Data

Scientific Method	**Uncertainty**
1. Observation	* units (metrics)
2. Define the Problem	* measuring
3. Test/Experiment	* sig. figs.
4. Hypothesis	* Data Manipulation
5. Collect Data/Manipulate	
6. Conclusion	

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 Vecctors
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
Vχ= (0)+ (-22 cos47)+(-10 cos78)+(30) =12. 9m
*(N&S) Sum of the
Vχ= (-18)+ (-22 sin47)+(10 sin78)+(0) =-24. 3m
*Resultant υ =
$((12.9)^2 + (24.3)^2)^{1/2}$ =27. 5m
* $\theta = \tan^{-1}\frac{(24.3)}{(12.9)}$ = 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

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

Kinematic Formulas

X Direction	*Y Direction*
$\upsilon = \upsilon_o + \underline{a t}$	$- g t$
$\chi = \chi_o + Vo\, t + \underline{½ a t^2}$	$- ½ g t^2$
$\chi = \chi_o + ½ (\upsilon + \upsilon_o) t$	------
$\upsilon^2 = \upsilon_o^2 + \underline{2 a (\chi - \chi_o)}$	$- 2 g ($

Change χ (o) to Y(o)

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

X	Y
$\chi = V\chi\, t$	$Y = ½ g t^2$
$T = \frac{\chi}{V\chi}$	

Full
* 45deg has max. range

Steps:
1. $\upsilon_o \cos\theta_o / \upsilon_o \sin\theta_o$
2. Find the TIME (check Y)
3. Find the height / range

X	Y
$\chi = V\chi\ t$	$t = \frac{2\upsilon_o}{g}$
$(Vx = \upsilon_o \cos\theta_o)$	$(V_o = \upsilon_o \sin\theta_o)$

$$y\ max = \frac{\upsilon_o^2}{2g}$$

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 / s² = 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 = coefficent of friction (Ratio of parallel force to perp. Force)
   $\mu = \frac{F_f}{F_N}$ (3 decimal places)
   $F_f = \mu m g$ Ff = Fw (on flat surface)
   μ = tan θ (when υ is constant)
   Pressure: P = Force/area
4. opposes motion which causes decelleration
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 force
*Directly related to torque
$\tau = F\ (perp.)\ l$

Circular Motion
Moving at a constant speed while accelerating
A = v → speed: constant
dxn: constantly changing

Centripetal Acceleration
Inward seeking $Ac = \frac{\upsilon^2}{r}$

Centripetal Force
Causes centripetal acceleration
Fc = m Ac (F = m a)
$Fc = \frac{m\upsilon^2}{r}$. (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		$\omega = \omega_o + \alpha t$
See other corner		$\theta = \theta_o + \omega_o t + ½ \alpha t^2$
		$\theta = \theta_o + ½ (\omega + \omega_o) t$
		$\omega^2 = \omega_o^2 + 2 \alpha (\theta - \theta_o)$

Rotational Inertia
Resistance to begin or stop rotation

- Depends on amount of mass AND where it is placed

Solid Sphere → **2/5 mr²** Solid Disk → **½ mr²**
Hollow Sphere → **2/3 mr²** Hollow Disk → **1 mr²**

- 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 (A_c)
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 = m υ (N s)
- causes body to want to fly off tangent

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

Conservation of Momentum
In the absence of an external force, the total momentum of a system is constant
$$m_1 \upsilon_1 + m_2 \upsilon_2 = m_1 \upsilon_1 + m_2 \upsilon_2$$

Work (J)
* Need to apply force **W = F d**
* implies motion

Power (watt -- w)
$$P = \frac{W}{t} = \frac{(F\,d)}{t}$$
$\frac{J}{s} = 1\,w = \frac{N\,m}{s} = \frac{1\,kg\,m^2}{s^2}$
1 horse power = 746 w

Energy
Ability to do work
Mechanical: energy of motion or position
Kinetic (K) : motion
$K = ½ m \upsilon^2$ (J)
Potential (U) : position
U = m g h (J) (W = F d)
When not given distance…(or force)
$W = ½ m \upsilon^2 - ½ m \upsilon_o^2$ (W = ΔK)
(K final) – (K initial)

Conservation of Energy
Energy change from one to the other w/o any net loss
$U_{TOP} = K_{BOT}$ ($mgh = 1/2mv^2$)

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.

