<https://www.youtube.com/watch?v=TrrfVHpqmUw>

Smooth curve made using interpolation

Matlab costs money :( - can use matplotlib on python instead

Coefficient of resititution equation for time taken to fall = 2\*sqrt(2h/g)\*((1/(1-c))-½)

2 balls (1 big, 1 small), H/h = v^2/u^2=(C1-(m/M) + C2\*C1+C2)/(1+(m/M))^2

Make calculators for these equations in excel

H = (((2C+1)-(m2/m1))/(1+(m2/m1))^2\*h

Distance from centres to other centre during collision= > r1+r2

0 momentum frame V = (m1u1+m2u2)/(m1+m2)

0 momentum frame means velocities must be such that total momentum of frame = 0

(im good at coding but idk how to use excel so im going to use excel)

<https://www.youtube.com/watch?v=RKVS2FVbLAc>

Travelling to the moon uses only newtonian laws

Most basic astrophysics only requires newtonian laws until more gravity is added when general relativity is needed

G=6.67x10^-11m3kg-1s-2

Rate of area swept = 0.5\*sqrt(G(M+m(often insignificant))(1-epsilon^2)a)

epsilon=eccentricity of ellipse, eccentric if >0, 0=circle, 1=parabola, >1=hyperbola

Epsilon = sqrt(1-(b^2/a^2))

Moonfall = how much moon ‘falls’ - orbits and gets lower/closer to earth, following orbit

Moonfall can be calculated using pythagoras, newtons laws and galileos principles

Use ratios as axes for models

Time period = sqrt((3pi)/(Grho))

42 (answer to everything) = time taken to get from 1 point of earth to the other

Most planets in solar system follow ecliptic (2d model is ok) - pluto does not

Draw straight line between 2 planets every month n times (until circle is made) to create a spirograph

Can plot spirographs of whole solar system relative to 1 planet

<https://www.youtube.com/watch?v=v0mpRRfDQn0>

Light - best understood of all physical phenomena

Only means for us to understand cosmos well beyond inner solar system

Light is a wave - reflects, refracts, diffracts

Speed of propagation = c= 2.998x10^8m/s

Electricity and magnetism are linked in electromagnetism

All electromagnetic waves travel at the same speed

Field strength is proportional to current

Force between 2 charges = square inverse law

Wave speed is independent of relative speed of em wave source and receiver

Surface waves are vibrations of mediums

Have characteristic speed depending on density and stiffness of molecular bonds

Em waves are not vibrations of mediums, waves themselves move

Speed of light as a particle = c\*sqrt(1+v^2/c^2) - can not be correct

time progressing at a different rate dpeending on relative motions of two frames of reference

For speeds much less than c, moving frame = lab frame

No time elapses when moving at speed of light

So far Einstein’s special relativity has passed every test

Moving clocks run slow

Astronauts perspective = 7 years due to time dilation, earth perspective takes 11 years

Faster = larger gamma

Cosmic radiation creates muons in upper atmosphere

To travel 10km from upper atmosphere to earth, 15.5 half lives pass so most decay

As moving clocks run slow, ⅛ decay

Muon experiences 10km as 1.99km

Length is contracted - if times is different, length is different also

Loss of simultaneity - clocks become shifted

Twins paradox - earth twin would be older than astronaut twin, to astronaut earth twin would be younger

Loss of simultaneity - frame of reference going back is not same as going forward

Earth bound twin is older by 4 years due to considering lorentz transforms, as reference frames change, time dilation can not be applied

Lornetz transforms cause all to be squished

Loss of simultaneity result causes difference in time, loss in time due to changed reference frame

Extra earth time = missing time

Twins paradox is thus not a paradox

During deceleration, earth time speeds up, during acceleration, time slows down, when not moving, earth time is the same

From spacecraft perspective, during acceleration earth time is time dilated

All comes from c being constant

<https://www.youtube.com/watch?v=nExrYszBIZ0>

All waves are decompositions of sine waves

C = f\*lambda

F = 1/t

Omega = 2\*pi&f

K = 2\*pi/lambda

Omega = c\*k

Acos(kx-omega\*t-phi)

Example of standing wave - guitar string

Time variation remains the same

L = 2n-1

Frequency intervals of simple fractions yield harmonious music

Octave = frequency ratio of 2 (\*2/2)

Equal tempered scale divides octave into twelve parts such that fn=2n^n/12=^n/12sqrt(2)

Using smoke machine, lasers can be seen to fan out to make interference pattern

Fermats theorem - time taken to travel from a - b is minimised - most likely path, although all paths are taken

