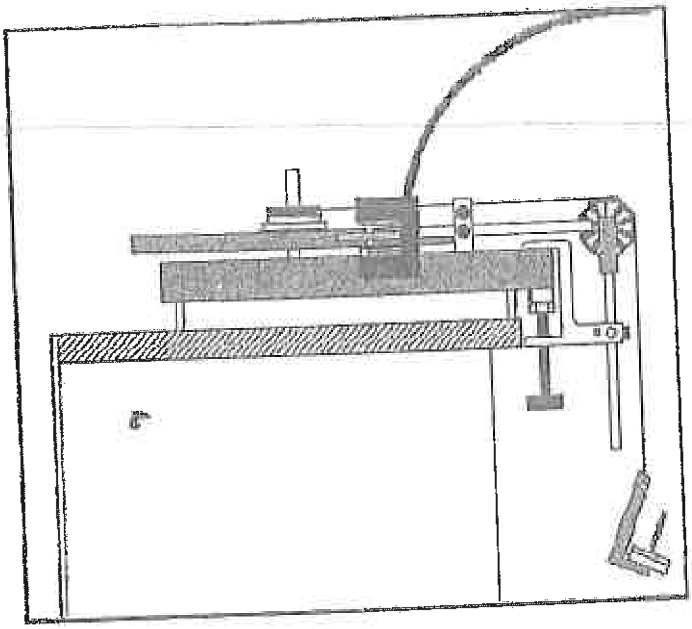
YALOVA UNIVERSITY

ENGINEERING FACULTY



PHYSICS LOBORATORY-1 EXPERIMENTS

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FİZİK 1 LABORATUVARI ÖĞRENCİLERİNE

1. Her öğrenci kendisine ayrılan ve ilan edilen laboratuar saatinde laboratuarda yerini almış olmalıdır.
2. Öğrenci laboratuara gelmeden önce, o gün yapacağı deney ile ilgili temel bilgileri, deney düzeneğini ve deneyin kılavuzunu çalışmış ve anlamış olmalıdır.
3. Öğrenciler deney sonunda öğrendikleri bilgileri, topladıkları verileri ve gerekli grafikleri çizerek hazırladıkları deney raporunu 1 hafta sonra deney sorumlusuna teslim ederler.
4. Her öğrenci çizeceği grafikler için kendi grafik kâğıdını getirmek zorundadır.
5. Devamsızlık veya telafi sınırı 3 deneydir. Daha fazla sayıda deneye gelmeyen öğrenci dönem sonu sınav hakkını kaybeder. Başka bir deyişle, laboratuar dersinden kalmış olur.
6. Mazereti nedeni ile laboratuara gelemeyen öğrencilere final sınavlarından önce yapmadıkları deneyleri yapma hakkı tanınır.

Öğrenci laboratuarda bulunan cihaz ve düzeneklerin diğer arkadaşlarının da kullanacağı şekilde, sağlam ve kullanıma hazır kalması için titiz ve sorumlu davranmalıdır.

Deney Raporu Yazım Basamakları ve Açıklamaları

- Raporunuzun ilk sayfasında ortada olacak şekilde isminizi, grubunuzu, numaranızı, hangi öğretimde olduğunuzu ve deney adını yazınız; bu sayfaya başka herhangi bir şey yazmayınız.
- Başlık ortalı bir şekilde yazılacak ve raporun hazırlanması işlemi aşağıdaki gibi yapılacaktır.
- *Raporlar elle yazılacaktır, bilgisayar çıktısı kabul edilmeyecektir.*

I. TITLE: (Deneyin Adı)

II. PURPOSE: (Deneyin Amacı)
Yaptığınız deneyde neyi hedeflediğinizi kendi cümlelerinizle yazınız.

III. EXPERIMENTAL PROCEDURE: (Deneyin Yapılışı ve Her Adımdaki Gözlemleriniz)
Öncelikle deneydüzeneğini ve kurulumunu anlatıp, ölçüm sonuçları ve hesaplamaları belirtin. Grafikler için milimetrik kağıt kullanınız.

IV. COLLECTİON OF EXPERIMENTAL DATA AND SYSTEMATIC RECORDING:
(Deneysel Verilerin Toplanması ve Sistematik Kaydedilmesi)
a. Deneydeki değişkenlere ilişkin gözlem ve ölçüm verilerinizi "Sistematik Tablo, Çizelge vb." biçiminde birimleri de dikkate alarak kaydediniz.

V. *DATA ANALYSİS AND CALCULATİONS*: (Verilerin Analizi ve Hesaplamalar)
a. Deneyde "Grafik Çizimi" isteniyorsa milimetrik kağıda çizerek analiz basamağına yerleştiriniz. Grafikte istenen eğimi, alanı vb.hesaplayınız.
b. Deneyde teorik ve deneysel verilerin analizini karşılaştırarak hesaplayınız.
c. Deneyin analizinden elde ettiğiniz kendi analiz sonucunuz ile grup arkadaşlarınızın analizlerini bir tabloda karşılaştırarak değerlendiriniz.

VI. *EXPERİMENT RESULTS AND INTERPRETATİON*: (Deney Sonuçları ve Yorumu)
a. Deneyde ulaştığınız en genel sonuçları açıklayın ve yorumlayın.
b. Deneyde hesapladığınız işlemsel sonuçları ve kavramsal sonuçları açıklayın ve yorumlayın.
c. Teorik ve deneysel değerleri karşılaştırarak sonuçları yorumlayın.
d. Hata hesabını yaparak deneyi yorumlayınız.
e. Yukarıdaki sonuçlarınızdan yola çıkarak olası "Hata Kaynaklarınızı" yazınız.

