Newtonian Physics
Part One

- Physics at work.
- Not going to cover Wow Modern Physics you see on TV.
- My topic is over 200 years old.
- Sir Isaac Newton (1642 - 1727) 85yrs

Why Physics?

- Ham radio operators like learning about technology.
- There is fulfillment in learning. “Learning for the sake of learning is good”.
- Physics formulas allow you to use your ingenuity to build or fix stuff.
- Problems that you thought were impossible to solve become easy.
- Physics can save you from injury or even death.

Scope

- Physics is a two semester course at TAMUCC.

  The first semester is mechanics.

  The second semester is electricity.
- As usual without much time, I will have to skip some of the details.
- Systems of units, Newton's three Laws of Motion, Newton's Law of Gravitation.
- These are the basic tools to understand radio and other sciences.

Physics Part 1

I do not have time tonight to cover the derived units, shown in the following slide, as much detail as they should be covered. This will have to wait until the opportunity of another meeting.

I will have to postpone covering rotational motion, liquids, and gases.

Units to be Defined

Standard Units	Derived Units
displacement	**force**
mass	**velocity**, **acceleration**
	angular velocity
	angular acceleration
time	**torque or moment**
angle	work (energy), power

- *Bold are vector quantities. Others are scalars.*

In A System of Units Correction Factors Not Required

- In the following slides I will present tables showing the standard systems of units.
- British, mks, and cgs units will be shown.
- The mks system of units in 1960, became a subset of the International System of Units, SI. The amp, mole, kelvin, and candela are the the rest of the standard units in SI.
- mks, stands for meter, kilogram, second
  cgs, stands for centimeter, gram, second.

Systems of Units

- The British system of units is a Gravatational system, based on the pull of the earth to define force.
- The two metric systems mks and cgs are absolute systems based on Newton's second Law of force.
- In any event it is possible to convert between these two systems.

Standard Systems of Units

A system of units means formulas will give the right answer, without a correction factor.

System	Length	Mass	Angle	Time
British	feet ft	slug W/32	degrees o	second sec
mks	meter m	kilogram kg	radians unit less	second sec
cgs	centimeter cm	gram g	radians unit less	second sec

Force

- British   Pound lb (If weight at sea level pound force is abbreviated, lb f). A pound of force can be in any direction.
- mks   Newton nt
- cgs   Dyne
- See Newton's second Law later. The Newton and the Dyne are derived from this Law.

Note

- Unit conversion tables can be found in the Amateur Radio Handbook, along with examples of how to use them for units not shown in the table.
- Plus a whole chapter on mathematics.

Standard Units

- The accuracy of Standard Units can be traced back to the National Bureau of Standards, and the International Bureau Weights and Measures S`evers, France.
- This is very important to the military and industry.

Length

- One meter is equal to 3.28 feet or about the same thing as a yard stick.
- A decimeter is almost like a foot = 0.1 meter.
- A centimeter is almost an inch = 0.01 meter.
- For some reason some people are emotional about learning the metric system.

Mass

- Mass is confusing. At sea level as the mass goes up so does the weight. In outer space the mass it had at sea level stays the same, while it's weight goes down.
- The slug is defined as the weight at sea level divided by 32. The 32 is about the acceleration of gravity. Guys who do this day in and day our just skip talking about slug's.
- Warning, make sure you use the ground level weight when calculating slugs (mass) lb f.

Mass

- It is interesting that a 100 pounds of lead and a 100 pounds of pop corn have the same Mass. (They have to be at the same height to weigh the same.)
- Mass depends on both the density of the material and the volume. The following is a hand waving formula, we are not going to actually work a problem. Just talk about what determines Mass, and along the way the meaning of the point form of a quantity. In this case density.

Density

- The units of density are mass per unit volume. The unit of Volume is distance cubed. d^3
- The one we need is mass density, do not be confused by weight density.
- Note, density can change as you move around inside an object (say the popcorn), heterogeneous.
- The density in the lead example is the same everywhere in the 100 lbs, homogeneous.
- Density is the mass at a point.

