PHYSICS 020 LAB 5: Newton's Second Law 2 hours

INTRODUCTION:

The general definition of the net force acting on a mass is given by the following equations:

$$\vec{F}_{net} = \sum \vec{F}$$

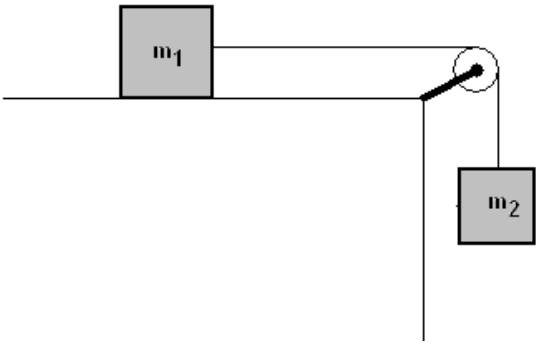
$\vec{F}_{net} = m \cdot \vec{a}$ **where $\vec{a}$ is relative to a stationary observer**

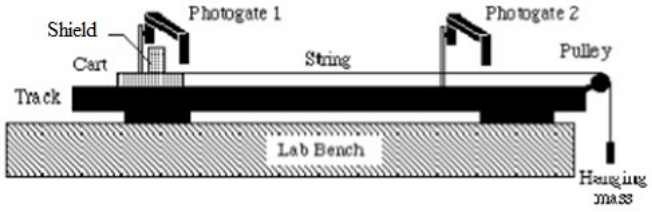
If two initially stationay masses are connected by an unstretchable string around a fixed pulley as shown below, and the system is free of friction, then the net force acting on the system is due to gravity pulling on m_2 downwards only and is such that the pulley will turn clockwise. Given m_1 and m_2 are connected by an unstretchable string, a tension is created between the masses and the net force has to pull both m_1 and m_2, which affects the acceleration of the system. The magnitude of net force acting on such a system of masses would then be given by the following equations:

$$F_{net} = m_2 \cdot g$$

$$F_{net} = m_{Total} \cdot a$$

Fletcher's Trolley





If the masses are each initially stationary and move through a given distance d in a time t, then the constant acceleration a of the masses can be calculated using:

$$d = \frac{1}{2} \cdot a \cdot t^2$$

OBJECTIVES:

- **To determine the Experimental Total Mass and compare it to the Accepted Total Mass for two different Fletcher's Trolley set-ups.**

% Error < 10 % for each setup

APPARATUS:

1 - Pasco Track
2 - Pasco Track stands
1 - Photo gate-timer (Pasco)
2 - Photo gates (Pasco)
1 - Set of weights (total mass of 40 g)
1 - Iron mass
Electronic balance (one per class)
String
Safety knife (one per class)
1 - Pulley
1 - Picket fence
Microsoft Excel or similar program

THEORY:

If a Fletcher's Trolley experiment is such that m_1 (cart and added mass) and m_2 (hanging mass) vary, while m_{Total} (total mass) stays constant, then net force (F_{net}) and the acceleration (a) will vary (depending on m_2). If m_2 is large, then the net force and acceleration will be large, and if m_2 is small, then the net force and acceleration will be small.

This lab uses a set of 40 g weights (10 g mass holder + 10 g weight + 20 g weight), so that m_2 can vary between being 10 g, 20 g, 30 g or 40 g, while the remaining weight(s) are in the cart, so that the total mass remains constant!

If the Net Force vs Acceleration is plotted, the data will be fairly linear with the slope of the Line of Best Fit (Trendline) being equal to the constant Experimental Total Mass, which can then be compared to the Accepted Total Mass.

$$F_{net} = m_{Total} \cdot a \quad \text{(Line in } y = m \cdot x \text{ form)}$$

$$\%\ Error = \frac{|Experimental\ m_{Total} - Actual\ m_{Total}|}{Actual\ m_{Total}} x\ 100\ \%$$

PROCEDURE

PART A:

1. **Record the mass of the cart in g in the Initial Data Table provided.**

2. **Attach the two laser gates to the track. One gate is connected at the 80 cm mark, and this gate is connected to the Pasco photo gate time in port one. The second gate is connected to the track at the to the 30 cm mark, and is connected to the second port on the Pasco photo gate.**

3. **Adjust pulley at the 0 cm mark on the end of the track, and attach the stands to each side of the track. Adjust the stand so that is slopes a tiny bit toward the pulley. This will help negate the friction in the system. If you place a cart on the track, give it a small push and it moves across at a constant velocity then track is positioned properly.**

