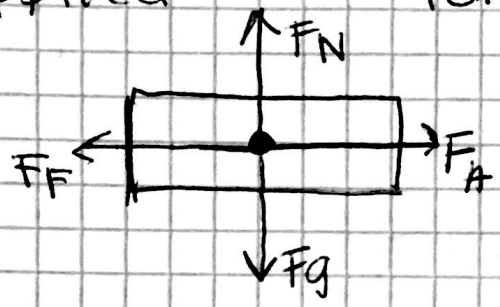
Title: Determining The Coefficient of Friction (31)

Date: 15 SEPT 2016 Exemplar (pre-lab)

1)

a) - Force of Friction
- Force Applied
- Force Normal
- Force Gravity

b)



c) y-direction: $\Sigma F = F_N = F_g$

because:

$\Sigma F = F_N - F_g = ma$

$\Sigma F = F_N - F_g = 0$

$\Sigma F = F_N = F_g$

x-direction: $\Sigma F = F_A = F_F$

because:

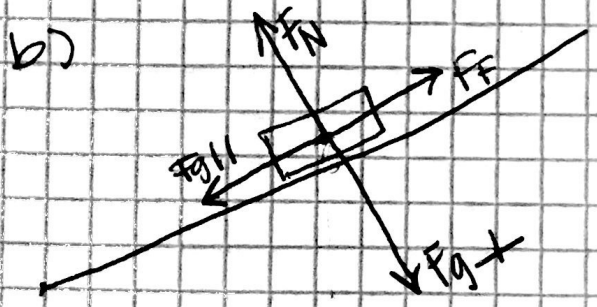
$\Sigma F = F_A - F_F = ma$

$\Sigma F = F_A - F_F = 0$

$\Sigma F = F_A = F_F$

2) a) - Force of Friction
- Force Normal
- Force of Gravity $\perp$
- Force of Gravity $\parallel$

b)



c) x-direction:

$\Sigma F_{\parallel} = F_F = F_{g\parallel}$

because

$\Sigma F = F_F - F_{g\parallel} = ma$

$\Sigma F = F_F - F_{g\parallel} = 0$

$\Sigma F = F_F = F_{g\parallel}$

$\Sigma F = F_F = F_{g\parallel}$

y-direction:

$\Sigma F_{\perp} = F_N = F_{g\perp}$

because:

$\Sigma F_{\perp} = F_N - F_{g\perp} = ma$

$\Sigma F_{\perp} = F_N - F_{g\perp} = 0$

$\Sigma F_{\perp} = F_N = F_g$

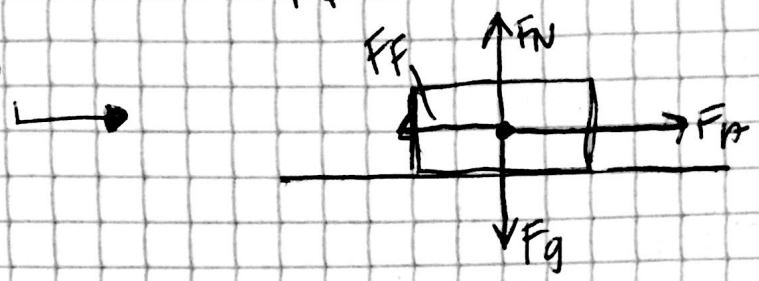
$\Sigma F_{\perp} = F_N = F_{g\perp}$

Title: Determining The Coefficient of Friction (33)

Date: 15 SEPT 2016

3. a) F_F = Force of Friction F_N = Force Normal
F_A = Force Applied F_g = Force of gravity

b)



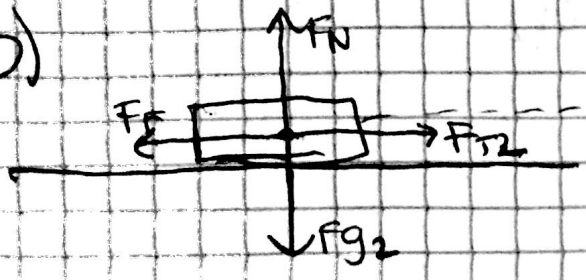
~~c) x-direction = because~~

c) The Free Body Diagrams of an object sliding across a horizontal surface with a constant velocity and the free body diagram of an object that accelerates across a horizontal surface are different. They are not equivalent because the Force of Friction and the Force Applied for an object moving at a constant speed are the same, but for an accelerating object, the applied force is greater than the force of friction.

d) ~x-direction = $\Sigma F = F_A - ma = F_F$
because:
$\Sigma F = F_A - F_F = ma$, where $a \neq 0$
$\Sigma F = F_A = F_F + ma$
~~$\Sigma F = F_A$~~
$\Sigma F = F_A - ma = F_F$

~y-direction = $\Sigma F = F_N = F_g$
because:
$\Sigma F = F_N - F_g = ma$, $a = 0$
$\Sigma F = F_N = F_g = 0$
$\Sigma F = F_N = F_g$