Aside, Math Review
Functions

- There is a special notation for functions that is confusing if you have never seen it before.
- Example: $v = v(t) = 3t^2 + 4t + 5$
- This reads, the voltage equals the voltage as a function of time equals the example equation.
- In v(t), we are not multiplying v times t! The notation is poor. It would be easy to write vt, if we wanted to multiply.

Density

- For a homogeneous volume (uniform material)

$$m = \rho V \ , \rho \ has \ the \ units \ kg/m^3 \ for \ mks$$

$$Where \ m = mass \ , \rho = density \ , V = Volume$$

- In this case the density ρ (Greek letter rho) would be a constant independent of position. Measured in mass per distance cubed (volume). You can look these densities up in a table, given for different materials.

Density Heterogeneous Material

- Density

  $$\rho \; could \; be \; written \; \rho = \rho(v)$$

- This would give it's value at each position or point inside the volume of the object.
- The point is a very small volume, despite the large units that are given to it.
- You have to be practical. The small volume must include enough molecules to be measured. But, does stretch the imagination.

Density Function Example

- Say for the rectangular coordinate system,

$$\rho = \rho(v) = \rho(x, y, z) = 3\mathrm{x} + 4\mathrm{y} + 5\mathrm{z}$$

$$0 < x < 25, 0 < y < 30, 0 < z < 35\ kg/m^3$$

- You would pick values for x,y,z substitute in the equation to find the density at that point.
- Or

$$\rho = \rho(x, y, z) = ax + by + cz$$

Mass
Mother Formula

- Hand waving formula.

$$M = \int_{\text{from one side}}^{\text{to the other}} \rho(v)\,dv$$

- The $\int$ looks like an S for sum.
- Sum what? The product of the point density times each little speck (differential volume) inside the object.
- See the Math jargon.

Different Versions of the Integral Sign

- All the following all mean the same thing.
- The circle indicates that the entire object will be covered.

$$\int \quad \oint \quad \oiiint$$

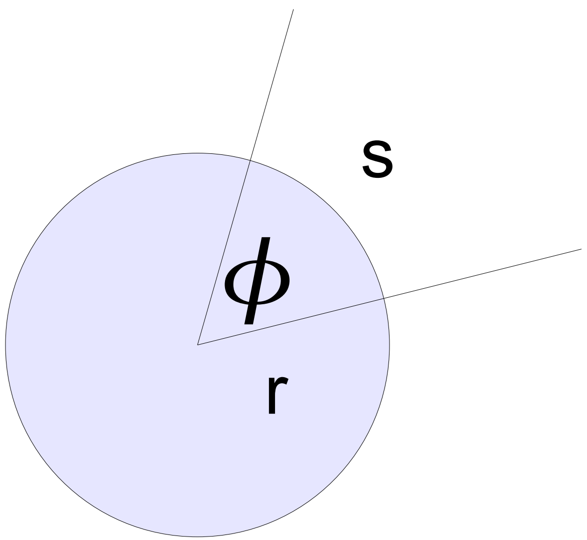
- The three integral signs mean, we are covering three dimensional space.

Triple Integral Analogy of Density

- Consider a Janitor collecting trash in a rectangular corporate office building with the building closed.
- The trash-can in each office is the same. The amount of trash in the can is the density of the trash in that office.
- He covers the first isle, goes to the next isle until the floor is complete. Then moves to the next floor.
- At dawn he has the total mass of the trash.

Angle

- Radians are unit less, being the ratio of the arc of a circle divided by the radius. This is a curved axis.



$$\phi = s/r$$

$$s = r\phi$$

Converting Between Radians and Degrees

- All you need to remember is there is two pi radians in 360 degrees. Why 2 π ?
  The circumference of a circle =π times the diameter. If I use the radius, C=2πr.
- You need to remember that two pi radians, 6.28 radians, corresponds to 360 degrees.
- 1 radian is 57.3 degrees.
- Let r=1 of any unit and see what happens.

Ratio and Proportion

$$\frac{360 \text{ degrees}}{6.28 \text{ radians}} = \frac{b \text{ degrees}}{a \text{ radians}}$$

Cross multiply to find the unknown. That could be either a or b. Both sides of the equation can be flipped over to make it easier to solve.