4. **Plug in the power cord to the Pasco Gate timer. Click the red button once to set time. Click the blue button three times to bring up two gates. Click the black button once and you will see an "*" on the screen. This means the system is ready to record. For each run you just need to hit the black button once for it to be ready to record.**

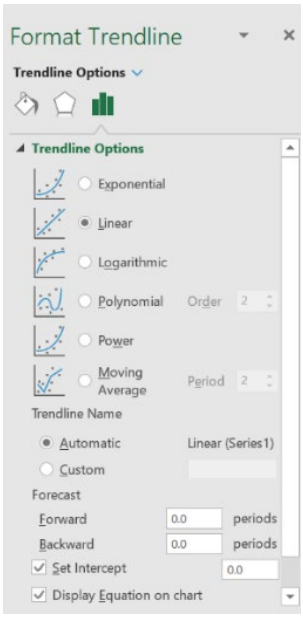
5. **Attach the string to the cart, and hang the string over the pulley with the 40g weight attached to the other end (ie. m_2 = 40 g). Place the cart, with the picket fence attached to it, just before gate #1, release and record the time for it to pass through the second gate. Do this a total of 3 times and record the measurements in the Initial Data Table provided.**

6. **Repeat Step 5, using 30 g attached to the hanging string. That is, change m_2 = 30 g and place 10 g in the cart, so that total mass remains constant.**

7. **Repeat Step 5, using 20 g attached to the hanging string. That is, change m_2 = 20 g and place 20 g in the cart, so that total mass remains constant.**

8. **Repeat Step 5, using 10 g attached to the hanging string That is, change m_2 = 10 g and place 30 g in the cart, so that total mass remains constant.**

9. **Create a Microsoft Excel Scatter Plot of Net Force vs Acceleration ($F_{Net} = m_{Total} \cdot a$) . Add a Linear Trendline. Display the Equation on the Chart. Ensure the y-int is set to 0. The equation will be of the form $y = m \cdot x$ where the slope is the Experimental Total Mass in kg. Given the y-intercept should be zero, ensure to set the intercept using the Format Trendline dialog box as shown below.**



10. **Record the slope of the Trendline as the Experimental Total Mass in kg precise to the nearest gram in the Final Results Table.**

11. **Create a title section named: Calculations and show sample calculations for Part A.**

12. **Complete the Final Results Table provided for Part A. State all quantities precise to three significant digits.**

PART B:

13. **Place the iron mass in the cart. Record the new mass of the cart in g in the Initial Data Table.**

14. **Repeat Steps 5 to 12 for Part B. (Part B calculations can be under the same general title of Calculations.**

15. **Compile and submit your completed lab to your instructor by the due date. No conclusion is needed for this lab!**

Your completed lab should contain:

- **Initial Data Tables for Parts A and B**
- **Calculations for Parts A and B**
- **2 Separate Microsoft Excel graphs of Net Force vs Acceleration (one for each Part)**
- **Final Results Tables**

See your lab instructor for a more detailed format for the completed lab submission.

Initial Data Tables

Note: For the online course, use the Data Set Number provided to you to complete the Initial Data Table and complete the lab.

Data Set Number = _____

Part A: Total Mass is Constant

Mass of Cart = _____

Actual Total Mass = _____

d = _____

Mass in Cart (g)	Mass on string m_2 (g)	Time of run (s)		
		Run 1	Run 2	Run 3
0.0	40.0			
10.0	30.0			
20.0	20.0			
30.0	10.0			

Part B: Total Mass is Constant

Mass of Cart = _____

Actual Total Mass = _____

d = _____

Mass in Cart (g)	Mass on string m_2 (g)	Time of run (s)		
		Run 1	Run 2	Run 3
0.0	40.0			
10.0	30.0			
20.0	20.0			
30.0	10.0			

Calculations:

Show a "sample calculation" for each calculation in Part A and a "sample calculation" for each calculation in Part B.