Travel time is minimised when sin(theta) = sin(phi), theta=phi

For refraction time is minimized when n1sin(theta) = n2sin(phi)

Any light rays going horizontally through a perfect ideal converging biconvex lens end up going through the focus some point behind the lens

Can help with coordinate transform

Can also be done through magnifying glass

Images in spherical/concave mirror are real

Upright, distorted virtual image seen in cylindrical image

Make photograph cylindrical and surrounding unit circle

Y extent = range

X extent = arc

* Anamorphic images

Doppler effect = source of waves comes towards you

Waves catch up with observer

Waves produced as you move, wavelengths thus change depending on relative distance to observer

Doppler effect = ratio of speeds times frequency

Machs construction - when travelling faster than speed of waves themselves

Mach number = u/c

At sub-sonic speeds, doppler effect occurs

At sonic speeds shockwaves occur

<https://www.youtube.com/watch?v=ZI2Htkp1ms0>

Ratio of electrical forces between 2 particles compared to gravitational forces = 4.2x10^42

Energy per unit charge = sum of potential differences

P = epsilon^2R/(r+R)^2

Pvi = curve - looks quadratic

Pvr = strange curve, irregular

Max power = epsilon^2/4r, when R = r

Positive and negatives charges each manifest electric fields, and magnetic if moving, fields go out from charge

Force between charges = inverse square law

Charge \* electric field strength = force

With more than one charge in one system, charges are added as vectors

Charges can be rings or points

Plates of charges form uniform electric fields between charges

Capacitance - when in parallel, are added

When applying a voltage across capacitor plates, charge is separated within capacitor by current

Charge that is separated is proportional to voltage

B = (mu0\*I/4\*pi) \* integral(dI\*(r-r’)/modulus(r-r’)^3)

Cyclotron - desktop device for accelerating particles

Particles introduced into cyclotron

Oscillating voltage within charges up particles

Magnet within causes circulation of particles

When current is alternated, particles accelerate faster and faster until eventually pops out through hole as very fast moving particle

Can achieve 1000000 eV

Every time particle reaches cyclotron frequency, particle gains boost in kinetic energy

<https://www.youtube.com/watch?v=PEsLEcUIZcA>

Thermodynamics = physics of heat

Temperature = mean kinetic energy of molecules

Absolute temp is proportional to mean ke of molecules

Heat engine extracts energy from hot reservoir to perform work, transferring energy to cold reservoir

First law of thermodynamics = total energy input into system = sum of useful work done by system and heat output

Second law of thermodynamics = total entropy change for any change in system >= 0

Combining laws, efficiency of heat engine >= 1-ratio of cold reservoir temp to hot reservoir temp

Carnot engine represents theoretical maximum efficiency achievable - challenging to realize in practice

Work done on gas within a cylinder = - pressure \* change in volume

Heat engines that rely on gas compression and expansion require this principle

Ideal gas equation = PV = nRT

Carnot cycle = theoretical thermodynamic cycle

Can be analyzed using isothermal processes and isentropic processes

Carnot engine operates through cycle of 4 processes: isothermal expansion, isentropic expansion, isothermal compression, isentropic compression

Rectangle on temperature entropy graph - area = total work performed by engine during 1 cycle

Work generated by gas is counterbalanced by decrease in internal energy - reduction of gas’s temp

Carnot cycle’s efficiency = 1-Tc/Th

Autocycle = compressing substance adiabatically at atmospheric pressure, increasing pressure by adding heat at constant volume, expanding without heat exchange and releasing fuel at constant volume

Diesel engines compress adiabatically and then expand by adding heat and increasing volume at constant pressure - isobaric process

sqrt(mean displacement in a random walk^2) = L\*sqrt(num steps)

<https://www.youtube.com/watch?v=Qlfv77GPS5Y>

Equations can be represented in excel to solve differential equations

Can be visualised by dragging down equations in excel to create curves

Differential equations can be solved using matlab code - use for loop to iterate through equations

Comments in python are used to explain code functionaility

Square brackets for array indices

Apps can create interactive visualization of models

Apps allow for adjustments to parameters, displaying resulting changes

Who used similar models to track ebola outbreak

Stochastic processes should be used to account for randomness and probability

Poisson distribution = describes probability of certain number of events occurring in fixed interval of time and space

Can be used to model spread of epidemic

Mean of poisson = average number of events in given interval - determines shape of distribution curve

Poisson distribution used to model change in number of susceptible, infected and dead individual over given time step in context of epidemic model

