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# Physics 101, Lesson #4
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# dx     = displacement (delta-x)
# t      = time
# a      = constant acceleration
# v0     = initial velocity
# v      = final velocity
# g      = gravity at -9.81 meters per second^2

# Lesson #1 Kenetic Equations
# The 4 equations are:
# (1) v = v0 + (a * t)
# (2) dx = ((v + v0) / 2 ) * t
# (3) dx = (v0 * t) + (1/2) * a * t^2
# (3) Equation of Motion: y = y sub-zero + V sub-zero sub-y * time + 1/2 * a * t^2
# (3) Parabolic Motion = Horizontal and Verticle Equations:
#       Horizontal = x =  V (sub-x) * t
#       Vertical   = y = (V sub-y * t) + (1/2 * (a * t^2)) (where a = gravity)
# So y = (V sub-y /  V sub-x) * x -  (1/2 * (g * (x^2 / V sub-x^2)))
# (4) v^2 = v0^2 + 2 * a * dx (remember to square root the right side of the equation
#                               to get vf squared)
# Lesson #2 Freefall Equations
# (5) distance = 1/2 * a * t^2
# (6) time to ground is (d * 2) / g = t^2 OR t = sqrt( (d * 2) / g) How much time to drop from a known height (ball drop)
# choose the formula that has BOTH the Unknown Variable AND three of the known variables

# Lesson Trig Review see separate file

# Lesson #3 Motion in two dimensions - Projectile or ballistic motion
# Horizontal motion is independent of verticle motion

# Lesson #4 Newton's Laws of Motion
# Relationships between force, mass, and acceleration
# First Law   - Inertia: Objects at Rest stay at Rest; Objects in Motion Stay in Motion until Acted Upon
# Second Law  - Mass:    An Object's Mass in the Ratio of the Force Appl;ied to the Object devided by Acceleration or
#              m = F / a or F = m * a Second Law
#              Mass is a Mesurement of Interia
#              Mass is in Kg, Acceleration is m/s^2 (meters / second squared), and force is N or newtons
#              Acceleration towards Earth is Gravity, the force keeping something hanging in air is Tension
# Third Law   - For Every Force there is an Equal but Opposite Force

# Lesson #5 Free Body Diagrams, or the ability to measure G, the force of gravity (on Earth)
#          Using Atwood machine to measure G at Earth's surface
#          Gravity is said to be a Fundamental Force, along with Electromagnetic force, and the Weak and Strong Nuclear forces

# The Free Body Diagram is a diagram of all the forces acting on an object (or body), and Free means just the object alone
# So let's look at a small object, say a small bottle in free-fall on the Earth's surface
# We know that one force, gravity, say F sub-g, is acting on the bottle at 9.81 m/s^2 with a down arrow vector pointing to the Earth
# In this case F sub-g is = to mass * gravity. That's the same as Projectile Motion! Only gravity is acting on the kicked soccer ball
# Another acting force is air resistance, say for parachuter: F sub-g vectors downward but F sub-air vectors upward (not equal)
# So here the sum of forces EF = F sub-air + F sub-g = 0 (note that the 'E' is a symbol that looks like a backward music quarter rest)
# Note the plus of air a gravity. That's because g should have the vaue of -9.81 m/s^2 with negative forces vectored to the Earth
# When an object (a body) reaches EF of 0 it means it has reached Terminal Velocity where up Force balances down force and the body
#    stops accelerating
# Now lets look at a Body in an Elevator, which we can consider to be a Scale (s)

# Lesson #6 Friction
# Also involves Inclined Planes
# Friction exerts a force opposite to an object's motion, especially on surfaces
# Open space has no effective friction
# The molecules on the surfaces of two rubbing surfaces like to stick due to related charges of the various atoms
# Friction depends on two main factors: (1) The make-up of the surfaces;
# and (2) the greater the force to exerted against each surface the greater the friction, or
# the Normal Force Perpendicular to the surface(s)
# The greater the Normal Force the greater the Friction