VII. *ANSWERİNG ASSESSMENT QUESTİONS*:

DİKKAT EDİLMESİ GEREKENLER

1- Laboratuarda bir sınıfta uyulması gereken tüm kurallara uyulmalıdır.
2- Kullanılacak fiziksel ifadelerde birim sistemleri dikkate alınmalıdır.
3- Deney kitapçığındaki ara işlemler öğrenci tarafından kontrol edilerek, tekrarlanmalıdır.
4- Birimlerin yazılması unutulmamalıdır.
5- Amaç –sonuç ilişkisi kurulmalıdır.
6- Grafik çizim kurallarına uyulmalıdır.
7- Grafikte eğim bulmak için nokta seçerken veri noktaları dışında, ara bölgelerden seçim yapılmalıdır.
8- Deneyin yorum kısmında: Sonuçlar nasıl çıktı?
Hatalar nereden kaynaklanabilir?
Nasıl giderebiliriz?
Şeklindeki sorulara yanıt aranmalıdır

FİZİKTE ÖLÇME VE HATA HESABI

Fizikte hiçbir ölçüm hatasız değildir. Deneylerde bulunan sayısal sonuçlar ölçüm hataları belirlenmedikçe hiçbir anlam ifade etmez. Yani her ölçülen sonuçta, bu sonucun anlamlılık sınırları, yani hata sınırları belirtilmelidir. Laboratuar çalışmalarında tek amaç, fiziksel sabitlerin ölçümü ya da verilerin geniş kapsamlı istatistik analizi değildir. Bununla birlikte, ölçüm sonuçlarının hangi sınırlar içinde anlamlı olduğunun saptanması gerekir. Bu amaçla hataların saptanmasına ilişik bazı pratik bilgiler aşağıda sunulmuştur.
İki tür hata vardır: Sistematik Hatalar ve İstatistiksel Hatalar.

A) Sistematik hatalar:
Bu tip hatalar, adından da anlaşılacağı gibi sistemin kendisinden gelen sabit hatalardır ve sonucu sürekli olarak aynı yönde etkilerler. Örneğin, 1 kilogramdan daha ağır bir kilo ile ağırlıklar ölçülmüşse, ölçüm sonucu aynı oranda daha küçük olacaktır. Bu tip hataların var olması durumunda hatalar tek yönlüdür; sonuç ya sürekli daha büyük ya da daha küçüktür. Sistematik hatalar aşağıdaki yöntemlerle azaltılabilir.

1. Ölçüm sonucunda gerekli düzeltme yapılarak,
2. Ölçü sistemindeki hata giderilerek
3. Ölçüm yöntemi değiştirilerek.

B) İstatistiksel Hatalar:
Fizikte ölçüm hassaslığının doğal olarak sınırlı oluşundan, ölçülen nesne ya da ölçüm sistemindeki kararsızlıklardan kaynaklanan, genellikle küçük ve çift yönlü hatalardır. Bu tip hataların varlığı, aynı ölçümün çok sayıda yinelenmesiyle görülebilir. Ölçülen sonuçlar birbirinden farklı olup belirli bir değer çevresinde dağılım gösterir. Bu hatalar ölçüm

sonuçlarından ayıklanamaz, ancak hata paylarının ve ölçülen büyüklüğün hangi sınırlar içinde anlamlı olduğunun yaklaşık olarak saptanması olasıdır. Bu tip hataların ölçüm sonuçlarına etkisi, aynı ölçümün çok sayıda yinelenmesi ve sonuçların istatistik değerlendirilmesiyle azaltılabilir

GRAFİK ÇİZME VE GRAFİKTEN YARARLANMA

Deney sonuçlarının grafiklerle verilmesi, pratik ve kolay anlaşılır oluşu nedeniyle hemen her bilim dalında yaygın olarak kullanılır. Grafikler her türlü bilgiyi herkesçe anlaşılır şekilde vermelidir. Grafik çiziminde aşağıdaki kurallara uyulmalıdır;

1. Grafiğin adı ve tarihi yazılmalıdır
2. Eksenlerin hangi büyüklüklere karşı geldiği ve birimlerinin ne olduğu belirtilmelidir
3. Her türlü yazı ve rakamlar kolayca okunabilir şekilde yerleştirilmelidir
4. Grafikte birim uzunluklar, çizilen grafik bütün kâğıdı kaplayacak şekilde seçilmelidir

III. GRAFİK ÇİZİLMESİ

Grafikten beklenen sonuçların sağlanabilmesi için grafik çiziminde aşağıdaki hususların dikkate alınması gerekir. Bu yapılmadığında grafikten yanlış bir bağıntı bulunabileceği gibi, çizenin dışındakiler grafiği yorumlayamayabilir.

Grafik Çiziminde Başlıca Kurallar

1. Koordinat Eksenlerinin Seçimi ve İşaretlenmesi

Serbest değişken yatay eksene (apsis), bağlı değişken düşey eksene (ordinat) yerleştirilir. Değişkenlerin adı ve parantez içinde birimleri yazılır.

2. Ölçek Seçimi

Yatay ve düşey eksende 1 birim (1 cm) uzunluğun gösterildiği değere, **fonksiyon ölçeği** ya da **ölçek** denir. Ölçek seçimi keyfidir. Ölçek ve değişkenlerin başlangıç noktasının seçiminde aşağıdaki kurallara uyulmalıdır.

- **a.** Ölçekte, ölçülen büyüklüğün tam sayı değerleri gösterilmeli, tam sayıdan sonraki kesirli kısımlar gösterilmemelidir. Bu kurala uyulmadığında, hem verilerin işaretlenmesinde hem de grafikten değer okunmasında güçlük çekilir.
- **b.** Veriler çok büyük ya da çok küçük sayılardan oluşuyorsa önce bunlar 10' un kuvvetleri şeklinde yazılırlar ve ölçek seçimi bundan sonra yapılır. Grafik kâğıdında üslü çarpan parantez içinde büyüklüğün birimi ile birlikte yazılır.
- **c.** Karşılaşılan verilere bağlı olarak x ve y eksenlerine ait ölçek birimleri eşit olmayabilir.
- **d.** Serbest ve bağlı değişkenlerin sıfır değerleri grafiğin orijininde bulunabileceği gibi genellikle değişkenlerden birinin ya da her ikisinin sıfır değeri orijinde bulunmayabilir.
- **e.** Grafik çizilirken x ve y eksenindeki değerler kesikli çizgilerle kesiştirilmemelidir.