Covid 19 provided useful data for future analysis

Uk requires death certificates therefore covid 19 mortalitiy rates are reliable

Sir equations used to estimate covid 19 infections during pandemic

Rate of change of deaths = proportional to number of infected individuals

Linear interpolation necessary to evaluate models at specific times

<https://www.youtube.com/watch?v=kWlaGmsh9Mg>

Newton’s 2nd law allows future positions and velocities of objects to be predicted if current positions and velocities are known

Quantum mechanics introduces randomness at smallest scales - impossible to measure position and momentum with infinite precision

Simple deterministic systems with few elements exhibit seemingly random behaviour - chaos - due to non-linearity and sensitivity to initial conditions

Interconnectedness of universe means causality is not easily computable

Chaos = unpredictable oscillations

Octave = free matlab

Excel = drag formula across cells

Logistic map equation can be used to explore chaos

Lists in python similar to vectors in matlab

Graph of iterations of a function show values can converge to a point after iterations

Bifurcation occurs when functions increase - lead to chaotic behaviour

Before this point - stable equilibrium reached - stabilizes at single value

Bifurcation = 2 possible values

Logistic maps reveal regions of stability and chaos

Exhibits fractal structure - appears similar at different scales

Ratio of successful bite successive bifurcation intervals is a universal constant, similar to Pi, irrational

Logistic map can be visualized using cobweb diagram

Probability map created by taking all possible values after certain number of iterations, creating bins, seeing how many final values fall into each bin

<https://www.youtube.com/watch?v=2dgpDPq9H9w>

Diagrams are helpful + algebra to solve physics problems

Programs can be created to demonstrate energy losses in systems with change in velocity

Speed of separation = speed of approach for elastic collision

During explosions, coefficient of restitution may be < 0 or > 1

Dimensionless = pure number

Analysing dimensions allow units to be determined

Dimensionless variables have no units

Newtons 2nd law can be used to find angle at with object accelerating sits on surface

Contact force = weight/cos(theta)

Acceleration = g\*tan(theta)

<https://youtu.be/oia1E6q4eVI?si=CuCkto9qzp0NUF-e>

Strain = thickness of bar/2\*radius of curvature

Radius of curvature = thickness of bar \* YM/2\*stress

Trigonometry and implicit differentiation can be used to relate the angle of observation, speed of an object and the time elapsed

Derivative of tan(theta)\*derivative of theta = H/V \* derivative of 1/T = -1/t^2

Critical angle occurs when light passes from medium with higher refractive index to lower refractive index and angle of refraction = 90 degrees

Snells law used to calculate critical angle

Critical angle = angle of incidence at which total internal reflection occurs

Refractive index of air often approximated as 1.0

Critical angle = sin^-1(1/n)

Capacitance = Q/V

Energy in capacitor = ½\*C\*V^2

Capacitance is proportional to area of plates

Capacitance is inversely proportional to distance between plates

Work required to separate plates = 4\*epsilon\*a\*v^2/d

<https://youtu.be/_2ofqnyiAVY?si=Pgi3cmi-ebsEoCFl>

Wiens law = wavelength at peak of planck spectrum is inversely proportional to absolute temperature

Can be used to determine temp of a star by measuring wavelength at maximum intensity of its spectrum

Weins displacement law = inverse relationship between wavelength of light emitted by star and its temperature

Can be used to calculate maximum emission wavelength of star at specific temperature

Stefan’s law = power radiated from star is proportional to stefan’s constant \* area of star \* emissivity \* absolute temperature^4

Size of crater created by meteorite impact is dependent on ke of meteorite, density of impacted rock, gravitational field strength of planet

Dimensional analysis can be used to determine relationship between variables

Barringer crater is large impact crater in america

Mass of meteorite creating barringer crater = 5.42\*10^8

Diameter can be calculated using diameter = 2\*(3\*mass/(4\*pi\*density))

## **ct Crater Size**

* The size of a crater (diameter D) created by a meteorite impact is dependent on the kinetic energy (E) of the meteorite, the density of the impacted rock (ρ), and the gravitational field strength (G) of the planet. Dimensional analysis can be used to determine the relationship between these variables.

## **Barringer Crater Meteorite**

* The Barringer Crater is a large impact crater located in America.
* The mass of the meteorite that created the Barringer Crater is calculated to be approximately 5.42 x 10^8 kilograms.
* Assuming the meteorite was spherical and composed of iron with a density of 8,000 kilograms per cubic meter, the diameter can be calculated using the formula: diameter = 2 \* (3 \* mass / (4 \* pi \* density))^1/3.
* A calculation is performed to determine the diameter of a meteorite based on its density (8,000) and other factors. The result is approximately 51 M.