# F sub-f = c-f * F sub-n Where c-f (Greek letter mu) = the coeficient of of the make-up of the surface(s) and F sub-n is the Normal Force
# Two types of Friction:, Kinetic and Static, it takes more force to go from static friction to kinetic motion so static friction is bigger

# Lesson 7 Circular motion
# Is found everywhere
# So to Newton, you need a force to keep you going in a circle (inertia)
# Consider driving in a car and turning right or left, a force 'pushes' you in the opposite direction
# So a force pushes you into a circle in the same direction as the motion
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# Consider an egg in a harness attached to a string with length r swung in a circle with radius r
# The egg's inertia wants keep going straight, but the string's tension prevents it from going in a straight line
# We would feel the tension as an outward force, but it is really directed inward to the circle's center
# Linear speed is the egg along it's motion path
# Angular speed is the speed of the rotation
# So the Force is proportional to the object's mass and velocity and inversly proportional to the radius
#
# the formula for circular motion is         F = m * v^2 / r
# m is kg, v is m/s^2, r is meters so,       F = kg * meters^2 / meters * seconds^2
# meters cancels meter^2 to just meters, or  mass * meters * seconds^2, = Newtons
# This is Centripetal Force (not centrifugal) pulls inward
# Acceleration                               a = v^2 / r

#%%
import numpy as np

# have 1 kg ball
m = 1.0
r = 2.0
t = 2.0 #ball rotates on rope in the circle every two seconds
c = np.pi * (r * 2)
a = c / t
Fsub_c = (m * a**2) / r

# Turning on a flat road, friction keeps you on the road
# What bank, or slope, can we put on a circular track, such that the car will drive around the track with no hands on the wheel
# Free body diagram

print(f'{m}  {a}  {a**2} {r}')
print(f'c is {c:.2f} and a is {a:.2f} and circular force is {Fsub_c:.2f}')


# %%

#%%

# Now let's add slope to the picture: Problem Two Cow on Hill, how steep the slope before the cow must fall down the hill?
slope = 0.0  #theta
# So normal force on the cow is perpendictular to the ground, angle down the slope, and 90-degrees to the slope
# SOH CAH TOA time, we will use sine and cosine
# down slope is sin of theta or                      -m*g*sin(slope)
# and 90-degrees to slope will be cosine of theta or -m*g*cos(slope)
# force uphill away from cow is the friction force, Fsub-f = mu * Normal Force, now +m * g * cos(slope)
# So force keeping the cow on the hill is mu * mass * g * cos(slope)
a = 0.0 #acceleration is zero when the cow is in place on the hill
# mass * gravity cancels out so mass does not matter!
# mu * cos(theta) = sin(theta) slope is theta
# mu = sin(theta) / cos(theta), so mu = tan(theta)
# tan(theta) = mu

# Kinetic Friction, Problem: Car skidding with the car's brakes
# Free Body Diagram"
# Car moves forward with vector v0 (inital velocity)
# There is an equal-but-opposite force to v0 that is F sub-f
# The dowward force is gravity. Say the car weighs 1,000 Kg and so

# Friction is F sub-f = c-f * F sub-n
mass = 1000.0 #kg
g = -9.81       #m/s^2
Fsub_g = mass * g
c_f = 0.7    #mu friction coefficent
Fsub_f = c_f * Fsub_g
# Newton f = ma, f = mass * a, f/a = mass, a = mass/f
v = (Fsub_f) / mass
# print(f'{mass}, {g}, {Fsub_g}, {c_f}, {Fsub_f}, {v}')
# print(f'Normal Force = {Fsub_g} Newtons, so F sub-friction = {Fsub_f} Newtons and volocity = {v}')


# %%

#%%
# if the Elevator Car is not moving then the Force sub-s = the Force sub-g
# Problem #1: A Body in an Elevator Car, does the body weigh more or less than when weighed 'at home'
# No, F sub-g is constant. The car pushes up on the scale and the scale pushes up on the body, but the car is not moving, it
#   is zero, so the object weighs the same as at home

m1 = 79.0    #Kg
m2 = 65.0
gD = -9.81  #m/s^2
gU = 9.81
g  = 9.81
t  = 2.15  #seconds
```