3. Verilerin İşaretlenmesi

Verilerin yerleri kendilerine ait eksenlerden bulunur ve bu noktalardan eksenlere çıkılan dikmelerin kesim noktaları Şekil 3' deki sembollerden biri ile işaretlenir (Biz birinci sembolü kullanacağız.). ***Veri değerleri kesinlikle koordinatlara yazılmamalıdır***. Aynı grafik kâğıdına birden fazla grafik çizilecekse her eğri için ayrı bir sembol kullanılmalıdır.

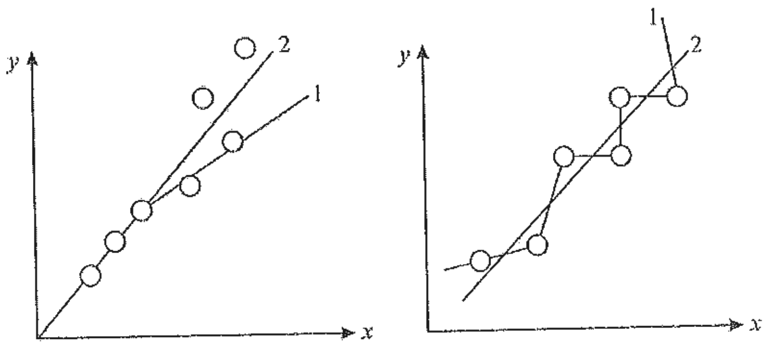
Veriler ölçülen büyüklüğün gerçek değeri olmayıp, ona en yakın ortalama değerdir. Dolayısıyla bir hata içerirler.

⊙ △ ⊡ + ×

Şekil 3. Grafik çiziminde verilerin işaretlenmesinde.kullanılan şekiller.

4. Eğrinin Çizilmesi

Grafik analizinde, veri çiftlerinin eksenlere yerleştirilmesi ile oluşan eğrinin şekli ile ilgilidir. Burada eğri sözcüğü, hem doğru hem eğri çizgi anlamında kullanılmaktadır. Bunu bölümün başında da belirtildiği gibi, fizik kanunları ve bağıntıları basit denklemler şeklindedir. Bu nedenle veri çiftlerini gösteren noktalar ya bir doğru ya da düzgün bir eğri oluştururlar. Veriler hata içereceğinden tüm noktalar eğri üzerinde bulunmayabilir. Hataların pozitif ve negatif olma olasılıkları eşit olduğundan, ***eğri; mümkün olduğu kadar çok sayıda noktadan geçecek ve noktaları ortalayacak şekilde çizilmelidir***. (Çizilen eğrinin tüm veri noktalarından geçmesi şartı yoktur. Dikkat edilecek husus, çizilen eğrinin altında ve üstünde eşit sayıda eğriyle kesişmeyen noktanın kalmasıdır). Şekil 4' de eğrinin nasıl çizileceği bazı örnekler üzerinde açıklanmıştır.



Şekil 4. Grafikte Eğri Çizimi. (1) yanlış çizimi; (2) doğru çizimi göstermektedir.

PHYSICS 1 LABORATORY
EXPERIMENT–1
MEASUREMENT

1. PURPOSE:

To study the vernier scale principle and to learn the use of vernier calipers (kompas) for the accurate measurement of length. To become familiar with the use of micrometer calipers for the accurate measurement of small lengths.

2. THEORY:

Careful quantitative measurements are very important for development of physics, the most exact of the experimental sciences. The measurement of length is basic to many of the experiments performed by physicists.

Discussion of Measurements: The simplest devices for measuring lengths utilize a linear scale of one kind or another. Most people have had occasion to use a yardstick or tape measure or some similar device for the measurement of length. In experimental physics, we quite often wish to know a length to higher accuracy than can be read using these common devices. We use one of two common devices which enable us to measure lengths to higher accuracy, the Vernier caliper and the micrometer caliper.

Vernier Caliper: The Vernier caliper is illustrated in **Figure 1**. This device has jaws for making inside, outside, or depth measurements. There are two scales on the caliper. The one scale is English and the other scale is metric. The instrument utilizes the Vernier principle to extend readability to 0.05 mm on the metric scale or 0.001" on the English scale.

The Vernier Principle: The Vernier is an auxiliary scale which bears a simple relationship to the main scale divisions. This scale divides (N-1) main scale divisions into N parts, e.g. a metric Vernier divides 19 mm into 20 parts so each unit on the Vernier scale is 0.95 mm. The difference between the main scale divisions and the Vernier division is called the least count. For the metric scale the least count is 1.0 mm - 0.95 mm = 0.05 mm. The least count is the accuracy to which the Vernier can be read. Figure 2 shows a Vernier reading of 4.55 mm. The Vernier principle can be used to divide main scale divisions into fractions other than 1/10 or 1/8. For example, angular scales often read to minutes of arc by dividing a degree scale into 60 parts. For each Vernier scale, you have to determine what main scale division the Vernier divides and thus, to what accuracy the Vernier reads.

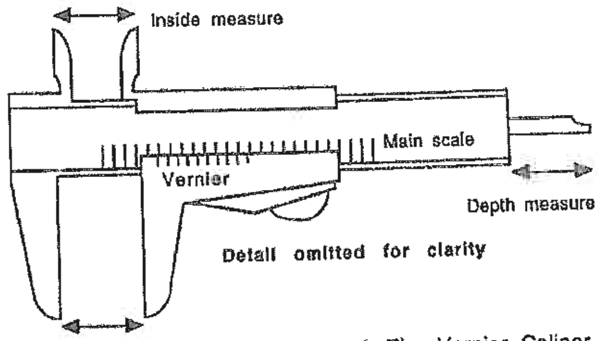


Figure 1. The Vernier Caliper

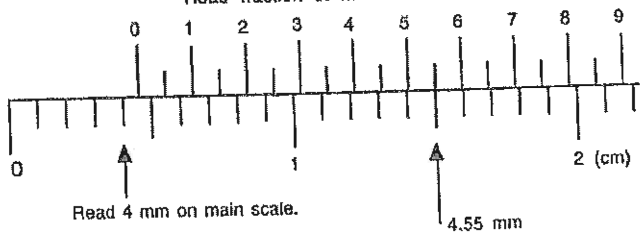


Figure 2. A reading on a vernier scale.

