MŰEGYETEM 1782

Physicist-Engineer BSc

Problem solving in Physics

Forces (mechanics) 2.

attendance:
https://forms.office.com/r/gHgLHJiqak

Budapest, 2023 October 10

Significant Digits

Rules for Counting Significant Digits:

- All non-zero digits and any zeros contained between non-zero digits count.

  300042 = 6 significant digits

- Leading zeros don't count.

  0.000034 = 2 significant digits

- Trailing zeros count if there is a decimal point.

  0.0002500 = 4 significant digits

- Trailing zeros may or may not count if there is no decimal point, so we go with the most conservative answer.

  190000 = 2 significant digits (could be up to 6)

Precision of operations

Rules for Calculating With Significant Digits:

- When adding or subtracting, round the answer to the least number of decimal places.

$$\begin{array}{r} 1.457 \\ +\ 83.\underline{2} \\ \hline 84.657 \end{array}$$

rounds to $84.\underline{7}$

$$\begin{array}{r} 0.\underline{0367} \\ -\ 0.004322 \\ \hline 0.032378 \end{array}$$

rounds to $0.\underline{0324}$

- When multiplying or dividing, round the answer to the least number of significant digits.

$$\begin{array}{r} 4.36 \\ \times\ 0.000\underline{13} \\ \hline 0.0005668 \end{array}$$

rounds to $0.000\underline{57}$

$$\frac{12.300}{0.0\underline{230}} = 534.78261$$

rounds to $\underline{535}$

Write numbers in scientific notation, with a precision of 3 significant digits

0.00012309991 = ?

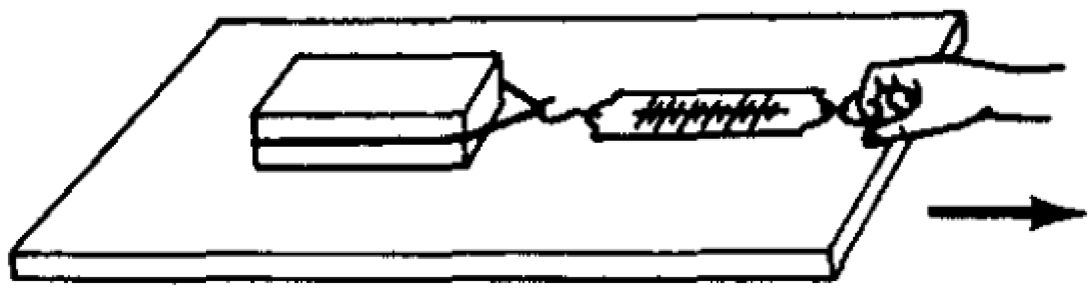
A) 12.3e-5 = $12.3 \cdot 10^{-5}$

B) 1.23e-4 = $1.23 \cdot 10^{-4}$

C) 1.231e-4 = $1.231 \cdot 10^{-4}$

D) 0.124e-3 = $0.123 \cdot 10^{-3}$

Force: push or pull exerted by an object on an another object. Can be measured by spring. Can lead to deformation, or change in motion. A vector quantity.



What causes them:

Elastic $\mathbf{F}_{\mathrm{el}} = -k\mathbf{x}$

Frictional $\mathbf{F}_{\mathrm{f}} = -\mu \mathbf{F}_N$

Air resistance (drag)

$$\mathbf{F}_{\mathrm{drag}} = -\rho C_d \frac{A}{2} v^2 \frac{\mathbf{v}}{v}$$

$$\mathbf{F}_{\mathrm{Stokes}} = -6\pi\mu R v \frac{\mathbf{v}}{v}$$

Gravitational $\mathbf{F}_{\mathrm{G}} = G\frac{mM}{r^2}\frac{\mathbf{r}}{r}$

Electric (Coulomb) $\mathbf{F}_{\mathrm{C}} = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2}\frac{\mathbf{r}}{r}$

Magnetic (Lorentz)? $\mathbf{F}_{\mathrm{L}} = q\mathbf{v} \times \mathbf{B}$

What role they play:

Centripetal $\mathbf{F}_{\mathrm{cp}} = m\omega^2 r$

Normal $\mathbf{F}_{\mathrm{N}}$

Newton's laws of motion (dynamics)

