T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY I
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Newtons's Second Law of Motion

PREPARED BY

NAME AND SURNAME:

STUDENT NUMBER :

DEPARTMENT :

Signature:

Experimental Procedure:

1. Experiment set-up is shown in Figure 3.3.

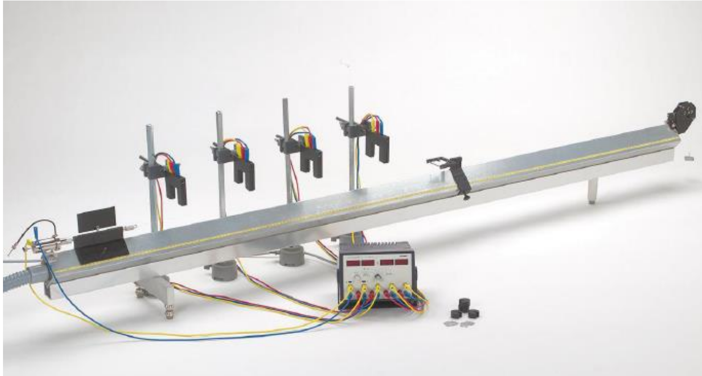

Figure 3.3: The experimental setup for the investigation of motion with constant acceleration.

2. Turn on the air pump and the timer. The switches are behind the devices.
3. The timer has two modes of operation. When set to "*continuous mode*" all four timers start measuring the time and continue until a body passes between the corresponding sensor. "*Intermittent mode*" measures the "passage time" of a body from a sensor as the corresponding timer only starts when a body enters between the sensor and stops when the body leaves it.
4. Measure the mass of the sled when it is empty ________________________________ *gr*
5. Measure the length of the slate on top of the sled (L) ___________________________ *cm*
6. Measure the mass of the holder hanging down from the pulley ___________________ *gr*
7. Lock the sled to its initial position and measure the following quantities before beginning the experiment using the ruler fixed to the rail. Always take vertical projections on to the ruler when taking those measurements. You can use a piece of paper or a small ruler to be sure of the alignments.
   Position of the front end of the slate (x_0) ____________________________________ *cm*
   Position of the 1. sensor (x_1) ____ *cm*
   Position of the 2. sensor (x_2) ____ *cm*
   Position of the 3. sensor (x_3) ____ *cm*
   Position of the 4. sensor (x_4) ____ *cm*
8. A typical procedure for a measurement set is given as below:
   a) Put the required masses on to the sled and on to the holder. (Taking into account the mass of the sled and the holder) record the total masses as m_1 and m_2 in compatible with the model shown in Figure 1.
   b) Lock the sled in its initial position.
   c) Switch the timer to continuous mode and reset it.
   d) Bring the air pump to full throttle.
   e) Release the sled.
   f) After the sled passes though the all 4 sensors and hits the bumper bring the sled to its initial position, lock it and bring the air pump setting to idle. Record the 4 time values displayed on the timer. Those are continuous mode measurements and they will be called t_1, t_2, t_3 and t_4, respectively.
   g) Bring the timer to the intermittent mode and reset it. Repeat the procedures (d) and (e). The displayed values are passage times and they are named as Δt_1, Δt_2, Δt_3 and Δt_4, respectively.

I. Put a mass of 10 gr on to the hanging holder. Don't put any mass on to the sled. Complete a measurement set using the procedure explained in the 8th step of the procedure. Record your measurements to the following table.

Table 3.1: m_1 = ____________ *gr* m_2 = ____________ *gr*

t_1	t_2	t_3	t_4
Δt_1	Δt_2	Δt_3	Δt_4

You are expected to draw position-time (x-t) and velocity-time (v-t) plots using the data taken in the 7th and 8th steps of the procedure.

A) Position-Time Plot

Fill in the following table using the positions that you have measured in step 7 and continuous mode times (t) in Table 3.1 (Write the appropriate units in the parenthesis)

Table 3.1.1: Position-time

t (____)	x (____)
0	

Express those data as points on a graph paper. Taking into account the theoretical considerations explained previously what type of a curve is supposed to pass through those points?