Micrometer: Figure 3 shows the other type of length measuring device commonly used in the laboratory, the micrometer caliper. This device utilizes a screw with pitch such that one turn of the barrel moves the arm a pre-determined distance. On the frame of the instrument is a linear scale and the barrel is divided into some number of divisions. The metric micrometer has the barrel divided into 50 parts and the pitch of the screw is such that it requires two turns of the barrel to move the arm 1.0 mm. Thus, this device is capable of being read to 0.01 mm. On this scale, the barrel must be turned through two revolutions for the arm to move one scale division so the user must pay attention to whether the marker has moved more than half a main scale division. **Figure 4** shows a metric micrometer reading which could be 5.25 or 5.75 mm. From the spacing it is 5.25 mm, but by reading only the number it could be either one. The English micrometer is like the metric micrometer, but reads in units of 0.001". The scale on the frame is in tenths of an inch and the barrel is divided into 25 parts. The pitch is so as to require 4 turns of the barrel to move the arm 0.1 inch. This divides 0.1 inch into 100 parts, making the micrometer readable to 0.1" x 0.01 = 0.001". Quite often the 0.1" divisions will be subdivided into 2 or 4 parts, as illustrated in Figure 5. The micrometer is often equipped with a Vernier scale which allows the reading to be carried one order further. It is common to use a micrometer caliper with Vernier to read 0.0001" or 0.002 mm.

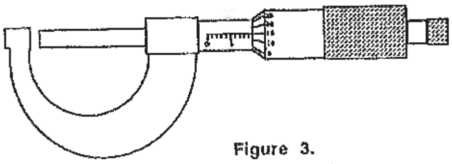


Figure 3.

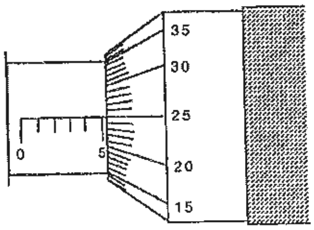


Figure 4.

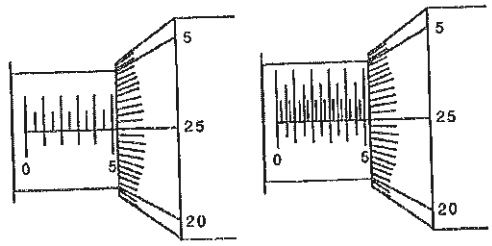


Figure 5.

3. Procedure:

Do all the calculations required to fill in the data tables with the vernier caliper and micrometer. Make sure you round off your answers to the proper number of significant figures and give the units of all measured and calculated quantities.

Blocks	Mass(g)	Height(cm)	Diameter(cm)	Volume(cm^3)	Density(g/cm^3)
Rectangular Prism					
Cylindrical Block					
Spherical Block					
Cone					

Hint: A density is found by

$$d = \frac{mass}{Volume} = \frac{m}{V}$$

where mass is found by using the scales device and Volume (V) is found by

$$Volume = V = length.width.height$$

4. Questions:

1. Give the probable error and report this with the proper number of significant figures.

2. The measuring devices used above which is most precise?

3. To improve on the accuracy of the density determination what measurement will have to be made with much better precision?

4. How could the error be improved in this experiment?

5. Why are several observations better than one in an experiment?

PHYSICS 1 LABORATORY
EXPERIMENT–2
VECTOR ADDITION

1. PURPOSE

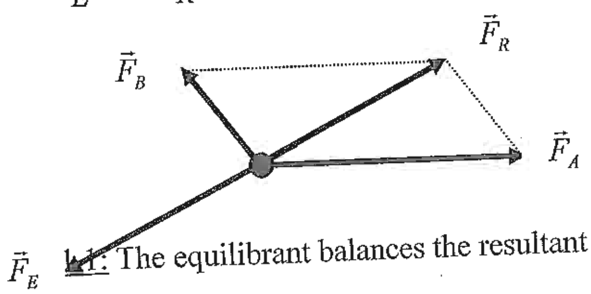
The purpose of this experiment is to use the force table to experimentally determine the force which balances two other forces. This result is checked by adding the two forces using their components and by graphically adding the forces.

2. THEORY

Many physical quantities can be completely specified by their magnitude alone. Such quantities are called scalars. Examples include such diverse things as distance, time, speed, mass and temperature. Another physically important class of quantities is that of vectors, which have direction as well as magnitude.

A-) Experimental Method: Two forces are applied on the force table by using masses over pulleys positioned at certain angles. Then the angle and mass hung over a third pulley are adjusted until it balances the other two forces. This third force is called the equilibrant ($\vec{F}_E$) since it is the force which established equilibrium. The equilibrant is not the same as the resultant ($\vec{F}_R$). The resultant is the addition of the two forces. While the equilibrant is equal in magnitude to the resultant, it is in the opposite direction because it balances the resultant (see Fig.1.1). So the equilibrant is the negative of the resultant:

$$-\vec{F}_E = \vec{F}_R = \vec{F}_A + \vec{F}_B \tag{1.1}$$



I 1.1: The equilibrant balances the resultant

B-) Component Method: Two forces are added together by adding the x- and y-components of the forces. First the two forces are broken into their x- and y-components using trigonometry:

$$\vec{F}_A = A_x\hat{x} + A_y\hat{y} \quad \text{and} \quad \vec{F}_B = B_x\hat{x} + B_y\hat{y} \tag{1.2}$$

where A_x is the component of the vector $\vec{F}_A$ and $\hat{x}$ is the unit vector in the x-direction as shown Fig. 1.2. To determine the sum of $\vec{F}_A$ and $\vec{F}_B$, the components are added to get the components of the resultant $\vec{F}_R$.