Determining Actual Total Mass

$$m_{Total} = m_1 + m_2$$

Determining Average Time

$$\mathbf{t} = \frac{(\mathbf{t_1} + \mathbf{t_2} + \mathbf{t_3})}{\mathbf{3}}$$

Determining Acceleration

$$a = \frac{2 \cdot d}{t^2}$$

Determining Net Force

$$\mathbf{F_{net}} = \mathbf{m_2} \cdot \mathbf{g}$$

Determining Experimental Total Mass

$\mathbf{m_{Total}}$ = slope of "$\mathbf{F_{net}}$ vs a" where $\mathbf{F_{net}} = \mathbf{m_{Total}} \cdot \mathbf{a}$

Determining % Error for Total Mass

$$\%\ Error = \frac{|Experimental\ m_{Total} - Actual\ m_{Total}|}{Actual\ m_{Total}} x\ 100\ \%$$

Final Results Tables

Data Set Number = _____

Part A:

Mass on string m_2 (kg)	Average Time (s)	Acceleration (m/s^2)	Net Force (N)
0.0400			
0.0300			
0.0200			
0.0100			

Slope of F_{Net} vs a = _____ (Experimental Total Mass)

Actual Total Mass = _____ (Actual Total Mass)

% Error = _____

Part B:

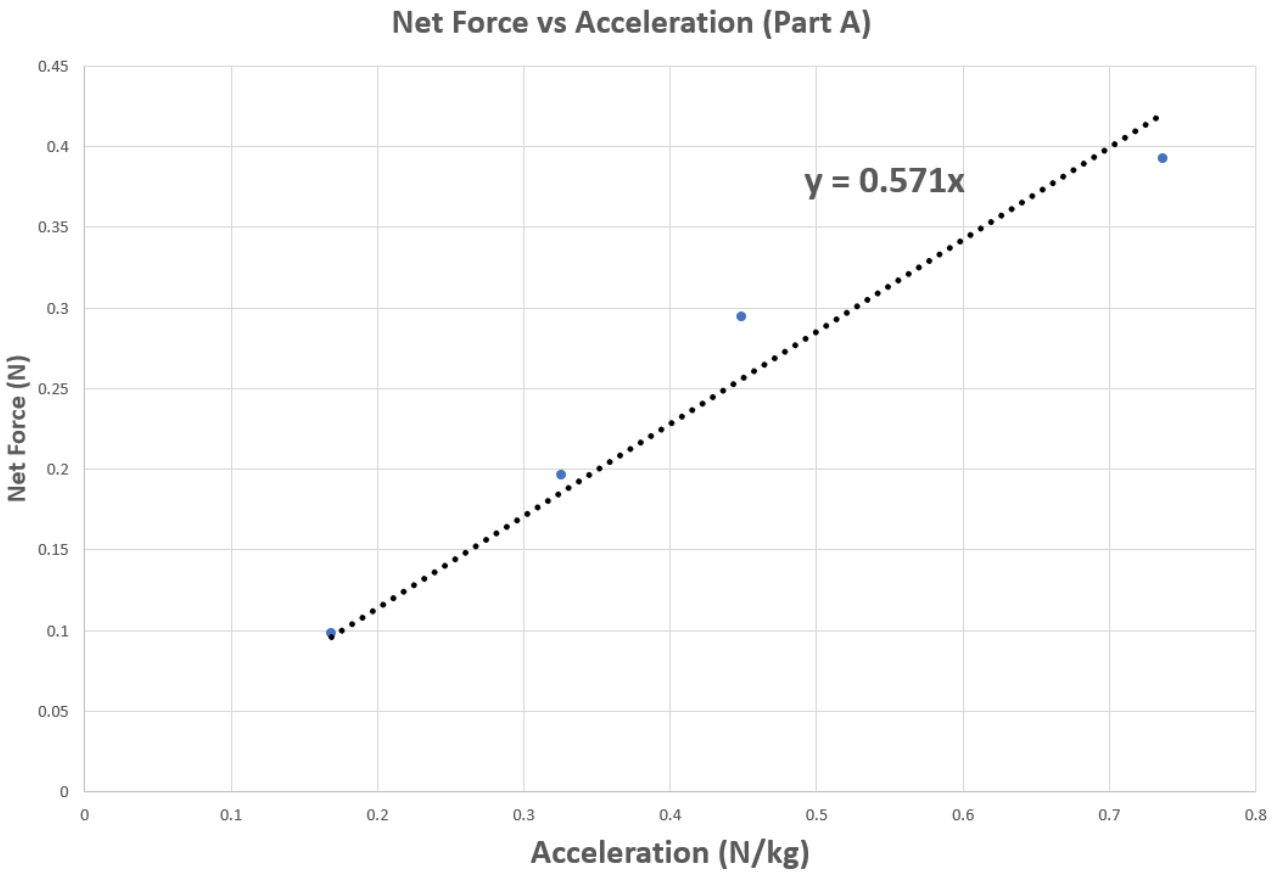
Mass on string m_2 (kg)	Average Time (s)	Acceleration (m/s^2)	Net Force (N)
0.0400			
0.0300			
0.0200			
0.0100			