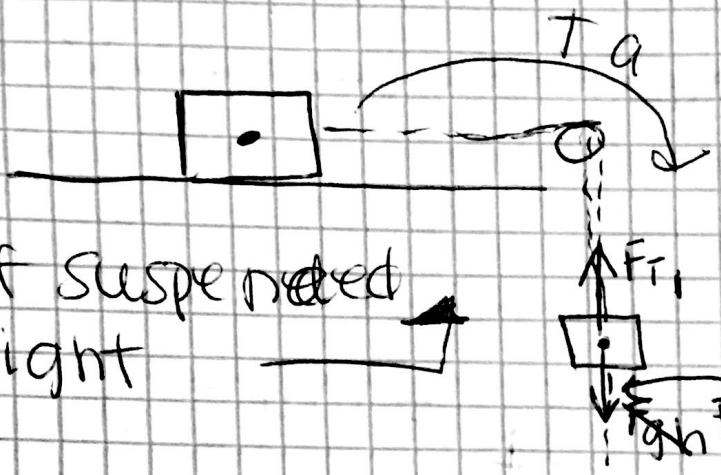
4) a, b)



FBD of the block

Title: Determining the coefficient of Friction (25)
Date: 15 SEPT 2016

a)



c) The force of tension is common to both of the free-body diagrams.

d) F_T is used to denote the force of tension in both diagrams.

e) Suspended weight
~~x-direction:~~
y-direction:

$$\Sigma F = F_{g_1} - F_{T_1} = (m_1 + m_2) a_{sys}$$

Block
x-direction

$$\Sigma F = F_{T_2} - F_F = (m_1 + m_2) a_{sys}$$

y-direction

$$\Sigma F = F_N = F_{g_2}$$

because

$$\Sigma F = F_N - F_{g_2} = ma = 0$$

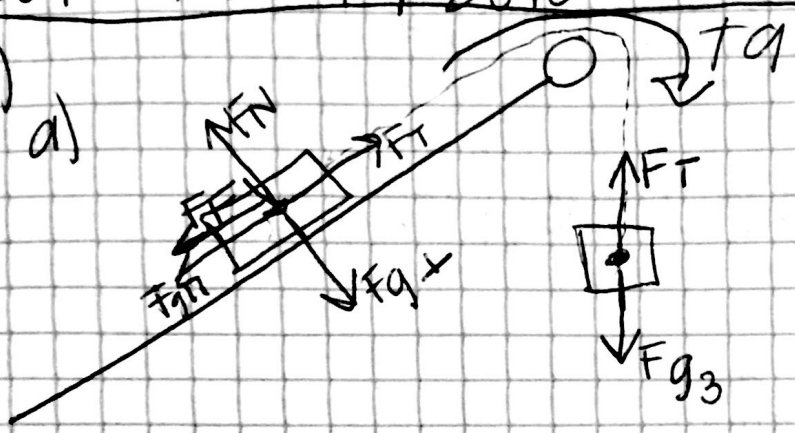
$$\Sigma F = F_N = F_{g_2}$$

Title: Determining the coefficient of Friction

Date: 16 SEPT 2016

5)

a)



b) Suspended Weight

y-direction:

$$\Sigma F_n = F_{g_1} - F_{T_1} = (m_1 + m_2)\, a_{system}$$

Block:

x-direction

$$\Sigma F = F_{T_2} - F_F - F_{g_{11}} = (m_1 + m_2)\, a_{system}$$

y-direction

$$\Sigma F_\perp = F_N - F_{g\perp} = ma = 0$$

$$\Sigma F = F_N - F_{g\perp}$$

Title: Determining the Coefficient of Friction (39)

Date: 16 SEPT 2016 Exemplar (lab)

Introduction:

This lab is titled Newton's Law: Determine the Coefficient of Friction, and the purpose of this experiment is to experiment different ways to determine the coefficient of friction. This lab is based off of Big Idea 3 which states that the interactions of an object with other objects can be described using forces. At the end of this lab, I should be able to express the motion of an object using narrative, mathematical, & graphical representations, I should be able to design an experimental investigation of the motion of an object, and be able to analyze the data in different/various ways. In ~~part~~ the lab, I expect the graph to start out flat and when ~~it~~ I pull the sensor, it will show the static friction, and then show the kinetic friction that keeps the block moving (It may possibly be higher or lower depending on the surface. To test out my hypothesis, the basic background information about friction needs to be known. Friction is a force that is created when two surfaces move or try to move across each other. Friction always opposes the motion or attempted ~~moth~~ motion of one surface across another surface. Friction is dependent on the texture of both surfaces. In this lab, we will see two types of friction in our graph. We will see static friction & kinetic friction. Static friction is the friction that exists between a stationary object & the surface that it's resting on. When the object starts to move, kinetic friction takes over. Kinetic friction exists between two objects moving relative to each other. Kinetic friction is not as strong as static friction, so the ~~can't will not be~~ object will be easier to move.