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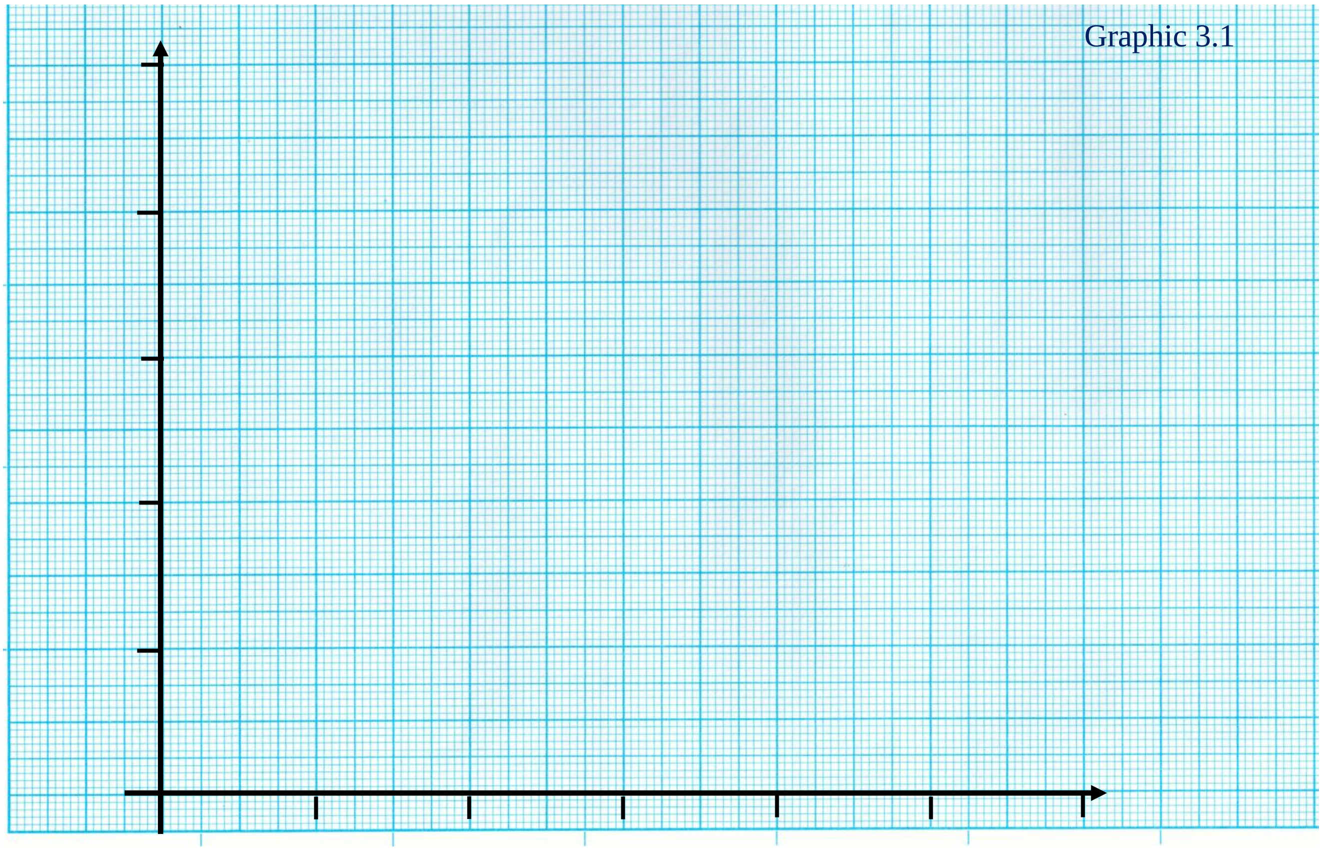
Use the values saved in the Table 3.1.1 and plot x – *t* graph on reserved milimetric space, as *x*-axis time *t* and *y*-axis position *x*. Plot the curve on your graph that fits best to your data points by <u>*crude eye estimation*</u>.