Time

- Time was first standardized by the Babylonians. 2700-538 B.C. You remember the wicked people, who put the Israelite into exile in the Old Testament.
- They must have counted on one hand. What would come after 5, but 6?
- With Atomic clocks we know within 1 second in 300 years as of 1958.
- On TV they said GPS satellites have improved over this.

Covering Next Newton's Three Laws of Motion

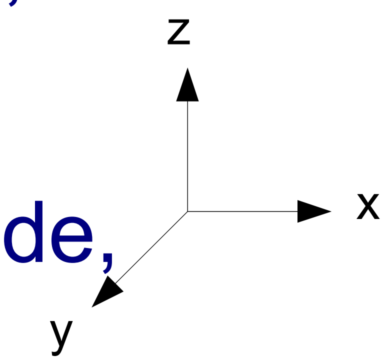
- I hope you have some inclination of what the vectors: force, velocity, and acceleration are.
- I must postpone a rigorous definition.
- It is helpful to remember that these quantities can be rendered positive or negative.
- Mass must remain positive.

Aside, Math Review
Vectors

- Vectors are quantities that have a magnitude and direction associated with them.
- This is a very big topic, that I can not begin to cover.
- Vectors can be represented in a number of different coordinate systems.
- The coordinate system is best chosen to match the symmetry of the problem. Work a problem in an easy coordinate system, then convert to another system such as the x, y, z.

Aside, Examples of Coordinate Systems

- Rectangular, Spherical, Cylindrical, Conical …
- Rectangular is the familiar x,y,z.



- Spherical is dear to Hams. Longitude, Latitude, and Radius.
- You will find math books, with the rules for converting vectors between these coordinate systems.

Aside, Math Review
Scalars

- Scalars are quantities that have no direction associated with them.
- Examples would be:

    3.14
    Mass
    time
    The length of your coax.

Aside, Math Review
Vectors

- Vectors can be used to represent fields.
- Vectors can be added and subtracted.
- The order this is done does not matter.
- You can zoom on them with a scalar.
- There are other important operations such as the Dot product, Cross product, Divergence, Gradient, Curl, and Laplacian.

Newtons Three Laws of Motion

First Law: A body at rest stays at rest , moving it stays moving at the same velocity in a straight line, provided no net force is acts on the object. It's inertia.
Momentum = Mass x velocity.

Second Law: If a net force acts on a body, the body will be accelerated; the magnitude of the acceleration is proportional to the magnitude of the force, and the acceleration is in the direction of the force. That is a change in momentum (or velocity).   F=Ma

Newton's Three Law's of Motion (continued)

Third Law: Whenever one body exerts a force on another, the second body exerts a force equal in magnitude and opposite in direction to the first body.

Momentum Equation

$$p = Mv$$

- Where p is the momentum
  M is the mass
  v is the velocity
- p is the dependent variable (range).
  M and v are the independent variables (domain).
- p and v can be constant, or functions of time.

Aside, Math Review

- Although 3 X 4 = 12 is common notation
- M X v is not cool. X is the key you would use on your calculator, however.
- Just Mv is better. Multiplication between “M” and “v” is implied.
- How would a computer read F=Ma?

Momentum

- Someone asked me, what keeps an asteroid moving in space?
- Well, what's there to slow it down? Friction is a force in the opposite direction to the motion.
- There is not enough dust in space to slow an asteroid down.
- This is analogous to a radio wave. What in the air is there to slow it down? Air is a very good dielectric. Imagine unimpeded weird shaped soap bubbles coming off your antenna.

Momentum that Stops

A change in momentum results in a force. See Newton's second Law.

- Consider the case where an mass with a momentum suddenly comes to a complete stop.
- Say a structure has an area “A”. Knowing the density of air, you can determine the mass of air that would go by in one second. Then in this special case, going from “v” to a full stop, the force would be, F=Mv.

