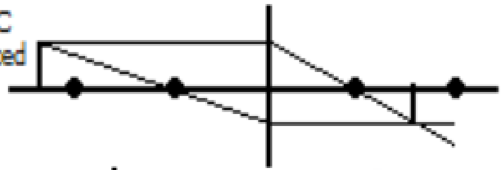
Magnification: $M = \frac{\mathrm{hi}}{\mathrm{ho}}$ M > 1 = big

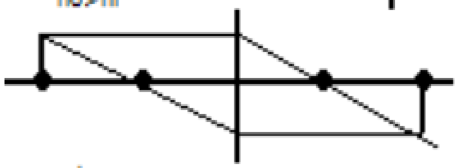
M< 1 = small

$\mathrm{hi} = \frac{\mathrm{hodi}}{\mathrm{do}}$ $\mathrm{f} = \frac{\mathrm{dodi}}{\mathrm{do} + \mathrm{di}}$ $\mathrm{do} = \frac{\mathrm{di\ f}}{\mathrm{di} - \mathrm{f}}$ $\mathrm{di} = \frac{\mathrm{do\ \ f}}{\mathrm{do} - \mathrm{f}}$



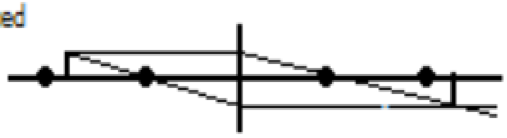
do>RC
Inverted
Real
do>di
ho>hi

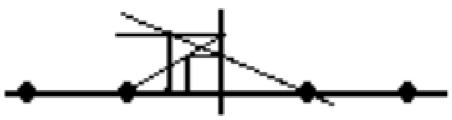




do=RC
Inverted
Real
do=di
ho=hi

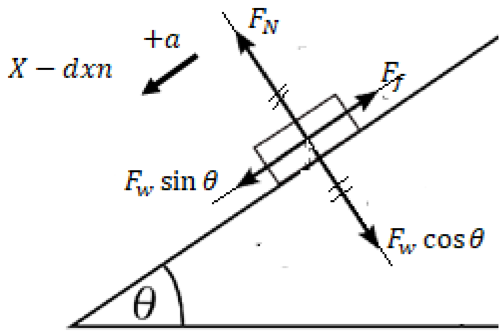
RC>do>F
Inverted
Real
do<di
ho<hi

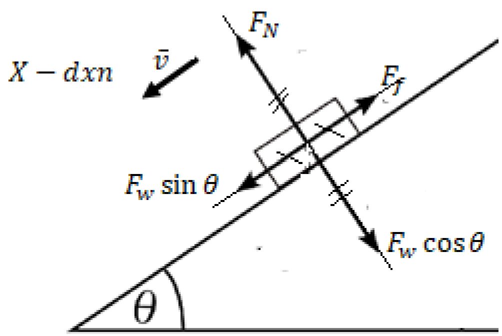




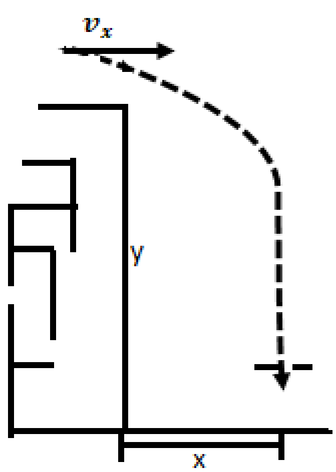
do<F
Erect
Virtual
do<di
ho<hi

If you have this	Do this	To get this
N	× .225	lb.
lb.	÷ .225	N
N	÷ 9.8	Kg
Kg	× 9.8	N
lb.	× .454	Kg
Kg	÷ .454	lb.





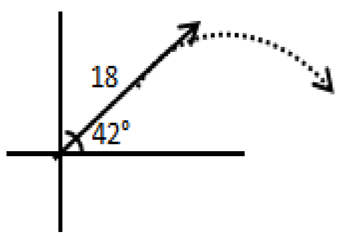
Buddy rides his bike off the top of a 24.5 m high building going 6.25 m/s. What will his range be?
Handle projectile motion problems in two columns representing the two directions (independent of each other)



If you're looking for "x", start in the "y" so find "t", (so vice versa)

X finish here	**Y start here**
$v_x = 6.25$	Y=24.5
$\chi = ?$	g = 9.8
$\chi = v_x t$	$t = \sqrt{\frac{2y}{g}}$
= (6.25)(2.236)	$= \sqrt{\frac{2(24.5)}{9.8}}$
= 13.9754	= 2.236
$\chi = 14.0\ m$	Notice that "t" is the link between the two directions

Ex- A football is kicked at 18 m/s, 42° above the horizontal ground. Find both its maximum height and range? set your problem up in two columns again