Graphic 3.1

B) Velocity-Time Plot

To be able to plot the *v*-*t'* graph you first need to calculate the velocities. That can be achieved by dividing the slate length to Δt's that were measured using the intermittent mode of the timer. It is important to note that calculating the velocity in this manner will only give you the "average velocity" during the passage since the sled is constantly accelerating. There is a trick however we can use to express this average velocity as instantaneous velocity and plot it as a "point" on the graph. To find that "instant" that correspond to the calculated velocity we need to add the half of the passage time (Δt) to the time measured in the continuous mode. (Think about the reason for this, give an explanation.)

So the velocity and the time values to be plotted on the graph can be calculated using the following formulae:

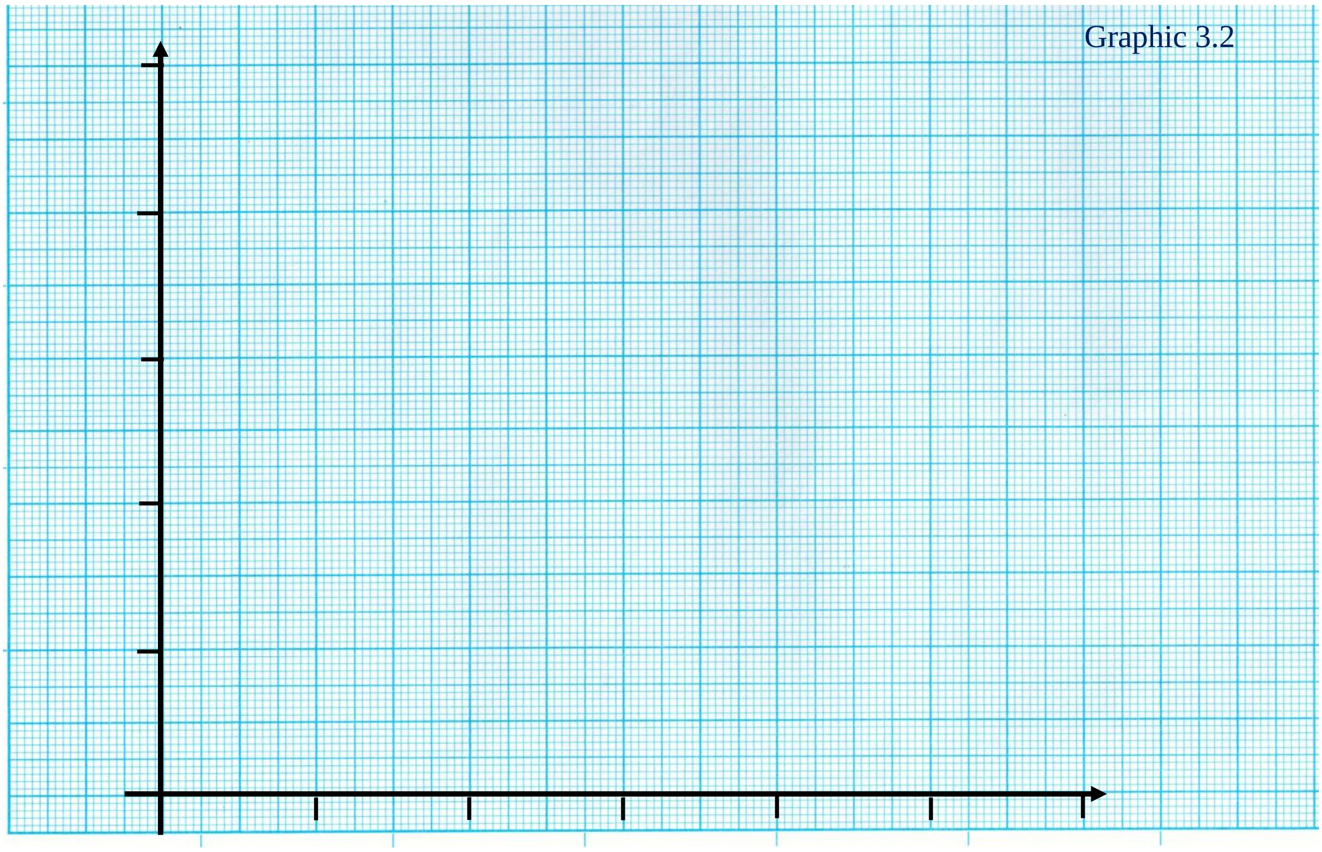
$$t'_n = t_n + \frac{\Delta t_n}{2} \Rightarrow v_n = \frac{slatelength}{\Delta t_n} \qquad 3.7$$