Force of Wind on Your Beam/Tower

- Consider a wind blowing on your beam or tower with velocity "V" . You can find the wind surface area from the manufacturer.
- The mass of the air hitting the beam or tower in one second would come to a complete stop.
- The force on the beam would be F=MV-0

Horizontal Force on a Beam/Tower Due to Wind

- Since, the velocity is used twice to calculate the volume and the momentum velocity, the formula becomes

$$F = \frac{AV^2}{K}$$

- “F” is in pounds. “A” area in inches squared. “V” is in miles per hour. “K” is a constant chosen to obtain the right answer.
- Note, the force at 100 mph would drop to ¼ it's value at 50 mph.

Pitfalls in Using A and K

- Call the manufacturer to find out what value of K to use for their product. Don't borrow a value from some example you have seen.
- Antenna and Tower manufacturers calculate wind surface area differently. Don't expect totals from one manufacturer to equate to that of another.
- Calculate the force, that is not going to fool you.

Worst Case Wind Conditions

- A triband yagi point into the wind. A VHF antenna with a long boom, broadside to the wind.
- The forces at the top of your tower can become quite large. A guy wire will cancel the force of the wind, but in doing so will pull down on the top of your tower. It may not fall over, but buckle.
- You can see where a knowledge of Physics is needed.

Conservation of Momentum

- The slides covering the conservation of momentum have been moved towards the end of the presentation, where you will have a better grasp of Newton's Laws.

Newton's 2nd Law of Motion

$$\vec{F} = M\,\vec{a}$$

Where:

F = The force on an object. For now consider it to be at the center of the object. No rotation. It is a vector Quantity. Has direction and magnitude. F=F(t) function of time.

M = Mass, a scalar.

a = Acceleration. Increase in velocity per second. At an instance of time.

$F = Ma$

- The arrows can be dropped, if you don't care about the direction of the force.
- The force will be in the same direction as the acceleration.
- M the mass is a scalar (has no direction).
- Note, it takes force to make an object change direction. This acceleration will be at right angles to the velocity (direction) of the object.
- Force and acceleration go hand in hand. You can not have one without the other.

Newton's 2nd Law of Motion

- Note, for the formula F=Ma to work, without a correction factor, a consistant system of units must be used.
- In many problems “a” is replaced by “g”.
  “g” is the acceleration of gravity in the vacinity of the earth.
- $g \approx 32\, ft/sec^2 \quad 9.8\, m/sec^2 \quad 980\text{cm}/sec^2$
- “g” is the acceleration that an object would have falling to the earth. The weight W is the Force on the object. (pounds, newtons, dynes)

Newton's Third Law of Motion Equal and Opposite Forces Occur Between Bodies

- Whenever one body exerts a force on another, the second body exerts a force equal in magnitude and opposite in direction on the first body.
- This is used in statics problems to determine the stability of structures. (Say, will a box slide down an inclined plane or not?)
- The law of action and reaction.
- The ground pushes up on your car. When you move forward, the ground pushes you forward.

Newton's Law of Gravitation

$$F = G_0 \frac{Mm}{r^2}$$

r^2 is the distance between masses M and m

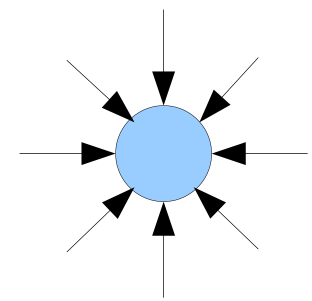
- G_0 is the gravitational constant.

$$G_0 = 6.670X10^{-8} \frac{dyne\,cm^2}{gm^2}$$

$$6.670X10^{-11} \frac{nt\ m^2}{kg^2}$$

The Gravitational Field I

$$I = \frac{F}{m} = G_0 \frac{M}{r^2}$$



- Newton was the first to prove that the field outside a spherical mass is identical with that of a mass concentrated at the center of the sphere.

$$I_e = \frac{W}{m} = g = G_0 \frac{M}{r^2}$$

r^2 is the distance from the center of the earth to an object "h" above the earth.

- Have fun and calculate the mass of the earth. The radius of the earth is 6,380 km.

Drag In The Air

- The block of wood and fishing weight in my demonstrations, will drop to the earth at the same time, despite their difference in weight.
- This is not true of a baseball. It experiences drag in the air. This drag depends on the size of the baseball and the viscosity of the air.
- When the drag resistance equals the weight of the baseball, it will go into equilibrium and reach a terminal velocity. By Newton's First Law it will go in a straight line.