Slope of F_{Net} vs a = _____ (Experimental Total Mass)

Actual Total Mass = _____ (Actual Total Mass)

% Error = _____

Sample Graph



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Lab 5 Data Sets

Data Set 1

Part A

Distance	0.500 m
Cart Mass	507 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.205 s	1.064 s	1.259 s
30.0 g	1.451 s	1.482 s	1.494 s
20.0 g	1.691 s	1.799 s	1.740 s
10.0 g	2.410 s	2.451 s	2.472 s

Part B

Distance	0.500 m
Cart Mass	1076 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.699 s	1.711 s	1.778 s
30.0 g	2.032 s	2.118 s	1.997 s
20.0 g	2.727 s	2.616 s	2.634 s
10.0 g	3.451 s	3.585 s	3.682 s

Data Set 2

Part A

Distance	0.500 m
Cart Mass	512 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.186 s	1.117 s	1.223 s
30.0 g	1.450 s	1.483 s	1.506 s
20.0 g	1.706 s	1.772 s	1.737 s
10.0 g	2.386 s	2.412 s	2.470 s

Part B

Distance	0.500 m
Cart Mass	1061 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.683 s	1.713 s	1.796 s
30.0 g	2.007 s	2.072 s	1.984 s
20.0 g	2.691 s	2.621 s	2.632 s
10.0 g	3.472 s	3.604 s	3.674 s

Data Set 3

Part A

Distance	0.500 m
Cart Mass	515 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.191 s	1.098 s	1.233 s
30.0 g	1.444 s	1.489 s	1.512 s
20.0 g	1.733 s	1.792 s	1.751 s
10.0 g	2.428 s	2.409 s	2.502 s

Part B

Distance	0.500 m
Cart Mass	1069 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.744 s	1.692 s	1.772 s
30.0 g	1.995 s	2.081 s	2.008 s
20.0 g	2.701 s	2.596 s	2.612 s
10.0 g	3.426 s	3.538 s	3.634 s

Data Set 4

Part A

Distance	0.500 m
Cart Mass	505 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.168 s	1.103 s	1.264 s
30.0 g	1.438 s	1.486 s	1.551 s
20.0 g	1.729 s	1.804 s	1.738 s
10.0 g	2.402 s	2.459 s	2.467 s

Part B

Distance	0.500 m
Cart Mass	1071 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.728 s	1.716 s	1.778 s
30.0 g	2.015 s	2.079 s	2.002 s
20.0 g	2.701 s	2.607 s	2.621 s
10.0 g	3.439 s	3.567 s	3.669 s

Data Set 5

Part A

Distance	0.500 m
Cart Mass	511 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.148 s	1.102 s	1.203 s
30.0 g	1.474 s	1.479 s	1.560 s
20.0 g	1.709 s	1.798 s	1.748 s
10.0 g	2.418 s	2.461 s	2.481 s

Part B

Distance	0.500 m
Cart Mass	1075 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.704 s	1.691 s	1.792 s
30.0 g	1.988 s	2.084 s	2.012 s
20.0 g	2.714 s	2.647 s	2.613 s
10.0 g	3.458 s	3.562 s	3.692 s

Data Set 6

Part A

Distance	0.500 m
Cart Mass	521 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.200 s	1.111 s	1.211 s
30.0 g	1.464 s	1.502 s	1.507 s
20.0 g	1.742 s	1.774 s	1.782 s
10.0 g	2.394 s	2.447 s	2.448 s

Part B

Distance	0.500 m
Cart Mass	1056 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.683 s	1.709 s	1.785 s
30.0 g	2.006 s	2.052 s	2.021 s
20.0 g	2.726 s	2.581 s	2.585 s
10.0 g	3.429 s	3.587 s	3.700 s

Data Set 7

Part A

Distance	0.500 m
Cart Mass	505 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.186 s	1.097 s	1.242 s
30.0 g	1.453 s	1.516 s	1.549 s
20.0 g	1.734 s	1.801 s	1.777 s
10.0 g	2.422 s	2.382 s	2.451 s

Part B

Distance	0.500 m
Cart Mass	1087 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.731 s	1.694 s	1.760 s
30.0 g	2.013 s	2.087 s	2.005 s
20.0 g	2.680 s	2.596 s	2.571 s
10.0 g	3.472 s	3.605 s	3.673 s

Data Set 8

Part A

Distance	0.500 m
Cart Mass	498 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.184 s	1.086 s	1.239 s
30.0 g	1.497 s	1.521 s	1.498 s
20.0 g	1.714 s	1.832 s	1.750 s
10.0 g	2.363 s	2.462 s	2.485 s