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

Cosine Curves
Y = A cosB (x – C) + D
A = amplitude (0) : how much energy it has
CosB = 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

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

Principle of Superposition
Constructive Interference : added
Deconstructive : subtracting (adding negatives)
$V = \frac{\lambda}{T}$ $V = \lambda f$

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

Interference in Diffraction
Crest + crest = antinode Crest + troph = node

Sound
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
$$I = \frac{Pow}{Amp} \qquad \left(P = \frac{W}{t}\right)$$
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 (Io) = 1 x 10⁻¹² w / m²
Threshold of sound = 1 w / m²
$$\beta = 10 \log \left(\frac{I}{1 \times 10^{-12}\ w / m^2}\right)$$
"How many powers of 10 are in that number?"
$$Decibel = \frac{w / m^2}{w / m^2}$$

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)	l	f
	f	fund.	1st har.	2 *l*	½ λ	v/2*l*
	f 2	1st ov.	2nd har.	*l*	λ	v / *l*
	f 3	2nd ov.	3rd har.	2/3*l*	3/2 λ	3v/2*l*
	f 4	3rd ov.	4th har.	1/2*l*	2 λ	2v/ *l*

$$f_n = \frac{n\,\upsilon}{2\,l} \qquad hn = \frac{2\,l}{n} \qquad f_n = N f_1$$

Woodwind	n	name	synm	wavl (λ)	l	f
	f	fund.	1st har.	4 *l*	1/4 λ	v/4*l*
	f 2	------	-------	-----	-----	----
	f 3	1st ov.	2rd har.	4/3*l*	3/4 λ	3v/4*l*
	f 4	------	-------	-----	-----	----
	f 5	2nd ov.	3rd har.	4/5*l*	5/4 λ	5v/4*l*

$$f n = \frac{n\,\upsilon}{4\,l} \qquad hn = \frac{4\,l}{n}$$

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 / Waves	+ reflection, refraction, diffraction, interference
+ travel in straight lines	
+Hertz – light is energy	
+ Einstein – wave particle duality	

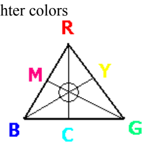
Polarized Light: Light oriented to one plane (calc.)
Liquid Filter Display : lets only one degree of light in
Visible Spectrum :
Radio * Micro * Infrared * Ultraviolet * Xrays* Gamma
Big wavelength →→→→→→→ Small wavelength
Red Orange Yellow Green Blue Indigo Violet
Transparent: see through it and light 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

* Brighter colors



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 $n = \dfrac{3 \times 10^8}{v}$

(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
* υ is DIRECTLY related to θ

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

Lasers

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

Total Internal Reflection: no refraction

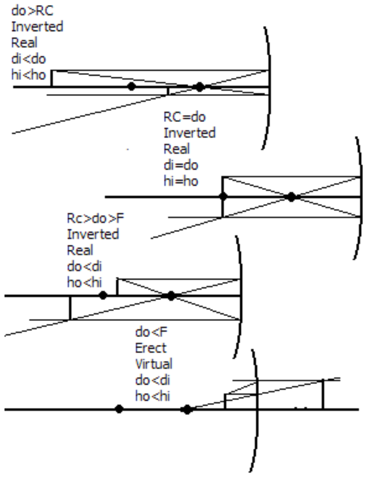
Optics

Reflection: mirrors
Refraction : lenses

Mirrors

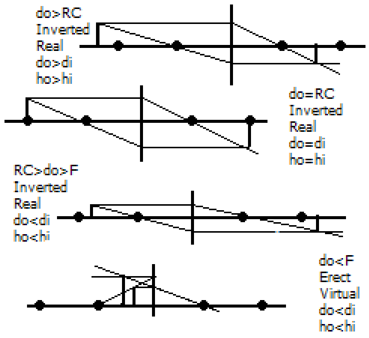
Concave : converging and upside down after foc. pt
Convex : diverging, upright and smaller
Magnification : $M = \dfrac{hi}{ho}$ M>1 = big, M<1 = small