1. A body remains at rest, or in motion at a constant speed in a straight line, unless acted upon by a force.
2. When a body is acted upon by a net force, the body's acceleration multiplied by its mass is equal to the net force.
3. If two bodies exert forces on each other, these forces have the same magnitude but opposite directions.[2]

$$\sum_j \mathbf{F}_j = \mathbf{F}_{\text{total}} = m\mathbf{a}$$

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

[2]: "For every action, there is an equal and opposite reaction"

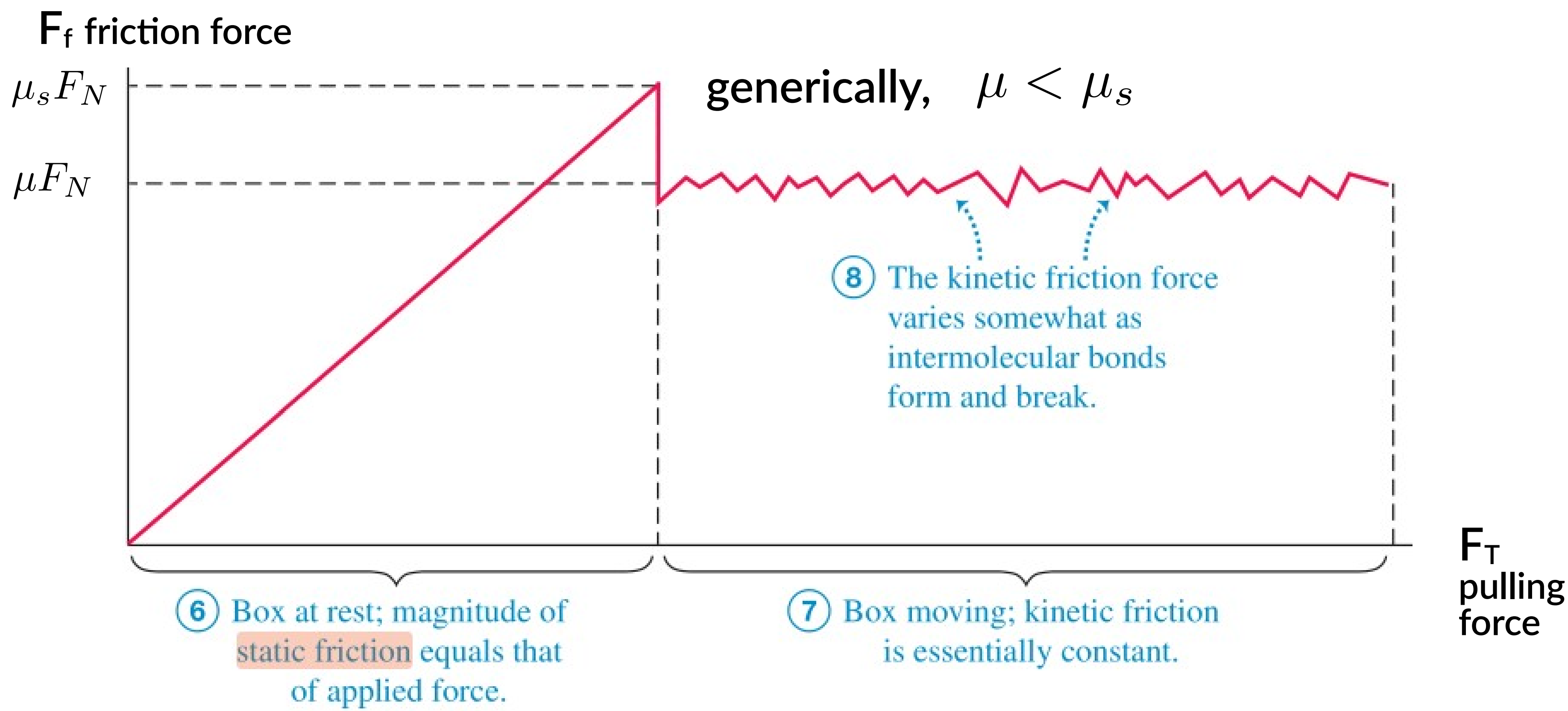
Static friction: can take any value up to the limit $\mu_s F_N$