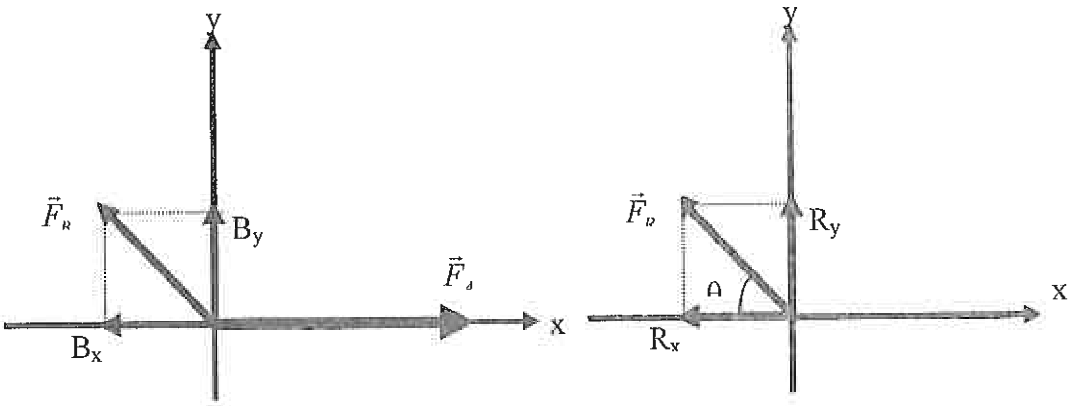


Figure 1.2: Vector Components

$$\vec{F}_R = (A_x + B_x)\hat{x} + (A_y + B_y)\hat{y} = R_x\hat{x} + R_y\hat{y} \tag{1.3}$$

To complete the analysis, the resultant force must be in the form of a magnitude and a direction (angle). So the components of the resultant (R_x and R_y) must be combined using the Pythagorean theorem since the components are at right angles to each other:

$$|F_R| = \sqrt{R_x^2 + R_y^2} \tag{1.4}$$

and using trigonometry gives the angle:

$$\tan\theta = \frac{R_y}{R_x} \tag{1.5}$$

C-) Graphical Method: Two forces are added together by drawing them to scale using a ruler and protractor. The second ($\vec{F}_B$) is drawn with its tail to the head of the first force ($\vec{F}_A$). The resultant ($\vec{F}_R$) is drawn from the tail of the $\vec{F}_A$ to the head of $\vec{F}_B$ as shown in Fig.1.3. Then the magnitude of the resultant can be measured directly from the diagram and converted to the proper force using the chosen scale. The angle can also be measured using the protractor.

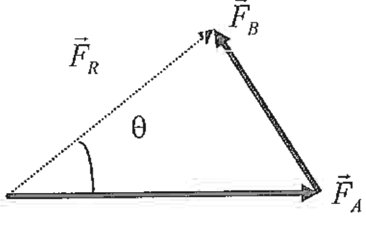


Figure 1.3: Adding vectors head to tail

3. 1.EXPERIMENTAL PROCEDURE-A

1. Assemble the force table as shown in the Assemble section. Use three pulleys (two for the forces that will be added and one for the force that balances the sum of the two forces).
2. If you are using the Ring Method, screw the center post up so that it will hold the ring in place when the masses are suspended from the two pulleys. If you are using the Anchor String Method, leave the center post so that it is flush with the top surface of the force table. Make sure the anchor string is tied to one of the legs of the force table so the anchor string will hold the strings that are attached to the masses that will be suspended from the two pulleys.
3. Hang the following masses on two masses on two of the pulleys and clamp the pulleys at the given angles:

	Force	Mass	Angle
EXP-1	F_A	50 g	0^0
	F_B	100 g	120^0
	F_E		
EXP-2	F_A	30 g	25^0
	F_B	125 g	45^0
	F_E		

Experimental Method:
By trial and error, find the angle for the third pulley and the mass which must be suspended from it that will balance the forces exerted on the strings by the other two masses. The third force is called the equilibrant $\vec{F}_E$ since it is the force which establishes equilibrium. The equilibrant is the negative of the resultant:

$$-\vec{F}_E = \vec{F}_R = \vec{F}_A + \vec{F}_B \qquad (1.6)$$

Record the mass and angle required for the third pulley to put the system into equilibrium in Table 1.1.
To determine whether the system is in equilibrium, use the following criteria.

Ring Method of Finding Equilibrium:
1. The ring should be centered over the post when the system is in equilibrium. Screw the center post down so that it is flush with the top surface of the force table and no longer able to hold the ring in position. Pull the ring slightly to one side and let it go. Check to see that the ring returns to the center. If not, adjust the mass and/or angle of the pulley until the ring always returns to the center when pulled slightly to one side.
2. See Fig.1.4 to use this method, screw the center post up until it stops so that it sticks up above the table. Place the ring over the post and tie one 30 cm long string to the ring for each pulley. The strings must be long enough to reach over the pulleys. Place each string over a pulley and tie a mass hanger to it.

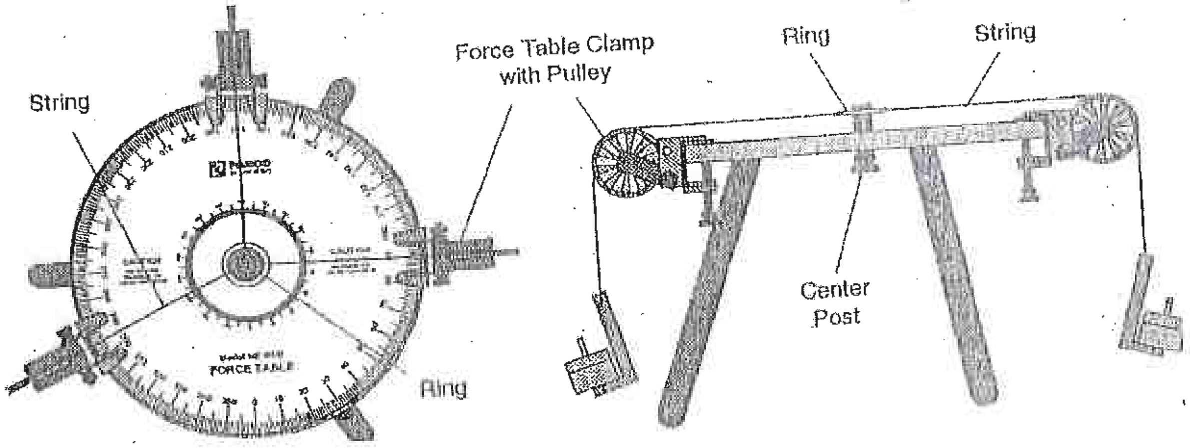


Figure 1.4: Ring method of stringing force table.