$hi = \dfrac{ho\, di}{do}$ $f = \dfrac{do\, di}{do + di}$ $do = \dfrac{di\ f}{di - f}$ $di = \dfrac{do\ f}{do - f}$



Lenses

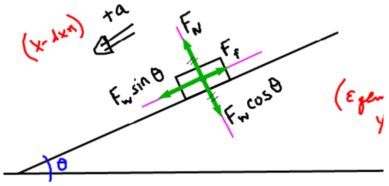
Concave : corrects *nearsightedness* diverging
Convex : corrects *farsightedness* converging

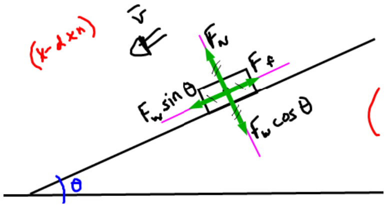


If you have this	*Do this*	*To get this*
N	× .225	lb.
lb.	÷ .225	N
N	÷ 9.8	Kg
Kg	× 9.8	N

lb.	× .454	Kg
Kg	÷ .454	lb.

Incline Graphs





[EX] 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" & find "t". (& vice-versa)

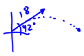
x — finish here...	start here... — y
$v_x = 6.25$	$y = 24.5$
$x = ?$	$g = 9.8$
$x = v_x t$	$t = \sqrt{\dfrac{2y}{g}}$
$= (6.25)(2.236)$	$= \sqrt{\dfrac{2(24.5)}{9.8}}$
$= 13.9754\cdots$	$= 2.236\cdots$

$\boxed{x = 14.0\text{m}}$

notice that "t" is the link between the two directions

[EX] A football is kicked at 18 m/s, 42o above the horizontal ground. Find both its maximum height and range?

set your problem up in two columns again...



do the components first

x	y
$v_x = V\cos\theta$	$v_{oy} = V\sin\theta$
$= 18\cos 42$	$= 18\sin 42$
$= 13.376$	$= 12.044$

the Y will always give you the "t" $t = \dfrac{2v_o}{g} = \dfrac{2(12)}{9.8} = 2.458\cdots$

for range $x = v_x t = (13.4)(2.46) = 32.879\cdots$

$y_{max} = \dfrac{v_o^2}{2g} = \dfrac{(12)^2}{19.6} = 7.3469\cdots$ for height

MAKE SURE you use the correct speeds in the correct places!!!

$\boxed{x = 33\text{ m} \quad y_{max} = 7.3\text{ m}}$

⑤ $\mu = .22$
$v_o = 8.96\,\text{m/s}$
$v = 0$
$F_w = 60\text{ N}$
$m = 6.122\text{ Kg}$
$F_f = ?\text{N}$
$a = -$

$x_o = 0$
$x = ?\text{m}$

$t = ?\text{ sec}$

$F_f = \mu F_N = (.22)(60) = 13.2$ $\boxed{F_f = 13.2\text{N}}$

$a = \dfrac{F_f}{m} = \dfrac{13.2}{6.122} = 2.156\cdots\ (-)$

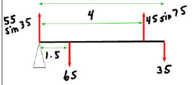
$\cancel{v^2} = v_o^2 + 2a(x - \cancel{x_o})$

$-\dfrac{v_o^2}{2a} = x = \dfrac{-(8.96)^2}{(2)(-2.156)} = 18.61815\cdots$ $\boxed{x = 18.6\text{m}}$

$\cancel{v} = v_o + at$

$-\dfrac{v_o}{a} = t = \dfrac{-8.96}{-2.156} = 4.1558\cdots$ $\boxed{t = 4.16\text{sec}}$

③



$\Sigma F_\uparrow = \Sigma F_\downarrow$
$(55\sin 35) + (45\sin 75) = 65 + 35$
$75.013 = 100$
$\therefore$ F is "up" & is 25 N

$\Sigma \tau_c = \Sigma \tau_{cc}$
$(65)(1.5) + (35)(5) = (45\sin 75)(4) + (25)(\ell)$
$3.9453 = \ell$

$\boxed{F = 25\text{N, up, 3.9 m from left end}}$

③ $x_o = 0$
$x = 12$
$v_o = 15$
$v = 0$
$a = -$
$m = 6.73$
$F_w = 66 \leftarrow (F_N)$
$\mu = ?$