Part B

Distance	0.500 m
Cart Mass	1075 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.689 s	1.733 s	1.727 s
30.0 g	2.020 s	2.080 s	2.001 s
20.0 g	2.693 s	2.603 s	2.577 s
10.0 g	3.478 s	3.602 s	3.721 s

Data Set 9

Part A

Distance	0.500 m
Cart Mass	502 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.152 s	1.053 s	1.283 s
30.0 g	1.488 s	1.533 s	1.540 s
20.0 g	1.723 s	1.813 s	1.736 s
10.0 g	2.401 s	2.437 s	2.516 s

Part B

Distance	0.500 m
Cart Mass	1087 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.712 s	1.757 s	1.776 s
30.0 g	1.965 s	2.107 s	1.968 s
20.0 g	2.735 s	2.634 s	2.588 s
10.0 g	3.445 s	3.538 s	3.661 s

Data Set 10

Part A

Distance	0.500 m
Cart Mass	495 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.181 s	1.086 s	1.218 s
30.0 g	1.480 s	1.453 s	1.508 s
20.0 g	1.716 s	1.757 s	1.763 s
10.0 g	2.386 s	2.442 s	2.486 s

Part B

Distance	0.500 m
Cart Mass	1064 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.697 s	1.722 s	1.777 s
30.0 g	1.995 s	2.059 s	2.002 s
20.0 g	2.702 s	2.581 s	2.587 s
10.0 g	3.452 s	3.574 s	3.660 s

Data Set 11

Part A

Distance	0.500 m
Cart Mass	497 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.149 s	1.078 s	1.272 s
30.0 g	1.471 s	1.533 s	1.527 s
20.0 g	1.689 s	1.804 s	1.748 s
10.0 g	2.397 s	2.426 s	2.452 s

Part B

Distance	0.500 m
Cart Mass	1078 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.702 s	1.697 s	1.776 s
30.0 g	2.063 s	2.080 s	2.016 s
20.0 g	2.659 s	2.604 s	2.615 s
10.0 g	3.421 s	3.576 s	3.689 s

Data Set 12

Part A

Distance	0.500 m
Cart Mass	496 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.211 s	1.101 s	1.228 s
30.0 g	1.440 s	1.507 s	1.533 s
20.0 g	1.682 s	1.811 s	1.736 s
10.0 g	2.398 s	2.390 s	2.481 s

Part B

Distance	0.500 m
Cart Mass	1063 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.672 s	1.705 s	1.802 s
30.0 g	2.015 s	2.072 s	1.991 s
20.0 g	2.695 s	2.635 s	2.547 s
10.0 g	3.435 s	3.622 s	3.688 s

Data Set 13

Part A

Distance	0.500 m
Cart Mass	498 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.170 s	1.060 s	1.224 s
30.0 g	1.470 s	1.522 s	1.534 s
20.0 g	1.706 s	1.770 s	1.722 s
10.0 g	2.399 s	2.412 s	2.497 s

Part B

Distance	0.500 m
Cart Mass	1072 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.704 s	1.701 s	1.813 s
30.0 g	2.000 s	2.135 s	1.989 s
20.0 g	2.695 s	2.638 s	2.603 s
10.0 g	3.411 s	3.573 s	3.691 s

Data Set 14

Part A

Distance	0.500 m
Cart Mass	496 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.165 s	1.126 s	1.279 s
30.0 g	1.474 s	1.500 s	1.497 s
20.0 g	1.694 s	1.817 s	1.748 s
10.0 g	2.370 s	2.466 s	2.527 s

Part B

Distance	0.500 m
Cart Mass	1085 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.711 s	1.751 s	1.799 s
30.0 g	2.033 s	2.094 s	1.997 s
20.0 g	2.693 s	2.643 s	2.635 s
10.0 g	3.394 s	3.620 s	3.666 s

Data Set 15

Part A

Distance	0.500 m
Cart Mass	497 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.211 s	1.074 s	1.234 s
30.0 g	1.458 s	1.518 s	1.525 s
20.0 g	1.688 s	1.793 s	1.722 s
10.0 g	2.367 s	2.394 s	2.480 s

Part B

Distance	0.500 m
Cart Mass	1075 g

Mass 2	Run 1	Run 2	Run 3
40.0 g	1.690 s	1.730 s	1.781 s
30.0 g	2.038 s	2.086 s	1.974 s
20.0 g	2.670 s	2.605 s	2.590 s
10.0 g	3.495 s	3.608 s	3.659 s