4. DISCUSSIONS

1. To determine theoretically what mass should be suspended from the third pulley, and at what angle, calculate the magnitude and direction of the equilibrant ($\vec{F}_E$) by the component method and the graphical method.

Component Method:

On a separate piece of paper, add the vector components of Force $\vec{A}$ and Force $\vec{B}$ to determine the magnitude of the equilibrant. Use trigonometry to find the direction (remember, the equilibrant is exactly opposite in direction to the resultant). Record the results in Table 1.1.

Graphical Method:

On a separate piece of paper, construct a tail-to-head diagram of the vectors of Force $\vec{A}$ and Force $\vec{B}$. Use a metric rule and protractor to measure the magnitude and direction of the resultant. Record the results in Table 1.1. Remember to record the direction of the equilibrant, which is opposite in direction to the resultant.

2. How do the theoretical values for the magnitude and direction of the equilibrant compare to the actual magnitude and direction?
3. Three forces and their resultant and equilibrant. Draw the space diagram as before. Then solve (on a second sheet of graph paper) by the vector polygon method for the resultant and the equilibrant (The vector polygon method is merely an extension of the vector triangle plot. The last plotted vector should, except for experimental error, close the polygon). Finally, solve for the resultant (magnitude and direction) of the three forces by the analytically method, using the technique of resolving forces into their horizontal and vertical components.
4. Compare the results with the actual experimental values from the force table.

5. Explain how the experiment has illustrated the principles of vector addition. What does the vector equation $\vec{R} = \vec{F_1} + \vec{F_2}$ Express? How would you write the same expression in algebraic terms?

Table.1.1 : Data table

Table 1.1		
Method	Equilibrant (F_E)	
	Magnitude	Direction (θ)
Experiment:		
Component: R_x=__________ R_y=__________		
Graphical:		

5. QUESTIONS

1. List as many vector quantities as you can think of.
2. Show how you would add the following three vectors: 10 units North, 10 units South, and 10 units straight up.
3. Start by choosing a coordinate system and sketching the vectors. Use graphical techniques to get a qualitative estimate of the resultant.
4. Does a unit vector have units?
5. Add the x components algebraically to find the resultant a value and add the y component algebraically to find the resultant y value.
6. (a) If you walk three city blocks east and then four blocks north, how many blocks are you from your starting place? (b) What direction are you from the starting point? Give your answer as an angle measured from due east.
7. Add the following vectors graphically in the order given, then add them in reverse order on a separate diagram, thereby testing that vector addition is commutative: A = 5 units at 60° and B = 7 units at 180°.
8. How do the theoretical values for the magnitude and direction of the equilibriant compare to the
   actual magnitude and direction?

9. Determine the % error is computed by this formula:

$$Percentage...difference = \frac{measured..value - accepted..value}{accepted..value} x100(\%)$$

Use the computed values as your accepted values.

10. Fill in the following table:

$A_x = 2.45$ N cos 40° = ________	$A_y = 2.45$ N sin 40° = ________
$B_x = 3.92$ N cos ___ = ________	$B_y = 3.92$ N sin ___ = ________
C_x = ______ cos ___ = ________	C_y = ______ sin ___ = ________
R_x = ________	R_y = ________

Draw a sketch of the components of the resultant in an xy coordinate system here (include the magnitude and direction of the resultant also):

The magnitude of the resultant is $R = \sqrt{R_x^2 + R_y^2} =$ ________________

The angle the resultant makes with the x – axis (reference angle) is

$$\theta = \tan^{-1}\frac{R_y}{R_x} = \_\_\_\_\_\_\_\_$$

According to your sketch above does the angle place the resultant in the correct quadrant? If not, what is the correct angle for the resultant vector?

Write the resultant in both polar and unit vector notation.

R = ________________ = ________________

11. On the graph to the right, draw a coordinate axis, and also the following vectors:
(a) 3**i** (b) 4**j** (c) 3**i** + 4**j** (d) 5**i** +**j**

12. What are the angles of each of the vectors, as measured from the x axis, in question 11?

13. On the graph to the right, draw a coordinate axis, and add **A** = 4**i** + 3**j** and **B** = 2**i** +5**j** graphically (i.e., add the arrows). What is the equation of the resultant vector? What angle does it make with respect to the x axis?

14. Suppose you go out for a walk. You walk straight ahead for 100 meters. Then you turn to your left and walk for another 50 meters. Finally you turn to your right and walk another 25 meters. How far are you from where you started? At what angle are you, with respect to the direction you started out walking? Do this problem using components.

PHYSICS 1 LABORATORY
EXPERIMENT–3
VELOCITY AND ACCELERATION

1. PURPOSE

The quantitative study of motion is a key element of physics. The simplest motion to describe is the motion of an object traveling at a constant speed in a straight line and to investigate the relationship between position, velocity, and acceleration for linear motion

2. THEORY

The concept of speed and know that the speed of an object is measured in units such as miles per hour, kilometers per hour, or meters per second. The speed is the ratio of the distance traveled to the time required for the travel. We define the average speed as the total distance, x traveled during a particular time divided by that time interval t;

$$\text{Average speed} = \text{total distance traveled / time interval for interval} = \frac{x}{t}$$

The definitation deals only with the motion itself, in the same, other definitions in kinematics are restricted to properties of the motion only. If the average speed is the same for all of a trip, then the speed is constant.