Mass of Wooden block	Mass added to wooden block (kg)	combined mass of ~~weight~~ & block + added mass	weight of block + added mass (N)	Observed Static Friction (N)	Observed Kinetic Friction (N)
0.176	~~1.000 kg~~			~~7.750~~	
0.176	0.900 kg			~~7.463~~	
0.176	0.900 kg			~~7.137~~	
0.176	0.700				
	0.600				
	0.500				
	1.000				

$\mu = \frac{F_F}{F_N}$ $\frac{4.750}{11.76}$

$\mu = F_F \cdot F_N$

$\mu = F_F \cdot mg \cos(1)$

$F_g = mg$

$F_N = mg \cdot \cos(1)$

$(0.176)(10) = 1.76\ N$

$(1.176)(10) = 11.76\ N$

$+10$

0.91

	observed Static Friction	observed Kinetic Friction	~~observed~~ μ_s	μ_k
1.000	7.750	4.750	0.67	0.41
0.900	7.463	4.358	0.70	0.41
0.800	7.137	3.500	0.76	0.36
0.700	6.163	3.450	0.71	0.40
0.600	4.320	2.700	0.61	0.35
0.500	4.023	2.056	0.61	0.31

$\mu_s = \frac{F_F}{F_N}$

Title: Determining the Coefficient of Friction
Date: 16 SEPT 2016

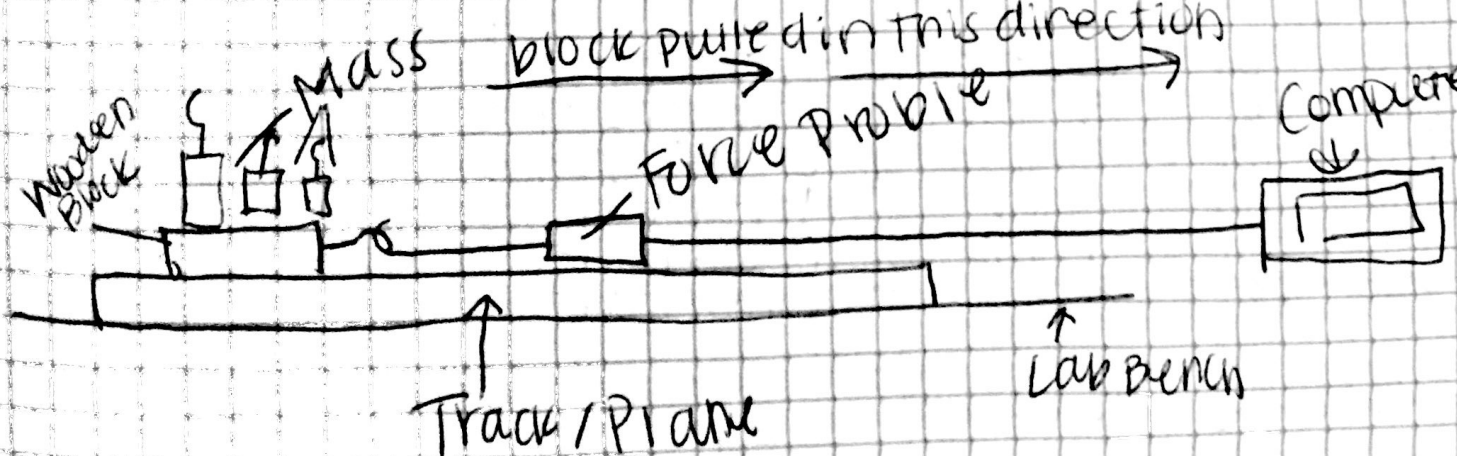
Methods, Materials, & Procedures (Part 1)

The methods, materials & procedures for this lab were followed according to the protocol outlined in AP Lab Investigation #5: Newton's Laws: Determine the coefficient of friction

Materials:
- Friction Block
- Force Probe & computer
- Aluminum inclined plane/track (~~layed f laidec~~ laid flat on surface)
- Different masses (Mass Set)

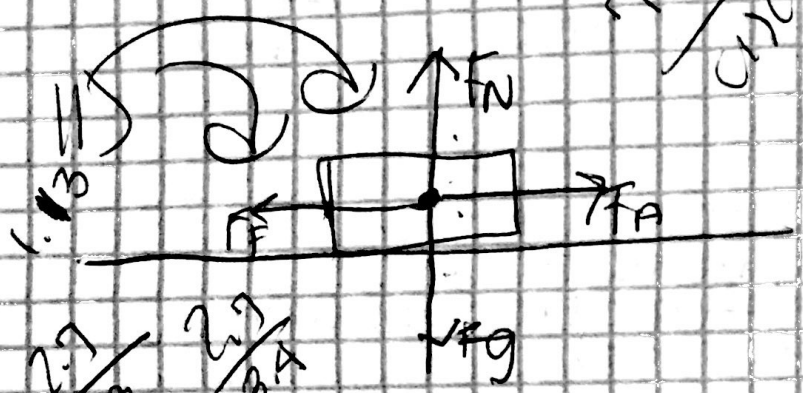
Methods:
We placed the track/plane on a stable horizontal surface, then set our computer to display a graph of force versus time. We weighed the wooden block, an placed the block on one end of the track. Then, we placed a 1 kg (1000 g) mass on top of the block, added the force probed to the hook & began pulling the block until it ~~moved at a constant speed~~ we could move the block at a constant speed. We repeated this for 0.90 kg (900 g), 0.80 kg (800 g), 0.70 kg (700 g), 0.60 kg (600 g), and 0.500 kg (500 g).