static friction

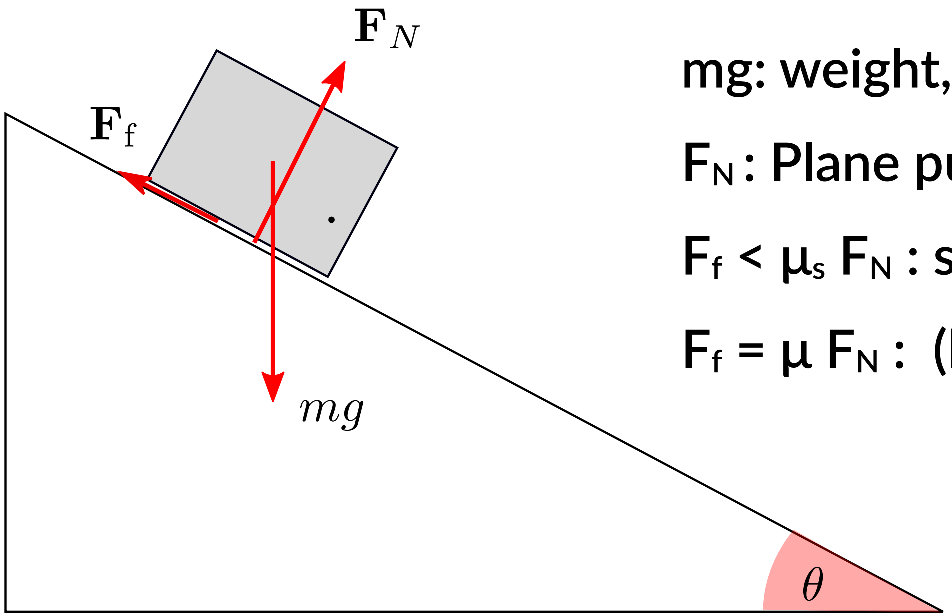
$$F_f < \mu_s F_N$$

kinetic friction

$$F_f = \mu F_N$$



Example: given μ_s , at what angle does the box start to slip?