$\cancel{v^2} = v_o^2 + 2a(x - \cancel{x_o})$

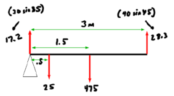
$-\dfrac{v_o^2}{2x} = a = -\dfrac{15^2}{(2)(12)} = -9.375\cdots$

$F_f = m\overset{(-)}{a} = (6.73)(9.375) = \overset{(-)}{63.09}\cdots$

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

$\boxed{\mu = 0.956}$

③



$\Sigma F_\uparrow = \Sigma F_\downarrow$
$(17.2 + 28.3) = (25 + 475)$
$45.5 = 500$
$\therefore F_{up} = 455\text{ N}$

$\Sigma \tau_c = \Sigma \tau_{cc}$
$(25)(.5) + (475)(1.5) = (28.3)(3) + (455)(\ell)$
$1.4068 = \ell$

$\boxed{F_{up} = 455\text{N, 1.4 m from left end}}$

[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 ?

$p = ?\ \text{Ns}$
$m = 6\ \text{Kg}$
$v = 3\ \text{m/s}$

$p = mv = (6)(3) = 18$ $\boxed{p = 18\text{ Ns}}$

$p_o = 18$
$p = 0$ $\Big\} \Delta p = -18$
$F = ?$
$t = 2$

$\Delta p = F\Delta t$

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

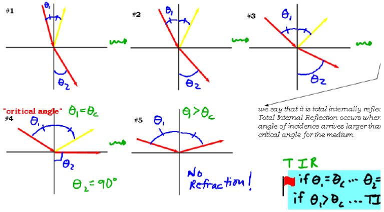
$\boxed{F = 9.0\text{ N in opposite dxn.}}$

* this could
with

* If you think abo
is really nothing
that is, this for
came from F=m
first kinematic
Impulse physics
adds the concep
mentum to the t
we have been d
You could have
of this with the
procedures we'v
all along, then,
we've shown it i
steps using imp

Total Internal Reflection

As you move through each example, notice
the angle of incidence gets larger and larg
also note that this causes the angle of refr
to increase as well. There will come a poin
the angle of incidence causes the angle of refraction to be ninety degrees... that is, the refracted light seems to g
spread out along the boundary (situation #4 below). The angle of incedence 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),



we say that it is total internally refle
Total Internal Reflection occurs whe
angle of incidence arrives larger tha
critical angle for the medium.

TIR
if $\theta_1 = \theta_c \cdots \theta_2 =$
if $\theta_1 > \theta_c \cdots$ 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.

radius · initial speed · final speed · time · NEG. acceleration · distance (linear & angular)

$\omega_o = \cancel{8\ \text{rev/s}} \rightarrow 50.26\ \text{RAD/s}$
must convert to RAD to do this problem
$\omega = \cancel{3\ \text{rev/s}} \rightarrow 18.85\ \text{RAD/s}$
$t = 3.5\ \text{sec}$
$\alpha = -?\ \text{RAD/s}^2$

$\omega = \omega_o + \alpha t$

$\dfrac{\omega - \omega_o}{t} = \alpha = \dfrac{18.8 - 50.2}{3.5} = -8.9742\cdots$

$\boxed{\alpha = -9.0\ \text{RAD/s}^2}$

simple kinematics

$\theta_o = 0$
$\theta = ?\ \text{RAD}$

$\theta = \theta_o + \frac{1}{2}(\omega + \omega_o)t$
$= (.5)(50.26 + 18.85)(3.5)$
$= 120.9425\ldots$

$\boxed{\theta = 120\ \text{RAD}}$

ANG. to LIN. conversion

$x = ?\ \text{m}$

$x = \theta r = (120.94)(.18) = 21.7696\cdots$

$\boxed{x = 22\text{ m}}$

⑤ (open)
$\ell = .86\text{m}$
$v = 344\ \text{m/s}$
$f_1 = ?\ \text{Hz}$

$f_1 = \dfrac{Nv}{2\ell} = \dfrac{(1)(344)}{(2)(.86)} = 200$

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

twice as much

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

$f_1 = \dfrac{Nv}{4\ell} = \dfrac{(1)(344)}{(4)(.86)} = 100$

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