General Set-Up:



Mass Wooden Block: 101.3g

→ 0.1013 kg



The normal force is equal to the force of gravity

Coefficient of Friction between wood & Aluminum

	Mass of Wooden Block (kg)	Mass added to wooden block (kg)	Combined mass (kg)	Combined mass (N)	μ_s	μ_k
1	0.1013	1.000	1.1013	10.82		
2	0.1013	0.900	1.0013	9.84		
3	0.1013	0.800	0.9013	8.84		
4	0.1013	0.700	0.8013	7.86		
5	0.1013	0.600	0.7013	6.88		
6	0.1013	0.500	0.6013	5.90		

$F_g = mg$ $g = 9.81$

$1.103 \cdot 9.81 = 10.82$
$1.003 \cdot 9.81 = 9.84$
$0.9013 \cdot 9.81 = 8.84$
$0.8013 \cdot 9.81 = 7.86$
$0.7013 \cdot 9.81 = 6.88$
$0.6013 \cdot 9.81 = 5.90$

	Observed static friction (N)	Observed kinetic friction (N)
1	~~2.04~~ 3.5	2.5
2	~~0.694~~ 2.7	2.0
3	0.419 2.4	1.7
4	~~1.094~~ 1.9	1.5
5	~~0.694~~ 1.7	1.3
6	~~0.455~~ 1.4	1.1

$F_{kf} = (\mu) mg \cdot \cos(\theta)$

These numbers are based on observations during the accurate

Title: Determining the Coefficient of Friction

Date: 19 SEPT 2016

Part I (Data Collection)

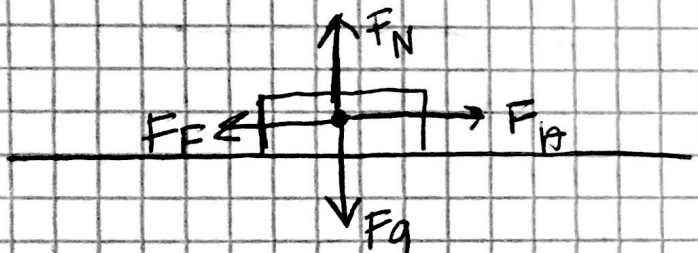
10)

Mass of Wooden Block (kg)	Mass added to block (kg)	Mass of blocks added mass (kg)	Weight of blocks added mass (N)	Observed Static Friction (N)	Observed Kinetic Friction (N)	μ_s	μ_k
0.176	1.000	1.176	11.[illegible]	7.750	4.750	0.67	0.41
0.176	0.900	1.076	10.[illegible]	7.403	4.350	0.70	0.41
0.176	0.800	0.976	9.57[illegible]	7.137	3.500	0.76	0.36
0.176	0.700	0.876	8.[illegible]59	6.165	3.450	0.71	0.40
0.176	0.600	0.776	7.61	4.620	2.700	0.61	0.35
0.176	0.500	0.676	6.63	4.025	2.050	0.61	0.31

Data Table: Coefficient of Friction Between Wood and Aluminum

Averages: $\mu_s = 0.67$ $\mu_k = 0.37$

11)



12) The normal force is equal to the force of gravity. I summed the forces in the y-direction to find this. $\Sigma F_y = F_N - F_g = ma = 0$, so $\Sigma F_y = F_N = F_g$.

Percent Difference (using the minimum & max values)

Static Friction:

$$\frac{7.750 - [illegible] - 4.025}{\left(\frac{7.750 + [illegible] + 4.025}{2}\right)} \times 100$$

= [illegible] % Difference

= 1.89% Difference

Kinetic Friction:

$$\frac{4.750 - 2.050}{\left(\frac{4.750 + 2.050}{2}\right)} \times 100 = 2.38\%$$

= [illegible] % Difference

= [illegible] % Diff.

Percent error (using the averages for μ)

Static Friction:

$$\frac{0.67 - 0.[illegible]}{0.67} \times 100$$

= [illegible] % error

10.45% error

Kinetic Friction:

$$\frac{0.37 - 0.[illegible]}{0.40} \times 100$$

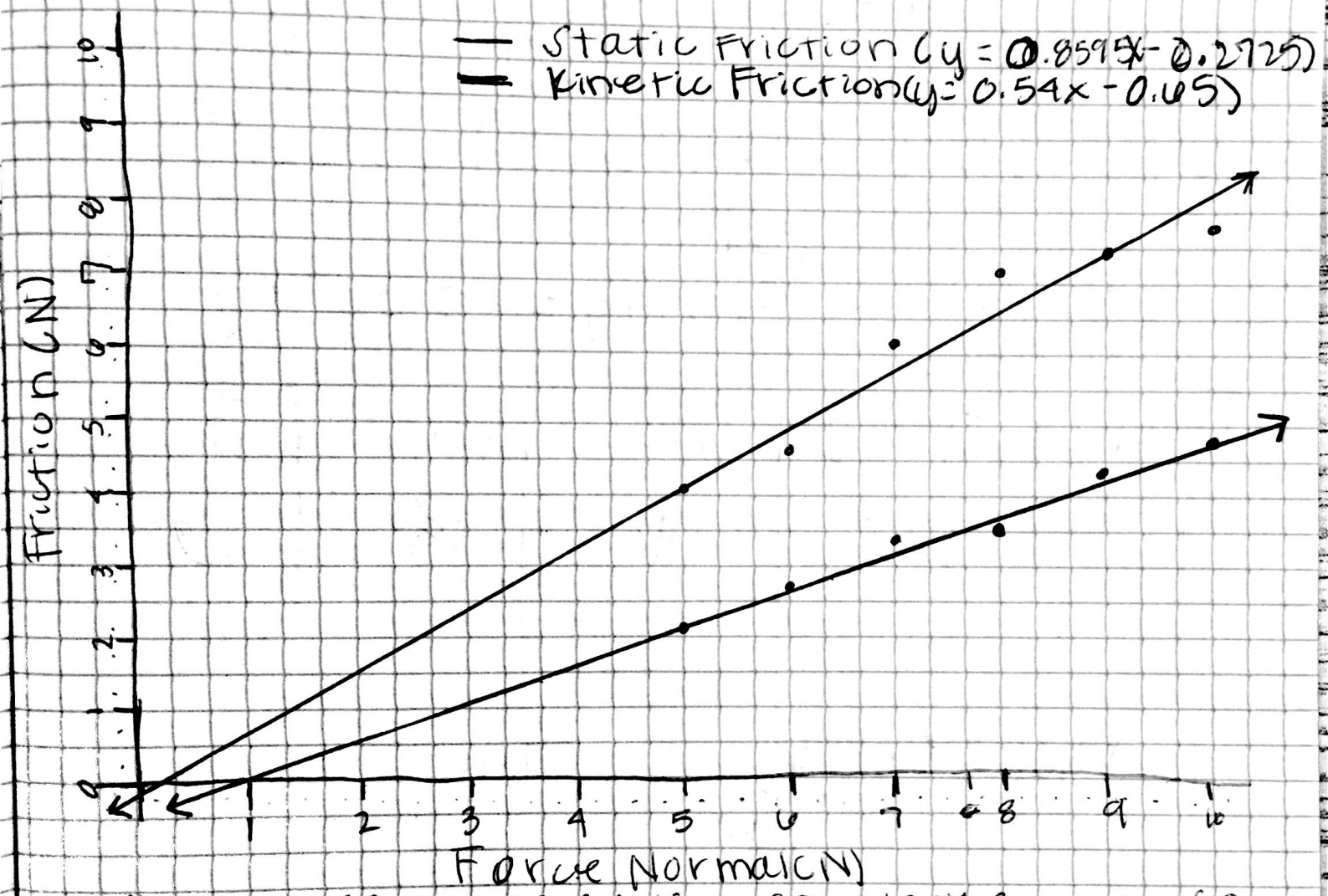
= 7.5% error

Title: Determining the Coefficient

Date: 21 SEPT 2016

Part 7: ~~Measuring the Coefficient of Friction on an Incline~~

Method, Materials & Procedures: #13)



#14) The coefficient of friction equals the slope of a graph of friction versus the normal force, so in $y = mx + b$, m will be μ; so $y = \mu x + b$

Coefficient of Static Friction

Taking (5, 4.025) & (9, 7.463)

$\mu = \frac{y_2 - y_1}{x_2 - x_1} \Rightarrow \frac{7.463 - 4.025}{9 - 5} =$

$\Rightarrow \frac{3.438}{4} = 0.8595$

$\mu = 0.8595$

Coefficient of Kinetic Friction

Taking (5, 2.050) & (10, 4.750)

$\mu = \frac{y_2 - y_1}{x_2 - x_1} \Rightarrow \frac{4.750 - 2.050}{10 - 5} =$

$\Rightarrow \frac{2.7}{5} = 0.54$

$\mu = 0.54$

Title: Determining The Coefficient of Friction

Date: 21 SEPT 2016

Part 2: Measuring The Coefficient of Friction On an Incline

Methods/Materials/Procedures:

* The methods, materials, and ~~this~~ procedure for this lab were followed according to the protocol outlined in AP Lab Investigation #5: Newton's Laws: Determine the coefficient of friction.

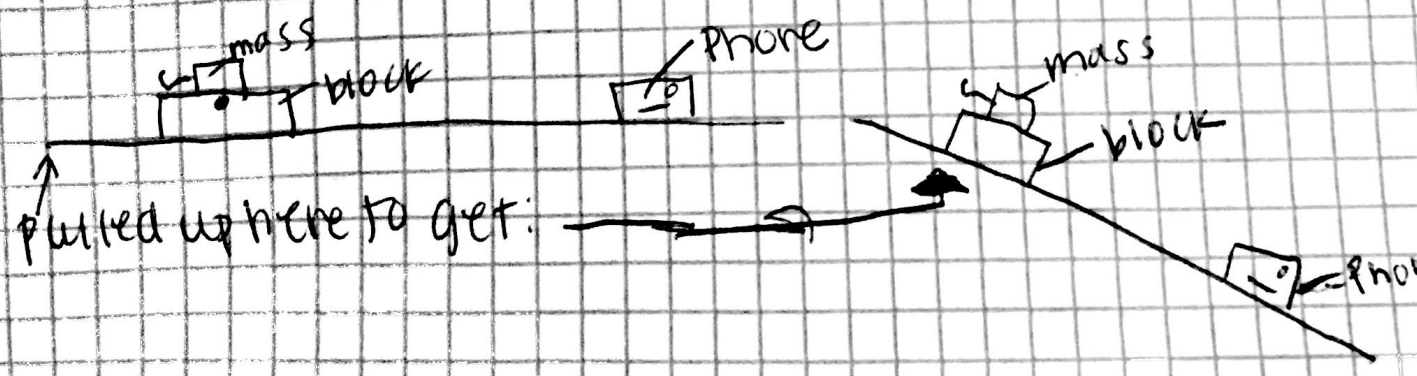
Materials:

- iPhone Inclinometer on the compass app
- Wooden block
- 200 g mass
- Aluminum inclined plane/track
- Masking tape.

Methods/Procedures:

We Taped the iPhone inclinometer on the lehdof the aluminum track. We taped the 200 g mass to the wooden block and made sure that there wasn't any tape on the bottom, to ensure that calculus wouldn't be added in. We weighed the wooden block, the wooden block with the 200 g mass and then converted this into Newtons. We did 5 trials to find both the angle observed for both static and kinetic friction & used these to find the coefficients of static and kinetic friction.

General set-up:



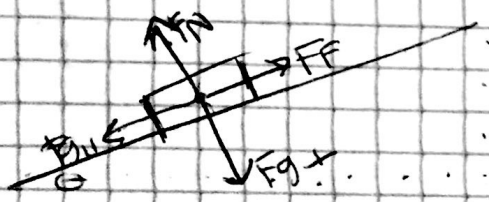
Title: Determining The coefficient of Friction (49)
Date: 26 SEPT 2016

2) Mass of block plus added mass = 0.303 kg
Weight of block plus weight = 3.03 N

Measuring Static Friction Force:

Trial #	1	2	3	4	5
Observed Angle	12°	13°	14°	15°	16°

Angle observed for static Friction: 14°



$\mu = \frac{F_F}{F_N} \Rightarrow \mu = \frac{mg\sin\theta}{mg\cos\theta}$

$\Sigma F_{||} = F_F - F_{g||} = ma = 0$

$\Rightarrow F_F = F_{g||} = mg\sin\theta$

$\Sigma F_{\perp} = F_N - F_{g\perp} = ma = 0$

$\Rightarrow F_N = F_{g\perp} = mg\cos\theta$

~~$mg\sin\theta = (0.03\,N)(1$~~

$mg\sin\theta = (0.303\,kg)(10)\sin(14°) = 0.73\,N$

$\Rightarrow 0.73N$

$mg\cos\theta = (0.303\,kg)(10)\cdot\cos(14°) = 2.94N$

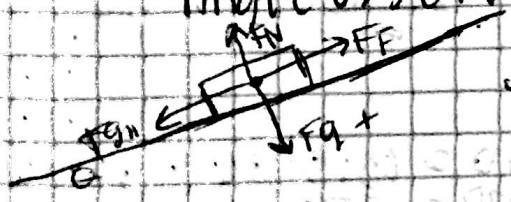
$\Rightarrow 2.94N$

$\mu_{SF} = \frac{mg\sin\theta}{mg\cos\theta} = \frac{0.73\,N}{2.94\,N} = 0.2483 \approx 0.25$

Measuring Kinetic Friction Force:

Trial #	1	2	3	4	5
Observed Angle	11°	12°	13°	13°	12°

Angle observed Force kinetic: 12.2°



$\mu = \frac{F_F}{F_N} \Rightarrow \mu = \frac{mg\sin\theta}{mg\cos\theta}$

$\Sigma F_{||} = F_F - F_{g||} = ma = 0$

$\Rightarrow F_F = F_{g||} = mg\sin\theta$

$\Sigma F_{\perp} = F_N - F_{g\perp} = ma = 0$

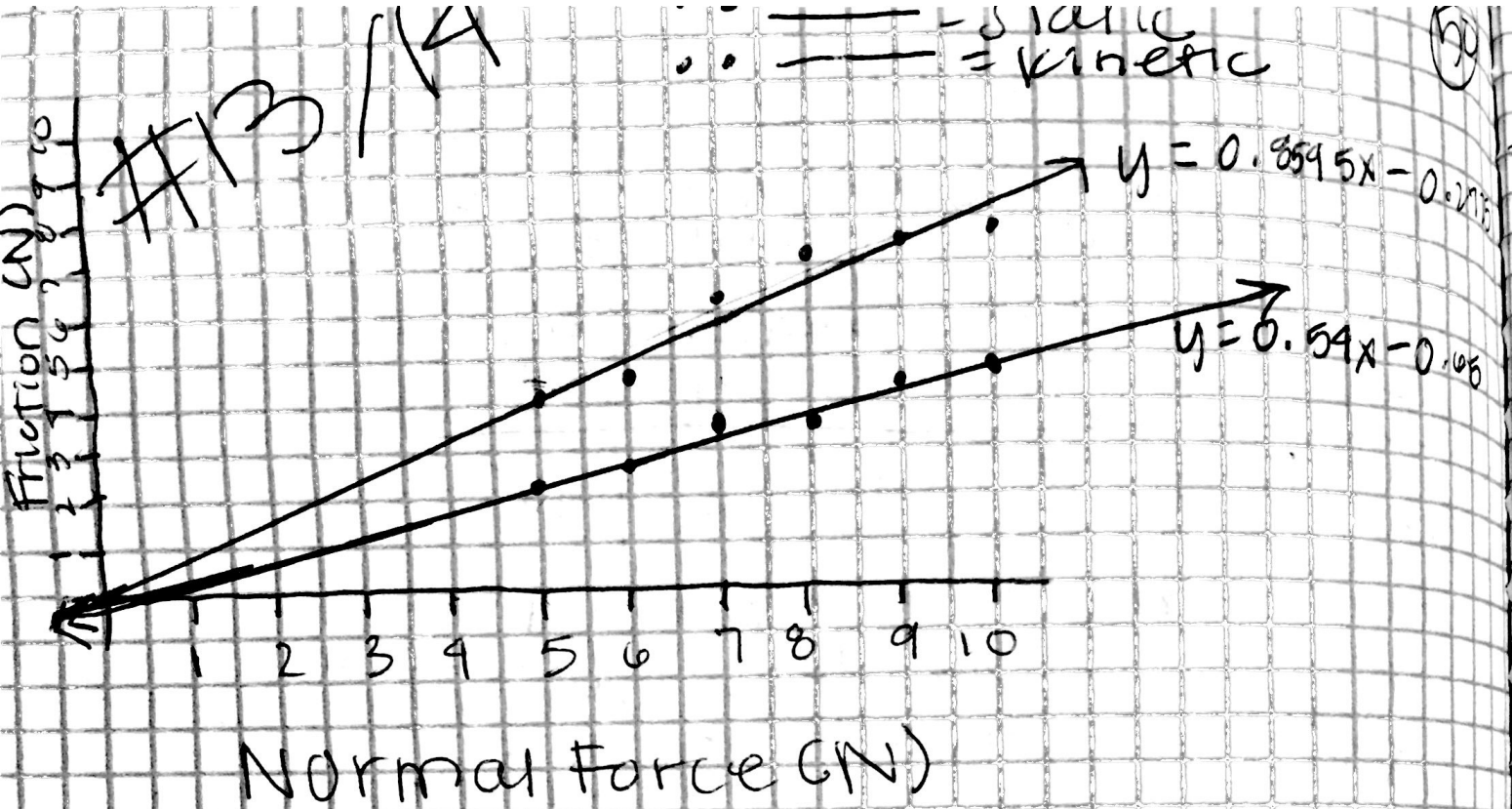
$\Rightarrow F_N = F_{g\perp} = mg\cos\theta$

$mg\sin\theta = (0.303)(10)\cdot\sin(12.2) = 0.64\,N$

$mg\cos\theta = (0.303)(10)\cdot\cos(12.2) = 2.96N$

$\mu_{KF} = \frac{mg\sin\theta}{mg\cos\theta} = \frac{0.64\,N}{2.96\,N} = 0.2162 \approx 0.22$

#13/14



Coefficient of static = Slope

Taking points (5, 4.025) & (9, 7.463)

$\frac{y_2 - y_1}{x_2 - x_1} \Rightarrow \frac{7.463 - 4.025}{9 - 5} = \frac{3.438}{4} = 0.8595$

Taking (5, 4.025)

y intercept: $y = mx + b \Rightarrow 4.025 = 0.8595(5) + b$

$b = -0.2725$

4.2975

Coefficient of kinetic = Slope

Taking points (5, 2.050) & (10, 4.750):

$\frac{y_2 - y_1}{x_2 - x_1} \Rightarrow \frac{4.750 - 2.050}{10 - 5} = \frac{2.7}{5} = 0.54$

Taking (5, 2.050)

y intercept: $y = mx + b \Rightarrow 2.050 = (0.54)(5) + b$

$2.050 = 2.70 + b$

$b = -0.65$

Title: Determining the Coefficient of Friction
Date: 27 SEPT 2016

Part 3: Coefficient of Friction of an Accelerating Object

Methods / Materials & Procedures:

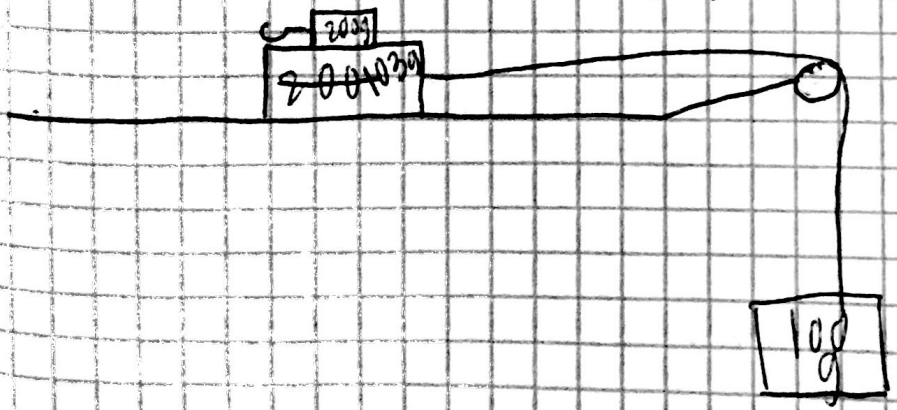
Materials:

- Mass set (200g & 100g)
- String
- Meterstick
- Aluminum Track
- Wooden Block
- Masking tape
- Stopwatch
- Huddle Technique:

Methods / Procedures:

We first cut a string to about 1.5 meter long. Then we taped the 200g mass to the wood without any tape on the bottom of the block. We attached the 1.5 meter long string to the hook on the mass - block system. We extended the string over the pulley placed the meterstick beside the track to measure displacement, and then suspended a 100 gram mass to the end of the string extended over the pulley which gently accelerated the block across the track.

General set up



was held, then Huddle Technique was used to record the change in time.

Title: Determining the coefficient of Friction

Date: 28 SEPT 2016

7) I know that the block accelerates rather than move at a constant speed down the track because I saw that the displacement was increasing, but not at a constant rate, which means there is an increasing velocity which means that there is a constant acceleration.

8) Distance block is to travel: 0.69 m

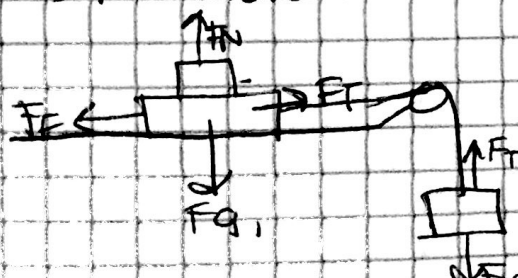
9) Distance the block is to travel (m)	Trial #	$\Delta t_{initial(s)}$	$\Delta t_{final(s)}$	Δt (s)
0.69	1	8.63	10.10	1.47
0.69	2	0.93	2.30	1.37
0.69	3	6.73	8.27	1.54

Average Δt = 1.46 s

Mass of block plus added mass = 0.303 kg

Weight of block plus weight = 3.03 N

10) Acceleration of the system: 0.05 m/s², because:



$\Sigma F_{1y} = F_N - F_g = ma = 0$

$\Rightarrow F_N = F_g = mg$

$\Sigma F_{sys} = F_{g2} + F_T + F_T - F_F = (m_1 + m_2) a_{sys}$

$\Sigma F_{sys} = F_{g2} - F_F = (m_1 + m_2) a_{sys}$

$\Delta x = 0.69$ m; $\Delta t = 1.46$ s; $V_i = 0$

$\Rightarrow$ so, $\Delta x = V_i \Delta t + \frac{1}{2} a \Delta t^2 \Rightarrow \frac{2\Delta x}{\Delta t^2} = a \Rightarrow \frac{2(0.69)}{(1.46)^2} = a = 0.65 \frac{m}{s^2}$

11) Coefficient of Friction = 0.24, because:

$F_N = F_g = mg \Rightarrow (0.303)(10) = 3.03$ N

$\Sigma F_{sys} = F_{g2} - F_F = (m_1 + m_2) a_{sys} \Rightarrow 1 - F_F = (0.303 + 0.100)(0.65)$

$\Rightarrow = -F_F = (0.303 + 0.100)(0.65) - 1 = -0.73805$

$F_F = 0.73805$ N ≈ 0.74 N

$\mu = \frac{F_F}{F_N} = \frac{0.74\text{ N}}{3.03\text{ N}} \Rightarrow 0.24$

$\mu_K = 0.24$

Percent error (μ_k)

$\left| \frac{0.20 - 0.24}{0.20} \right| \times 100$

$= 20\%$ error

Title: Determining the Coefficient of Friction

Date: 5 OCT 2016

12) After having experimentally determined the coefficient of friction between two surfaces using three independent methods, I saw that the results from each methods were similar because of the position the track/plane but also different because of the different masses placed on the wooden block. ~~The more the mass~~

Conclusion.

The objective of this lab was to experimentally determine the coefficients of static and kinetic friction. There were three different ways in which it was experimented: moving the block at a constant velocity, letting it slide on an incline, & through ~~dec~~ an accelerating system. My data contradicts my hypothesis in a way. But this is because ~~I~~ I didn't really know or understand enough at the time to make any hypothesis worth testing, but I did see that the ~~kin~~ coefficient of kinetic friction was always smaller than the coefficient of static friction. If I had done 10 trials for every part of the lab my measurements would be more accurate because I have more data to analyze from. Also, making sure I did the same experiment every time, my measurements would be more precise. My experimental procedure could have been better, but my conclusions can be justified ~~because~~ based on the procedure because for the most part, I did the same thing for every trial, even if they weren't necessarily precise. This lab made me think questions like "What would ~~be~~ the coefficient of friction be if I were to pull a block over a bridge (shaped like a semi-c I could explore this question by taking a force sensor, attaching it to a block of wood, and ~~to~~ sliding it over the bridge, and repeat this multiple times to see what