```python
t  = 2.15  #seconds
d  = 2 #meters
#2 meters (d) = .5 * a * t^2, 2/a = .5 * t^2, a = 2 / .5 * t^2()
a = d / (.5 * t**2)

# fDown = m1 * gD
# fUp   = m1 * gU
# print(f'force down of {fDown} and up of {fUp} equals {fDown + fUp} ' )
# Problem 1a: Now the Car is moving upwards which means the Body is accelerating (upwards): Now how does affect it's weight?
# yes, F sub-g is constant but F sub-scale is greater than gravity so the Body weighs more - let's math it

# fDown = m1 * gD   #on car
# fUp   = m1 * gU   #on car
# fA    = m1 * a    #car pulled up
# print(f'force down of {fDown} and up of {fUp} and car pull up is {fA} so total up is {fUp + fA}' )

# Now to the Atwood Machine. m1 and m2 accelerate at the same speed and the tension on each mass is equal (see 1a)
mx = 50.0

gCalc = a * ((m1 + m2) / (m1 - m2))
aCalc = g * ((2*mx - mx) / (2*mx + mx))

print(f'calculated gravity is {gCalc} and aCalc is {aCalc} and gg is {.333 * g}')

# %%

#%%

# Problem: (a) 2 square cows on a table on ice skates with no friction
#              1 cow has a mass of 4 Kg and the other a mass of 2 Kg
#              Force = 12N, what is the acceleration?
# (b) With what force is bigger cow pushing on smaller cow?

m1 = 4
m2 = 2
N = 12.0

# F = m * a, so F / m = a
a = N / (m1 + m2)
print(f'force is 12N and total cow weight is 6 Kg, so accelation is {a} m/s^2')

# Problem b, F = m * a
F = m2 * (a)
print(f'force on cow 2 is {F} newtons')

#Problem: 1 cow (1kg) hangs from tree and another cow (2kg) hangs from that cow, what are the forces?
# t1 = m1 * -g
# t2 = m2 * -g
# t3 = m1* g

# %%

#%%
import matplotlib.pyplot as plt
import numpy as np
import math as mt

a  = 2.0
t  = 1.0
g  = 9.81
v0 = 30.0
v  = 0.0
d  = 10.0
distance  = 4.0
seconds = 0.0
velocity = 0.0
theta  = 60

# now to projectile motion

# Problem Romeo and Juliet
# J is on the ground 4 meters from house wall and throws a object up at a 60-degree angel
# J's object leaves her hand about 1 meter off of the ground at about 30 m/s
# Romeo's window starts at about 6 meters from the ground
# SOC CAH TOA for time to het the wall, that is 4 meters
# Try CAH for horizontal velocity, or time to hit the wall

x = mt.cos(mt.radians(theta)) * v0
print(f'x  =v0 * cos of theta is adjacent side of {x:,.0f} meters/second over')
y = mt.sin(mt.radians(theta)) * v0
print(f'y = v0 * sin of theta is opposite side of {y:,.0f}  meters up')
z = distance / x
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# # Equation of Motion is (3 above)
a = 1 + (y * z) + (0.5 *(g * z**2))
print(f'a is {a:,.2f}  meters up')

# Parabolic
x = (v0 * z) #- distance
y = (v0 * z) + (0.5 *(g * z**2))

print(f'x of {x:,.2f}  meters y of {y:,.2f} meters ')

# Problem kick ball at initial velocity at some angle = how high and how far?
# Let's use trig - the SOC CAH TOA
# at highest point is Opposite
# x = mt.cos(mt.radians(theta)) * v0
# y = mt.sin(mt.radians(theta)) * v0
# print(f'v0 * cos of theta is adjacent side of {x:,.0f} meters over')
# print(f'v0 * sin of theta is opposite side of {y:,.0f}  meters up')
# timeToGround  = y / g * 2
# print(f'for a total flight time of {timeToGround} ')
# print(f'so total kicked distance is {x * timeToGround}')

# Have cliff 10 meters high and rocks extend about a meter out at the bottom
# How fast do you have to run to get past the rocks?
# %%
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