In reality, motion is usually not restricted to one dimension, and we must take account of the direction as wheel as the speed of an object's motion. The name for the quantity that describes both the direction and the speed of motion is **velocity**. Even though we are considering only one-dimensional motion, we must still take account of direction) for example, positive versus negative, or east versus west), so we will use the term velocity. Suppose a car is located at point x_1 at a time t_1, and at another point x_2 at a later time t_2. Then the car's **average velocity** v over the time interval is

$$v = \text{(final position – initial position)/(final time – initial time)} = \frac{(x_2 - x_1)}{(t_2 - t_1)}$$

The average velocity is the displacement divided by the time elapsed during that displacement. In general, a bar over a symbol (as in v) indicates the average value of that quantity, in this case the average velocity. Note that the average velocity can be either positive or negative. The difference between speed and velocity is more than just an algebraic sign; it involves the difference between the total distance traveled (for speed) and the net change in position (for velocity).

If the velocity of a moving body does not change with respect to time, the body's motion is called " uniform ". The instantaneous velocity of a moving particle at a particular time t is given by

$$\vec{v} = \frac{d\vec{x}}{dt} \tag{4.1}$$

where x is the displacement vector.

We defined the average velocity of an object as its change in position divided by the time elapsed, $v=\Delta x/\Delta t$. This tells s how the objects position changes with time. It is reasonable to define a quantity that indicates how the object's velocity changes with time. We define the **average acceleration,** a, as the change in velocity divided by the time required for the change. The average acceleration can be written as

$$a = \frac{(v_2 - v_1)}{(t_2 - t_1)} = \frac{\Delta v}{\Delta t} \qquad (4.2)$$

According to Newton's first law, an object set in motion on a perfectly smooth, level, frictionless surface continues to move in a straight line with constant velocity. If the velocity of a moving object changes in time either in magnitude or direction, the object is said to be in accelerated motion. The instantaneous acceleration at time t is given by

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2x}{dt^2} \qquad (4.3)$$

According to Newton's second law, when a force is applied to an object it experiences an acceleration which is proportional in magnitude to the applied force, in the direction of the force. This relation is expressed as

$$\vec{F} = m\vec{a} \qquad (4.4)$$

where m is the mass of the object.

3. EXPERIMENTAL PROCEDURE

Part A: Constant Velocity

Procedure: GLX Setup

1. Connect the Motion Sensor to one of the sensor ports on the top end of the GLX. Put the range selection switch on the top of the Motion Sensor to the 'near' (cart) setting as shown in figure 1.

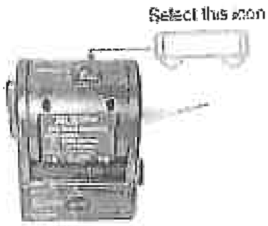


Fig. 1: Motion Sensor setting

2. Turn on the GLX.
   -The Graph screen opens with a graph of Position (m) versus Time (s).

Equipment Setup

1. Place the PASCO track on a table and attach the Motion Sensor to one end of the track as shown in figure 2.

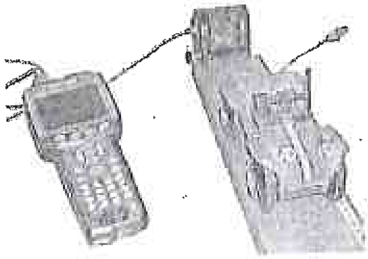


Fig. 2: Equipment setup

2. Place the cart about 15 cm from the Motion Sensor so that the back of the cart is facing the sensor.
3. Aim the sensor so its signal will reflect from the cart.

Record Data: Part 1;

1. Press Start on the GLX to begin measuring the sensor signal.
2. Turn on the switch on the side of the cart so the cart moves toward the other end of the track.
3. Press to end data recording just before the cart reaches the end of the track. Turn off the cart.

   -The Graph screen will display the plot of position and time for Run #1.

Record Data: Part 2;

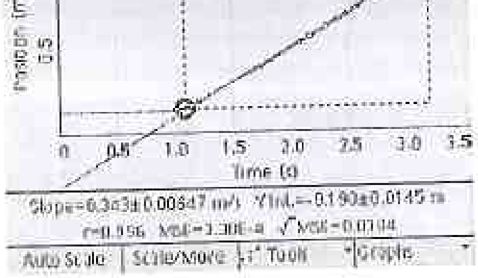
1. Fasten a block to the cart so it can be dragged behind the cart. Put a 500 g (0.5 kg) mass on top of the block.
2. Place the cart and the block on the track so the mass on top of the block is about 15 cm from the Motion Sensor. Aim the sensor so its signal will reflect from the mass.
3. Start on the GLX to begin measuring the sensor signal.
4. Turn on the switch on the side of the cart so the cart moves toward the other end of the track.
5. Press to end data recording just before the cart reaches the end of the track. Turn off the cart.

   -The Graph screen will display the plot of position and time for Run #2.

Analysis

Find the slope of each run of data for the cart.

1.The *Slope* of the linear fit is the speed of the cart.



Record the slope

2. Record the value of the slope in the Lab Report.
3. Repeat the data analysis procedure for the other two runs of data.

Questions:

1. Make a sketch of one run of position versus time data including labels and units fort he y- and x-axis.
2. Record your values for the slope for each run.

Run	Slope
1	m/s
2	m/s

3. What is shown on the vertical axis of your graph and what are the units?
4. What is shown on the horizontal axis of your graph and what are the units?
5. How long was the motorized cart moving each data run?

Run	Time of Motion (s)
1	
2	

6. What physical quantity does the slope of each plot represent?
7. What are the units fort he slope of each plot?
8. If the cart moves at a constant speed of 0.33 m/s, how far will it move in 5 seconds?

Part B: Acceleration

Procedure: GLX Setup

1. Connect the Motion Sensor to one of the sensor ports on the top end of the GLX. Put the range selection switch on the Motion Sensor to the 'near' (cart) setting as shown in figure.