Conservation of Momentum

- Consider a system of objects (Masses), that can have forces between them, but no external forces on the system.
- The momentum of the system would be the velocity of the center of gravity of the system times the total Mass of the system.
- The momentum of the system must remain the same, no matter what goes on inside the system.

Illustrative Example
Conservation of Momentum

- The following can be used to calculate the recoil velocity of a gun.
- Before the gun is fired, the bullet and the gun have zero momentum. After it is fired the two momentum's must add to zero.
- Momentum of bullet – Momentum of gun = 0

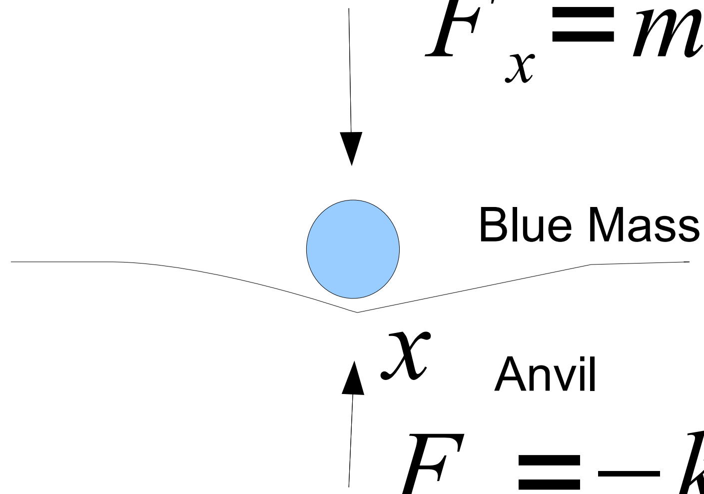
after it is fired, can be solved for the recoil velocity of the gun. The momentum of the gun will give you the maximum recoil force.

Elastic and Inelastic Impact

- When the total kinetic energy of the system remains constant the collision is Elastic.
- When the total kinetic energy of the system is less after the collision, it is inelastic (i.e. sound, heat, deform or fracture a body) energy is lost.
- One can not say much about an arbitrary inelastic collision.
- If the two objects stick together after the collision, they can be treated as one mass. This is a perfect inelastic collision.

How a Body Deforms Causing a Mass to Bounce Off

$$F_x = ma$$



$$F_x = -kx$$

k is the Hooke's law constant.

When the force of the Blue Mass equals the Hooke force the object comes to a stop. Then the Anvil pushes back, unless fracture takes place.

Example of Perfect Inelastic Collision

- The following can be used to calculate the velocity of a bullet by firing it into a block of wood at rest suspended by a wire.
- The momentum of the bullet will equal the momentum of the block of wood with the bullet imbedded in it (perfect inelastic collision) as it begins to swing.