X do the components first	**Y**
$v_x = V_{\cos\theta}$	$v_y = V_{\sin\theta}$
$= 18\cos 42$	$= 18\sin 42$
= 13.376	= 12.044
For range	The Y will always give you "e"
$\chi = v_x t$	$t = \frac{2v_0}{g} = \frac{2(12)}{9.8}$
= (13.4)(2.46)	= 2.458
= 32.879	$Y_{max} = \frac{{v_0}^2}{2g} = \frac{(12)^2}{19.6}$ for height
$\chi = 33\ m$	= 7.3469

$Y_{max} = 7.3\ m$ Make sure you use the correct speeds in the correct places!!!

5.

$\mu = 22$

$v_0 = 8.96\frac{1}{3}$

$v = \theta$

$F_w = 60N$

$m = 6.122\ kg$

$F_f = ?\,N$

$a = -$

$\chi_0 = 0$

$\chi = ?\,m$

$t = ?\,\Delta\mu$

$F_f = \mu F_N = (0.22)(60) = 13.2$

$a = \frac{F_f}{M} = \frac{13.2}{6.122} = 2.156$ ....

$v^2 = v_0^2 + 2a(\chi - \chi_0)$

$\frac{-v_0{}^2}{2a} x = \frac{-(8.96)^2}{2(-2.156)}$

= 18.61815

$v = v_0 + at$

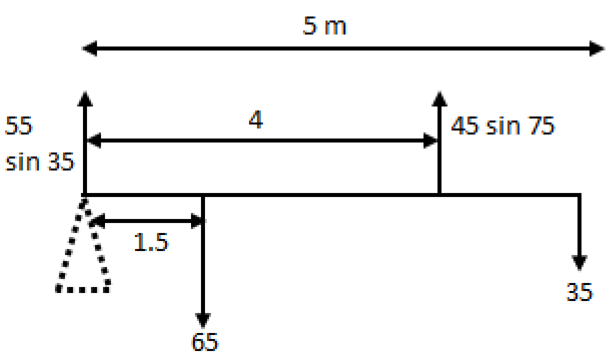
$\frac{-v_0}{a} = t = \frac{-8.96}{-2.156}$

= 4.1558

$F_f = 13.2N$

$\chi = 18.6\ m$

T=4.1 base



$\Sigma F \uparrow = \Sigma F \downarrow$

(55 sin 35) + (45 sin 75) = 65 +35

75.013 = 100

$\therefore F\ is$ "up" $\quad 25\ N$

$\Sigma\tau_c = \Sigma\tau_{cc}$

(65) (1.5)+(35)(5)= (45 sin 75)(4) + (25)(l)

3.9453 l

F = 25N, up, 39. M from left end

$\chi_0 = 0$

$\chi = 12$

$v_0 = 15$

$v = 0$

$a = -$

$M = 6.73$

$F_w = 66\ \ (F_N)$

$\mu = ?$

$v^2 = v_0^2 + 2a(\chi - \chi_0)$

$\frac{-v_0{}^2}{2\chi} = a = -\frac{15°}{2(12)} = 9.375$

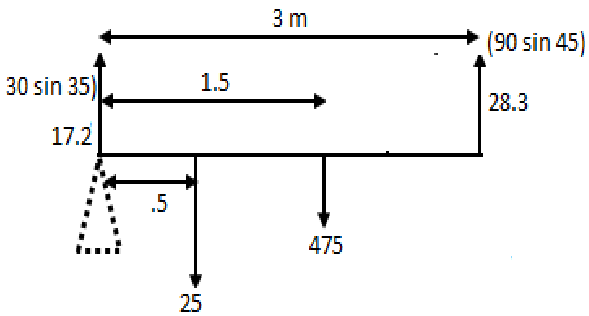
$F_f = ma = (6.73)(9.375)$

$= 63.09$

$\mu = \frac{F_f}{F_N} = \frac{63.09}{66} = .95596$

$\mu = 0.956$

4.



$$\Sigma F \uparrow = \Sigma F \downarrow$$

(17.2 + 28.3)= (25 + 475)

45.5 = 500

$$F_{up} = 455\ N$$

$$\Sigma\tau_c = \Sigma\tau_{cc}$$

(25)(.5)+(475)(1.5)=(28.3)(3)+(455)(l)

= 1.4068 = l

F_{up}=455 N, 1.4 M from left end

Ex- How much momentum does a 6.0 kg object have if it is moving at 3.0 m/s? What force would it take to bring it to rest in 2.0 seconds?

p=? Ns

m = 6 kg

v = 3 m/s

$p_0 = 18$

$p = \theta$

F = ?