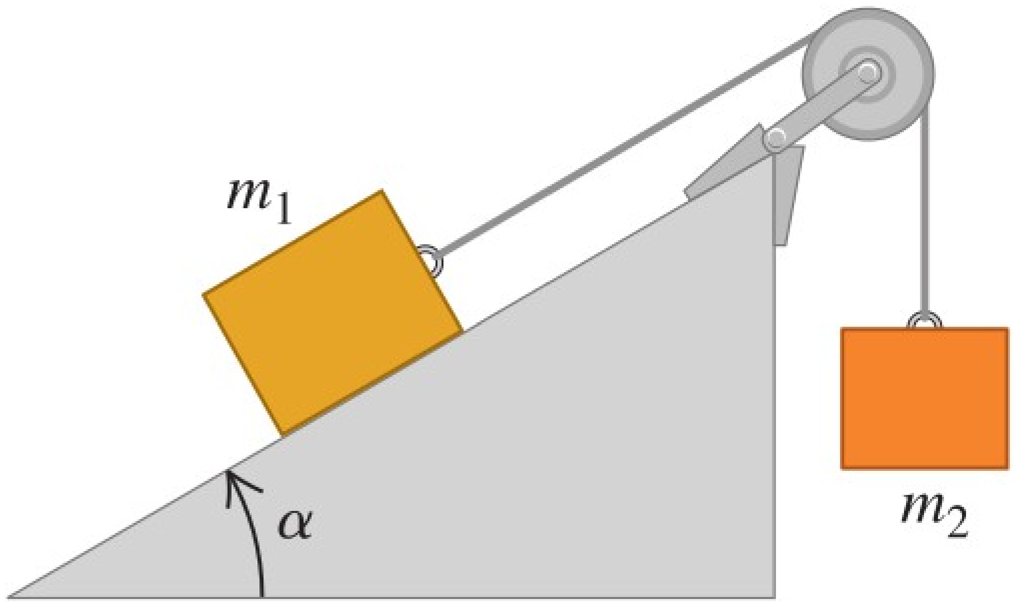
mg: weight, gravitational pull of Earth

F_N : Plane pushing on block, normal force

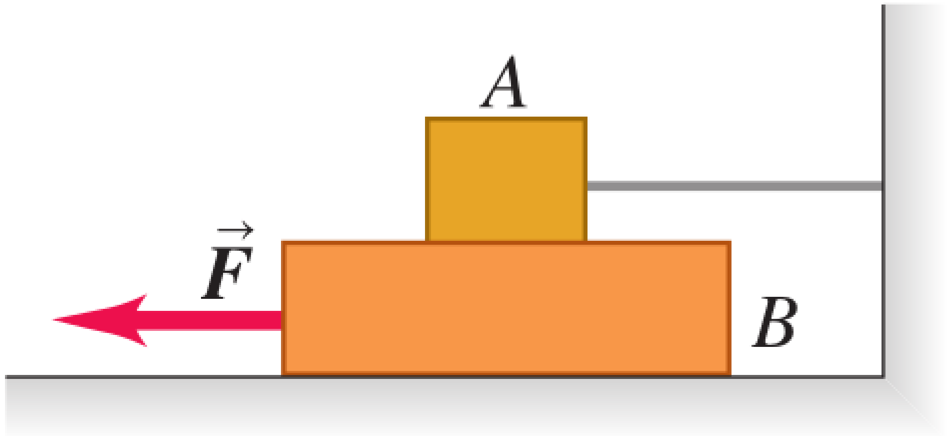
$F_f < \mu_s F_N$: static friction force

$F_f = \mu F_N$: (kinetic) friction force

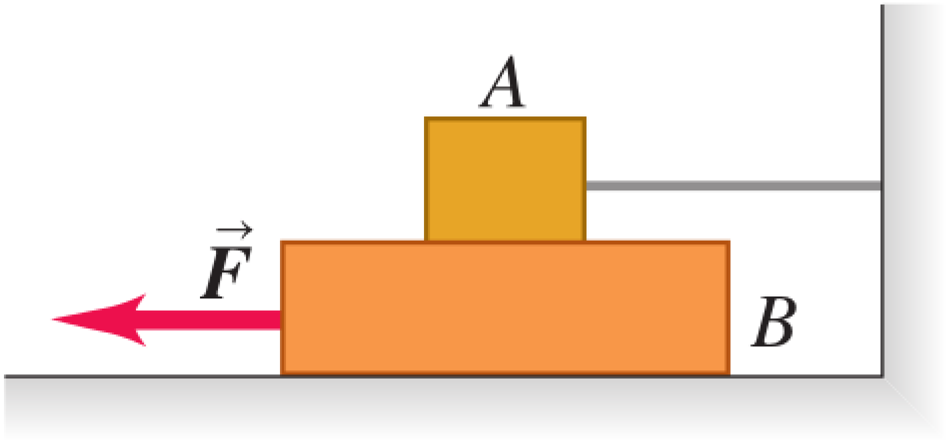
Example: given μ_s , at what angle does the box start to slip, if m_1=m_2?



What is the force required to get box B moving, if box A is tied to the wall? The static coefficient of friction is μ_s=0.33 between all surfaces, m_B=$2m_A$=2 kg?



How does the force required to get box B moving, change, if masses of both boxes are increased by a factor of 2?