Example of a Perfect Inelastic Collision

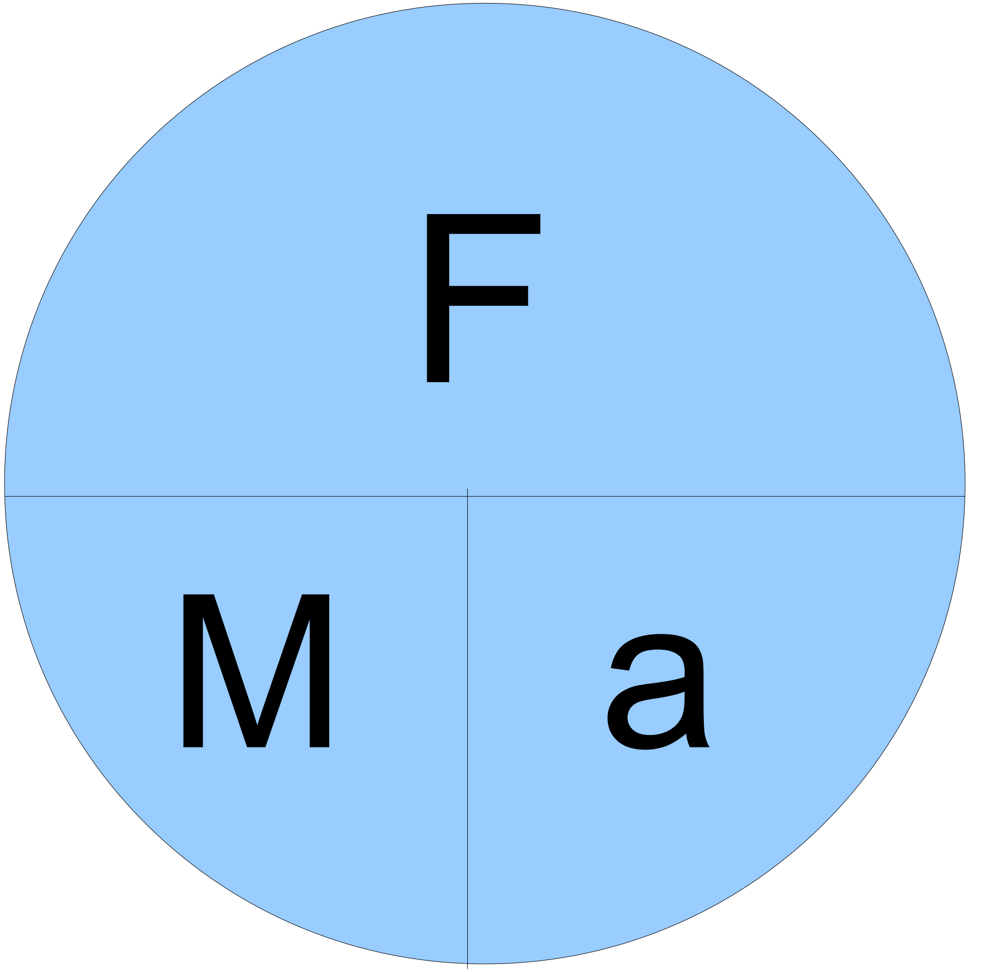
- $E_p = mgh$ $\qquad$ $E_k = (1/2)mv^2$
- The height of the swing can be used to calculate the potential energy (the point where the bullet and wood come to a stop and head in the other direction.
- This energy will equal the kinetic energy it had when the bullet struck. This can be solved for the velocity of the wood with the bullet in it. This will allow calculation of the bullet velocity by equating momentums.

Advantage of Knowing Algebra

- With the short Math Review, it is not necessary to memorize multiple versions of a given formula.
- In the next two slides look at the pains people go through to remember the three versions of Newton's Second Law.
- One chapter of the Radio Amateur Handbook is devoted to a math review.

Three Versions of 2nd Law

- F = M a, a=F/M, M=F/a
- Isn't this neat? Looks just like Ohm's Law.
- I had to use upper case F even though it could be time variant, because lower case “f” is spoken for.
- In some books lower case letters are understood to be time variant. You might see “a” for a(t). Vectors are bold print.



A way to help you remember Newton's Law

Aside, Math Review
Functions of time

- You should by now just know that:

  F(t) = M a(t) is the same thing you saw earlier.
- This reads: Force as a function of time is equal to the Mass multiplied by the acceleration as a function of time. You could say “a” depends on “t” if function is a strange word for you.
- M and a(t) are the independent variables or domain of the function (say time on the x axis).
- F(t) is the dependent variable or range of the function (say the answer on the y axis). UP

Aside, Math Review
Functions

- When you plot a function, say y=y(x)=f(x)=******, it will not double back on itself. This would mean, for a given set of inputs, there was more than one answer.
- The equation for a circle is a relationship. It is not a function.
- In our example, a vertical line, drawn anywhere on the graph, will only cross the plot one time.

Memorize
For the Rest of Your Life

$$\vec{p} = M\,\vec{v}$$

$$\vec{\boldsymbol{F}} = M\,\vec{\boldsymbol{a}}$$

Quiz

- What does momentum equal?
- What two things make the path of an object curve?
- What does mks stand for?
- What would the Mass weight divided by 32 equal?
- How far does the Gravity of my marble extend?
- F=Ma is:

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