Fill in the following table using the values Table 3.1 those formulae in 3.7:

Table 3.1.2: Velocity-time

t' **(_____)** $t'_n = t_n + \frac{\Delta t_n}{2}$	***v*** **(_____)** $v_n = \frac{slatelength}{\Delta t_n}$

Use the values saved in the Table 3.1.2 and plot $v - t'$ graph on reserved milimetric space, as x-axis time (t') and y-axis velocity (v). Express the values in this table as points on your graph. If we take into account our theoretical considerations we expect a line to pass through those points. The equation of this line is $v=v_0+at'$ in the theoretical background section. Use the experimental acceleration, which is calculated in the following step, as your line's slope and plot the $v=at'$ line on your graph by assuming $v_0=0$. Observe the fitness of the line to your data points.



Graphic 3.2

In this equation you are expected to calculate the acceleration: *a*. The acceleration should be calculated using the values in the above table with the statistical fitting method called "*least squares method*". The formula that is derived from the least squares method which will give you the acceleration is written below.

Calculate the four terms that are going to be used in this equation below:

$$\sum_{i=1}^{4} t'_i =$$

$$\sum_{i=1}^{4} v_i =$$

$$\sum_{i=1}^{4} t'_i v_i =$$

$$\sum_{i=1}^{4} t'^2_i =$$

Substitute those values in the equation and calculate the experimental acceleration using the space below:

$$a_{experimental} = \frac{4.\sum_{i=1}^{4} t'_i v_i - \sum_{i=1}^{4} t'_i \sum_{i=1}^{4} v_i}{4.\sum_{i=1}^{4} t'^2_i - (\sum_{i=1}^{4} t'_i)^2} =$$

$a_{\text{experimental}}$= ______________ *cm/s*^{2}

Calculate the theoretical acceleration using equation [3.4]$a = \frac{m_1 g}{m_1+m_2}$, (*g*=*980 cm/s*^{2}).

$a_{\text{theoretical}}$ = ______________ *cm/s*^{2}

Compare experimental and theoretical values with each other and discuss the compatibility of the model to the experiment.

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C) Force – Acceleration Plot

The measurements will be taken in following steps II, III, IV, V and VI are to observe how the acceleration changes with the the increasing force when the total mass is kept constant. Calculate the acceleration of those 4 measurement sets using the same method as above.

II. There are two nails on both sides of the sled. On each of them put 4 one-gram masses (That makes a total of 8 grams on the sled.) Keep the 10 grams that you placed on the previous procedure on the holder. Complete a measurement set as explained in the 8th step. Record your measurements to the following table.

Table 3.2: m_1 = ____________ *gr* m_2 = ____________ *gr*

t_1	t_2	t_3	t_4
Δt_1	Δt_2	Δt_3	Δt_4
$t_1{}' = t_1 + \frac{\Delta t_1}{2}$	$t_2{}' = t_2 + \frac{\Delta t_2}{2}$	$t_3{}' = t_3 + \frac{\Delta t_3}{2}$	$t_4{}' = t_4 + \frac{\Delta t_4}{2}$
$v_1 = \frac{slatelength}{\Delta t_1}$	$v_2 = \frac{slatelength}{\Delta t_2}$	$v_3 = \frac{slatelength}{\Delta t_3}$	$v_4 = \frac{slatelength}{\Delta t_4}$

$$\sum_{i=1}^{4} t'_i =$$

$$\sum_{i=1}^{4} v_i =$$

$$\sum_{i=1}^{4} t'_i v_i =$$

$$\sum_{i=1}^{4} t'^2_i =$$

$$a_1 = \frac{4.\sum_{i=1}^{4} t'_i v_i - \sum_{i=1}^{4} t'_i \sum_{i=1}^{4} v_i}{4.\sum_{i=1}^{4} t'^2_i - (\sum_{i=1}^{4} t'_i)^2} =$$

a_1 = ____________ cm/s^2

Signature:

III. Take 2 one-grams from the sled (one from right, one from left) and add those 2 grams to the holder. *<u>This way the total mass of the system will remain constant</u>*. Complete a measurement set as explained in the 8th step. Record your measurements to the following table.