A) Increase 2-fold

B) Increase 4-fold

C) Decrease to ½ of original

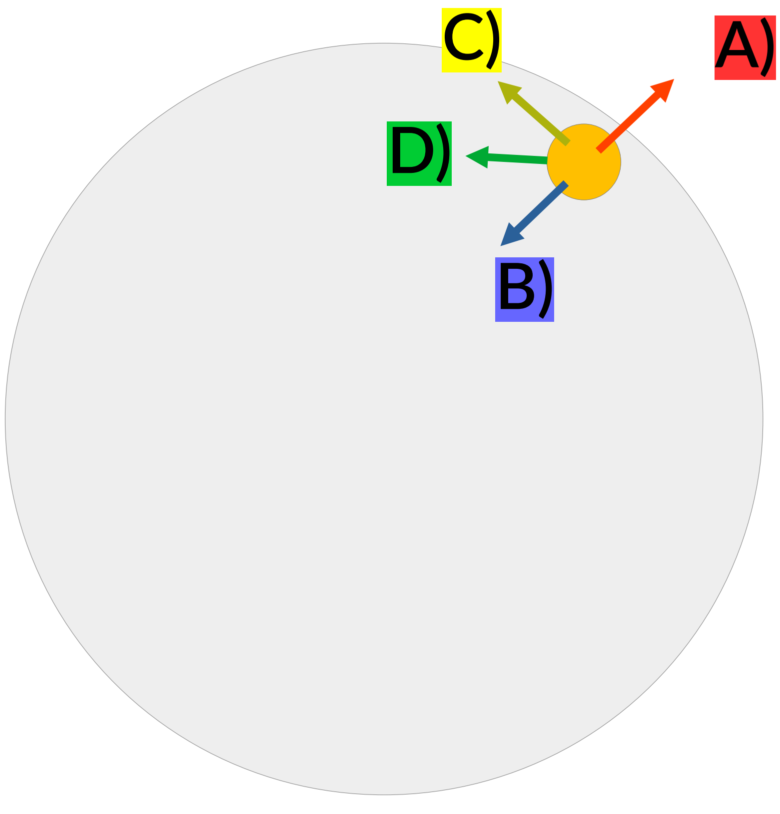
D) Does not change

Direction of static friction force: as required to keep the object still on the surface

Free-body diagram for an accelerating car

Direction of static friction force: as required to keep the object still on the surface

Coin on a uniformly rotating record player, held in place by static friction, top view. Which vector represents the static friction force on the coin?



Action-reaction counterpart of static friction

A coin on a rotating record player is held in place by static friction. Which force is the action-reaction counterpart of the static friction force exerted by the record player on the coin?

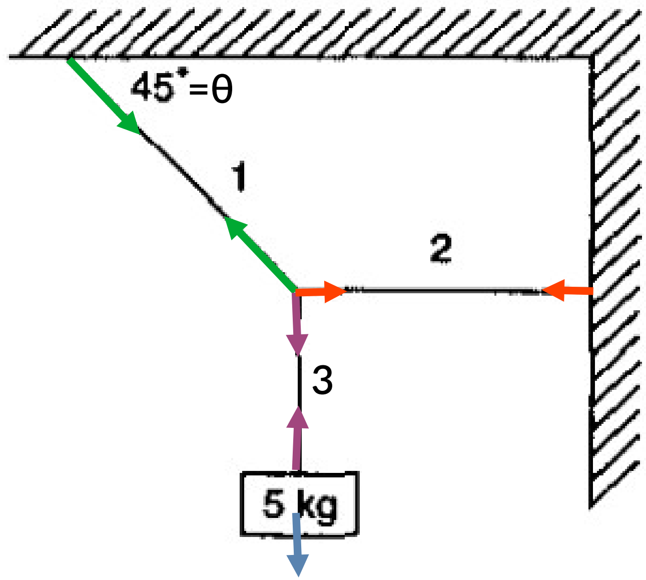
A) static friction force exerted by coin on record player, pointing away from center

B) static friction force exerted by coin on record player, pointing towards center

C) centrifugal force pointing away from center

D) air resistance

Static equilibrium: sum of all forces on a body must be 0. Can be used to deduce some forces



All ropes have negligible mass.