t = 2

p = mv = (6)(3) = 18

p = 18 Ns

= $\Delta p = -18$

$\Delta p = F\Delta t$

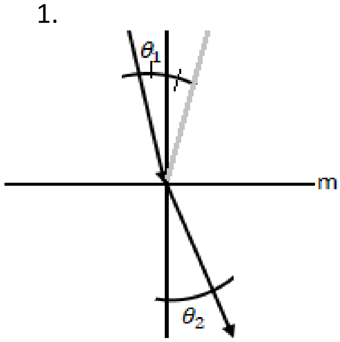
$$F = \frac{\Delta p}{\Delta t} = \frac{-18}{2} = -9$$

$F = 9.0\ N\ in$ opposite dxn

Total Internal Reflection

As you move through each example, notice the angle of incidence gets larger and large also note that his cause the angle of refraction to increase as well. There will come a pair the angle of incidence causes the angle of refraction to be ninety degrees…. That is the refracted light seems to go spread out along the boundary (situation # 4 below). The angle of incidence that causes this to happen is called 'critical angle' for that medium if the angle of incidence arrives any larger than the critical angle (situation #5)

1.



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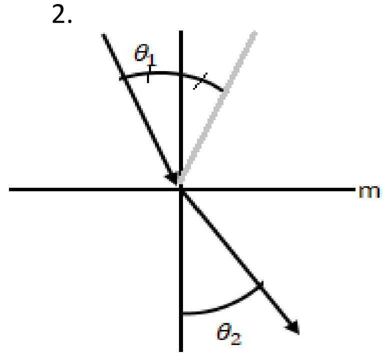
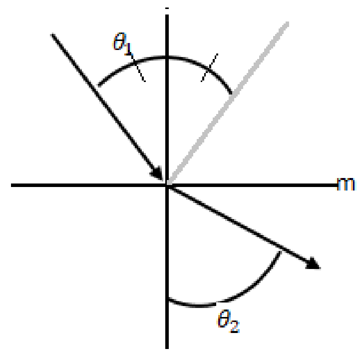
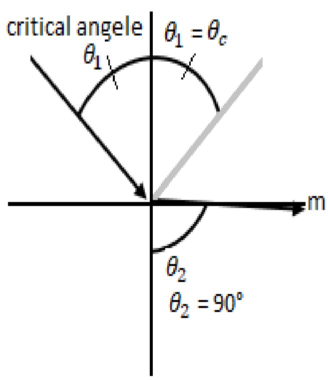


3.

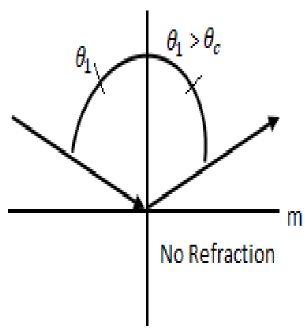


We say that it is total internally reflex total internal Reflection occurs when angel of incidence arrive larger that critical angle for the median.

4.



5.



TIR

If $\theta_1 = \theta_c \ldots\ldots..\theta_2$

if $\theta_1 > \theta_c \ldots\ldots..TI$

Ex. An 18 cm flywheel slows from 8.0 rev/sec to 3.0 rev/sec over a 3.5 second time interval. Find its angular deceleration & its angular & linear displacements.

$\omega_0 = 8.0\frac{\text{rev}}{\text{sec}} = 50.26\frac{\text{rad}}{\text{sec}}$ Must convert to RAD to do this problem	$\omega = \omega_0 + \alpha t$
ω =3 rev/sec = 18.85 RAD/s	$\frac{\omega - \omega_0}{t} = \chi = \frac{18.8 - 50.2}{3.5}$
t = 3.5 sec	= -8.9742
$\alpha = -?\ \text{RAD/s}^2$ simple kinematics	$\theta = \theta_0 + \frac{1}{2}(\omega = \omega_0)t$
$\theta_0 = \theta$	$= (.5)(50.26 + 18.85)(3.5)$
θ = ? RAD	$\theta = 120$ RAD = 120.9425
$\chi = ?$ RAD	$\chi = \theta r = [120.94](18)$
Ang. To LIN. conversion $\chi = ?\,M$ $\chi = 22$ m	= 21.7696.

6.

(Open)
$l = 0.86\ m$

$$f_1 = \frac{\text{Nv}}{2\text{l}} = \frac{(1)(344)}{2(.86)} = 200$$

$v = 344\ m/s$

$$f_1 = 200\ \text{Hz}$$

$f_1 = ?\ Hz$

$$f_1 = \frac{\text{Nv}}{4\text{l}} = \frac{(1)(344)}{2(.86)} = 100$$

(closed)
$f_1 = ?\ \text{Hz}$

$$f_1 = 100\ \text{Hz}$$