Table 3.3: m_1 = ____________ *gr* m_2 = ____________ *gr*

t_1	t_2	t_3	t_4
Δt_1	Δt_2	Δt_3	Δt_4
$t_1{}' = t_1 + \frac{\Delta t_1}{2}$	$t_2{}' = t_2 + \frac{\Delta t_2}{2}$	$t_3{}' = t_3 + \frac{\Delta t_3}{2}$	$t_4{}' = t_4 + \frac{\Delta t_4}{2}$
$v_1 = \frac{slatelength}{\Delta t_1}$	$v_2 = \frac{slatelength}{\Delta t_2}$	$v_3 = \frac{slatelength}{\Delta t_3}$	$v_4 = \frac{slatelength}{\Delta t_4}$

$$\sum_{i=1}^{4} t'_i =$$

$$\sum_{i=1}^{4} v_i =$$

$$\sum_{i=1}^{4} t'_i v_i =$$

$$\sum_{i=1}^{4} t'^2_i =$$

$$a_2 = \frac{4.\sum_{i=1}^{4} t'_i v_i - \sum_{i=1}^{4} t'_i \sum_{i=1}^{4} v_i}{4.\sum_{i=1}^{4} t'^2_i - (\sum_{i=1}^{4} t'_i)^2} =$$

a_2 = ____________ cm/s^2

Signature:

IV. Take 2 one-grams from the sled (one from right, one from left) and add those 2 grams to the holder. Complete a measurement set as explained in the 8th step. Record your measurements to the following table.

Table 3.4: m_1 = ____________ *gr* m_2 = ____________ *gr*

t_1	t_2	t_3	t_4
Δt_1	Δt_2	Δt_3	Δt_4
$t_1{}' = t_1 + \frac{\Delta t_1}{2}$	$t_2{}' = t_2 + \frac{\Delta t_2}{2}$	$t_3{}' = t_3 + \frac{\Delta t_3}{2}$	$t_4{}' = t_4 + \frac{\Delta t_4}{2}$
$v_1 = \frac{slatelength}{\Delta t_1}$	$v_2 = \frac{slatelength}{\Delta t_2}$	$v_3 = \frac{slatelength}{\Delta t_3}$	$v_4 = \frac{slatelength}{\Delta t_4}$

$$\sum_{i=1}^{4} t'_i =$$

$$\sum_{i=1}^{4} v_i =$$

$$\sum_{i=1}^{4} t'_i v_i =$$

$$\sum_{i=1}^{4} t'^2_i =$$

$$a_3 = \frac{4.\sum_{i=1}^{4} t'_i v_i - \sum_{i=1}^{4} t'_i \sum_{i=1}^{4} v_i}{4.\sum_{i=1}^{4} t'^2_i - (\sum_{i=1}^{4} t'_i)^2} =$$

a_3= ____________ cm/s^2

Signature:

V. Take 2 one-grams from the sled (one from right, one from left) and add those 2 grams to the holder. Complete a measurement set as explained in the 8th step. Record your measurements to the following table.

Table 3.5: m_1 = ____________ *gr* m_2 = ____________ *gr*

t_1	t_2	t_3	t_4
Δt_1	Δt_2	Δt_3	Δt_4
$t_1{}' = t_1 + \frac{\Delta t_1}{2}$	$t_2{}' = t_2 + \frac{\Delta t_2}{2}$	$t_3{}' = t_3 + \frac{\Delta t_3}{2}$	$t_4{}' = t_4 + \frac{\Delta t_4}{2}$
$v_1 = \frac{slatelength}{\Delta t_1}$	$v_2 = \frac{slatelength}{\Delta t_2}$	$v_3 = \frac{slatelength}{\Delta t_3}$	$v_4 = \frac{slatelength}{\Delta t_4}$