Body in equilibrium:
$mg = F_3$

Knot in equilibrium:
$F_1 \sin\theta = F_3$
$F_1 \cos\theta = F_2$

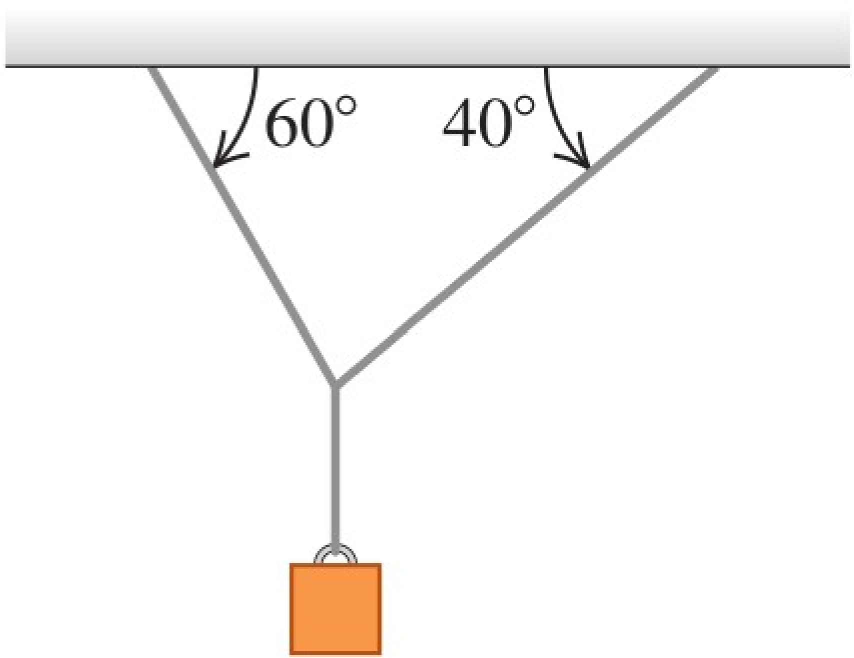
Ropes have 0 mass, Force/counterforce:
Colored forces are equal in magnitude

$$F_2 = F_1 \cos\theta = \frac{F_3}{\sin\theta}\cos\theta = \frac{mg}{\tan\theta}$$

in this case, rope 2 pulls the wall with the same force as the weight of body:
$F_2 = mg = 5*9.81N = \underline{\underline{49.05N}}$

Discussion: What if angle θ is really small?

Which rope has greater tension (larger force in it?)



A) The rope on the left

B) The rope on the right

C) Equal tensions

D) Depends on how heavy the mass is

Uniform circular motion: sum of all forces has to point to the center (centripetal force)

A steel ball of mass 500 g is attached to a spring, with unstretched length l_0=20 cm, spring constant k=200 N/m. We are swinging it around on a roughly horizontal plane, with a frequency of 100 RPM.

What is the elongation of the spring?

Hooke's law for force exerted by spring elongated by x: $\mathbf{F}_{\mathrm{el}} = -k\mathbf{x}$

Newton's 2nd law is very important: it allows us to predict the future

$$\sum_j \mathbf{F}_j = m\mathbf{a}$$

from time t to t+dt, the object

1. moves because it has a velocity (need to update its position)
2. accelerates because it has an acceleration (update velocity)
3. experiences forces (according to position, velocity)
4. $\sum_j \mathbf{F}_j = m\mathbf{a}$ (update acceleration)

Aim: plot trajectory, `plot(t, x)`, `plot(t, y)`, `plot(x, y)`. Algorithm:

1) Preparation: empty lists for t, x, y values.
2) Initial conditions: set t, x, y, vx, vy

3) *Loop*:
   * 0) $t_{new} = t + dt$
   * 1) $x_{new} = x + v_x*dt$; $y_{new} = y + v_y*dt$;
   * 3) $v_{x,new} = v_x + a_x*dt$ $v_{y,new} = v_y + a_y*dt$
   * 2) $a_x = sumF_x(x,y,v_x,v_y)/m$; $a_y = sumF_y(x,y,v_x,v_y)/m$
   * 4) append t, x, y values to the lists
   * 5) $x=x_{new}$, $y=y_{new}$, $v_x=v_{x,new}$, $v_y=v_{y,new}$

4) Plot the trajectories

Summary

- Forces are vector quantities that change the state of motion of objects.
- The inertia of an object is the tendency of the object to resist a force changing its state of motion.
- Inertia is proportional to the mass of the object.
- The sum of all the forces acting on a mass is called the net force.
- If the net force acting on a mass is equal to zero, the mass is in equilibrium.
- If an object is not moving in a given frame of reference, it is in static equilibrium.
- An object can be in dynamic equilibrium if it has a constant velocity in a given frame of reference.
- The centripetal force is a net force that acts toward the center of the circle.
- The centrifugal force is a ficticious force that is observed only in an accelerated frame of reference.
- Friction is a force that opposes motion as an object slides along a surface or as two masses slide against each other.
- The normal force is a force directed perpendicularly away from a surface.

Write numbers in scientific notation, with a precision of 3 significant digits

Please practice this

0.001200340056 = ……………………….
1200340056 = ……………………….
0.001295503056 = ……………………….
129550340056 = ……………………….