$$\sum_{i=1}^{4} t'_i =$$

$$\sum_{i=1}^{4} v_i =$$

$$\sum_{i=1}^{4} t'_i v_i =$$

$$\sum_{i=1}^{4} t'^2_i =$$

$$a_4 = \frac{4.\sum_{i=1}^{4} t'_i v_i - \sum_{i=1}^{4} t'_i \sum_{i=1}^{4} v_i}{4.\sum_{i=1}^{4} t'^2_i - (\sum_{i=1}^{4} t'_i)^2} =$$

a_4 = ____________ *cm/s*^{2}

VI. Take 2 one-grams from the sled (one from right, one from left) and add those 2 grams to the holder. Complete a measurement set as explained in the 8th step. Record your measurements to the following table.

Table 3.6: m_1 = ____________ *gr* m_2 = ____________ *gr*

t_1	t_2	t_3	t_4
Δt_1	Δt_2	Δt_3	Δt_4
$t_1' = t_1 + \frac{\Delta t_1}{2}$	$t_2' = t_2 + \frac{\Delta t_2}{2}$	$t_3' = t_3 + \frac{\Delta t_3}{2}$	$t_4' = t_4 + \frac{\Delta t_4}{2}$
$v_1 = \frac{slatelength}{\Delta t_1}$	$v_2 = \frac{slatelength}{\Delta t_2}$	$v_3 = \frac{slatelength}{\Delta t_3}$	$v_4 = \frac{slatelength}{\Delta t_4}$

$$\sum_{i=1}^{4} t'_i =$$

$$\sum_{i=1}^{4} v_i =$$

$$\sum_{i=1}^{4} t'_i v_i =$$

$$\sum_{i=1}^{4} t'^2_i =$$

$$a_5 = \frac{4.\sum_{i=1}^{4} t'_i v_i - \sum_{i=1}^{4} t'_i \sum_{i=1}^{4} v_i}{4.\sum_{i=1}^{4} t'^2_i - (\sum_{i=1}^{4} t'_i)^2} =$$

a_5 = ____________ cm/s^2

Signature:

Fill in the first column of the table below using the calculated acceleration values a_1, a_2, a_3 and a_4 above. The total force on the system which should be filled into the second column can be calculated using the formula:

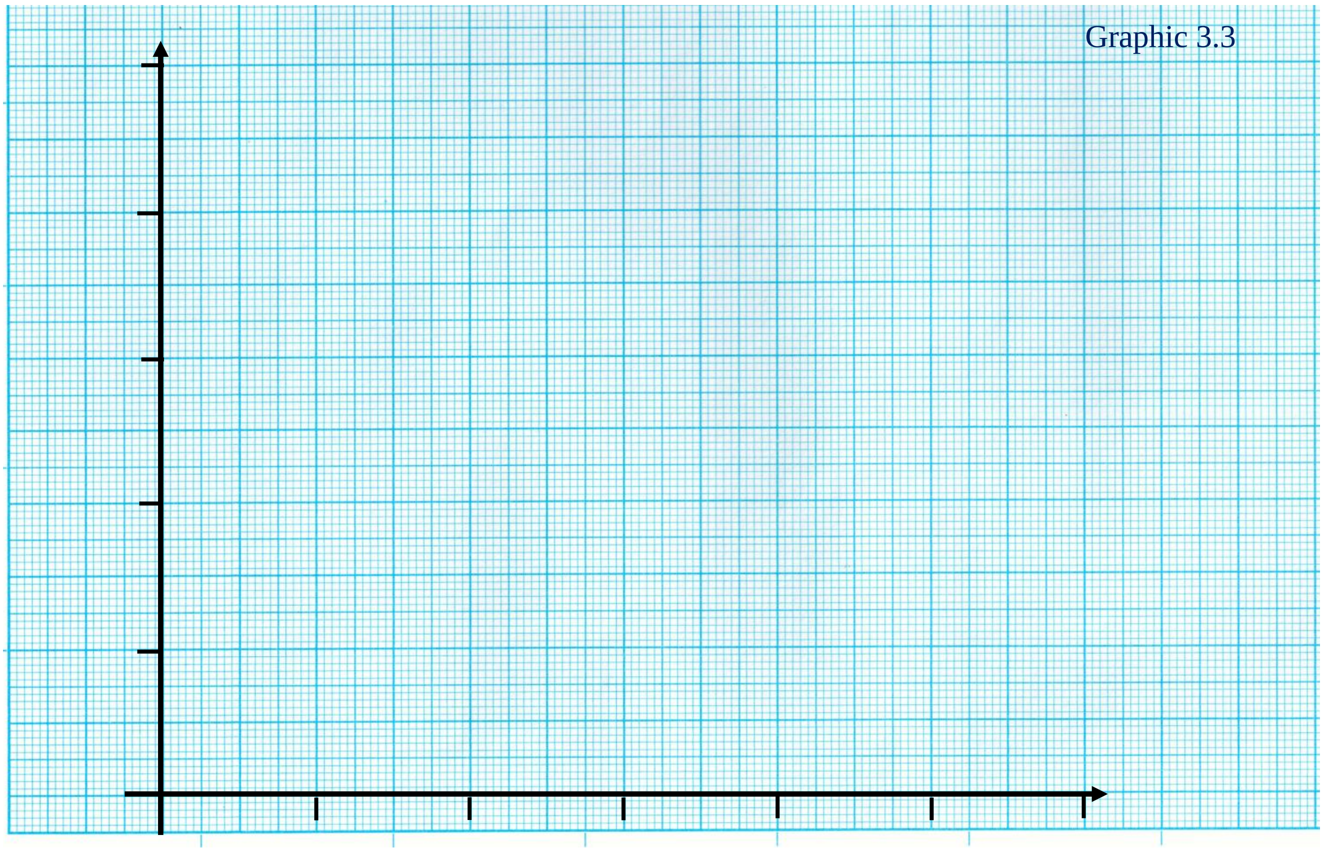
$$F = m_1 g$$

You can take the unit of mass as gr and gravitational acceleration as $g = 980\ cm/s^2$. In this case unit of force should be written as *dyn* ($gr.cm/s^2$).

Table 3.7: Acceleration-Force

***a* (____)**	***F* (____)**

Take the horizontal axis as acceleration a and vertical axis as the force F, and plot $F - a$ graph. Express the values in this table as points on your graph. Since we have kept the total mass constant in these measurements we expect to observe a *linear* relationship between the force and the acceleration as it is exactly what Newton's second law would predict. Use the measured total mass m_{total}, which is calculated in the following step, as your line's slope and plot the $F = m_{total} a$ line on your $F - a$ graph. Observe the fitness of the line to your data points.



Make a linear fit to the values above table and find the slope of the line that is supposed to pass from the points. This slope gives the total mass of the system.

$$\sum_{i=1}^{5} a_i =$$

$$\sum_{i=1}^{5} F_i =$$

$$\sum_{i=1}^{5} a_i F_i =$$

$$\sum_{i=1}^{5} a_i^2 =$$

$$m_{total} = \frac{5.\sum_{i=1}^{5} a_i F_i - \sum_{i=1}^{5} a_i \sum_{i=1}^{5} F_i}{5.\sum_{i=1}^{5} a_i^2 - \left(\sum_{i=1}^{5} a_i\right)^2} =$$

m_{total} = ____________ *gr*

Compare this value to the mass that you have directly measured as ($m_1 + m_2$). Discuss the reasons for probable differences.

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Conclusion, Comment and Discussion:

(Tips: Give detail explanation about what you've learned in the experiment and also explain the possible errors and their reasons.)

Signature:

Questions:

1) Taking into account the assumptions and approximations of the model shown in Figure 3.1 discuss the compatibility of the model in terms of representing the actual physical system.

2) Can Newton's 1st law of motion be derived from the 2nd law of motion? Discuss using the kinematics equations given in the theoretical background.

3) Search for the concepts "*gravitational mass*" and "*inertial mass*". Discuss the reason to use two different adjectives for a concept like "mass".