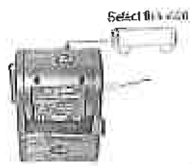


Fig. 1: Motion Sensor setting

2. Turn on the GLX.
   -The Graph screen opens with a graph of Position (m) versus Time (s).

Equipment Setup

1. Place the PASCO track on a table and attach the Motion Sensor to one end of the track as shown in figure 2.

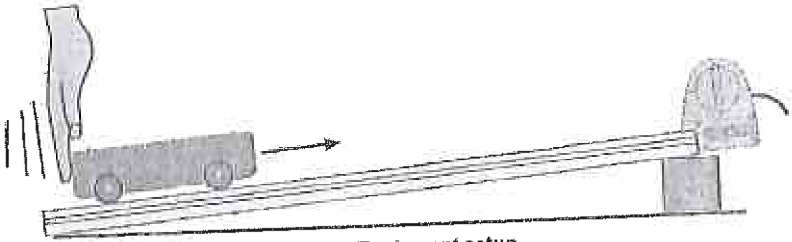


Fig. 2: Equipment setup

2. Use a couple of books to raise that end of the track so it is inclined at a small angle.
3. Place the cart at the bottom of the track so the cart is facing the sensor. Aim the sensor so its signal will reflect from the cart as the cart moves up and then back down the track.

Record Data

-NOTE: The procedure is easier if one person handles the cart and a second person operates the Xplorer GLX.

1. Press Start on the GLX to begin measuring the sensor signal.
2. Give the cart a firm push toward the Motion Sensor. (Don't let the cart get closer than 15 cm to the sensor.) Continue collecting data until the cart has returned to the bottom of the track.
3. Press √ to end data recording just as the cart reaches the end of the track.
   -The Graph screen will display the plot of position and time as shown figure 3.

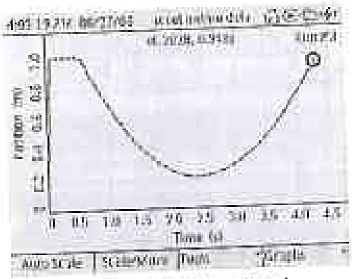


Fig. 3: Position graph

4. Fasten a block to the cart so it can be dragged behind the cart. Put a 500 g (0.5 kg) mass on top of the block.

Analysis

1. First, find the slope of the position versus square of time to determine the acceleration of the cart both whether it goes up the track and also when it comes back down the track.

2. Next, find the average value of the acceleration in the acceleration versus time graph.

Item	Value
Acceleration (slope)	m/s^2
Acceleration (average)	m/s^2

4. QUESTIONS

1. What are significant sources of error in this experiment?
2. Theoretically what should be the shape of the graph of part A? Is it so? If not, what factors may have caused this deviation from the expected shape?
3. Considering the time intervals to be errorless, calculate the percentage error in the velocity measured by you?
4. If the maximum error in the time intervals is %10, what is the % error in the measured acceleration?
5. In trying to determine an instantaneous velocity, what factors (timer accuracy, object being timed, type of motion) influence of the measurement? Discuss how each factor influences the result.
6. Can you think of one or more ways to measure instantaneous velocity, or is an instantaneous velocity always a value that must be inferred from average velocity measurements?
7. Can you think of physical phenomena involving the earth in which the earth cannot be treated as a particle?
8. Each second a rabbit moves half the remaining distance from his nose to a head of lettuce. Does he ever get to the lettuce? What is the limiting value of his average velocity? Draw graphs showing his velocity and position as time increases.
9. Average speed can mean the magnitude of the average velocity vector. Another meaning given to it is that average speed is the total length of path traveled divided by the elapsed time. Are these meanings different? If so, give an example.
10. When the velocity is constant, does the average velocity over any time interval differ from the instantaneous velocity at any instant
11. Can an object have an eastward velocity while experiencing a westward acceleration?
12. Can the direction of the velocity of a body change when its acceleration is constant?
13. Can a body be increasing in speed as its acceleration decreases? Explain.
14. In your write-up, include a description of the motion, a description of the graphs that you obtained, and try to generalize on what the different shapes of graphs mean of the motion they describe.
15. Sketch graphs to represent the following assumptions: (a) A car driven for 1 hour at a constant speed of 37 km/h, (b) A person runs as fast as possible to the corner mailbox and immediately runs back as fast as possible. Determine the average velocity and the average acceleration using the graphs.
16. Describe the position versus time plot of the Graph screen. Why does the distance begin at a maximum and decrease as the cart moves up the inclined plane?
17. Describe the velocity versus time plot.
18. Describe the acceleration versus time plot of the Graph display.
19. How does the acceleration determined in the plot of velocity compare to the average value of acceleration from the plot of acceleration?

PHYSICS 1 LABORATORY
EXPERIMENT–4
ACCELERATION DUE TO GRAVITY–FREELY FALLING BALL

1. PURPOSE

The purpose of this activity is to measure the acceleration due to gravity of a falling object.

2. THEORY

The most common example of motion with (nearly) constant acceleration is that of a body falling toward the earth. In the absence of air resistance we find that all bodies, regardless of their size, weight, or composition, fall with the same acceleration at the same point on the earth's surface, and if the distance covered is not too great, the acceleration remains constant throughout the fall. This ideal motion, in which air resistance and the small change in acceleration with altitude are neglected, is called "free fall". The acceleration of a freely falling body is called the acceleration due to gravity and denoted by the symbol $\vec{g}$. Near the earth's surface its magnitude is approximately 9.8 m/sec^2, which 980 cm/sec^2, and it is directed down toward the center of the earth.

Up to now, the relationships between kinematics quantities such as velocity and acceleration were not dependent upon any property of nature, but rather on how they were defined. Here, for the first time, we have introduced a quantity, the acceleration of gravity, which reflects a property of nature. We cannot calculate the acceleration of gravity from just our knowledge of the kinematical relationships but rather it must be measured. The value we measure depends on the coordinate system and, hence, the units of measurement. But the fact that all things fall with the same acceleration (in the absence of air friction) is a consequence of natural law.

The acceleration of gravity near the earth's surface is slightly different at different location on earth. The acceleration depends on latitude because of the earth's rotation. It also depends on altitude. But for any given location, the acceleration there is the same for all objects.

The force of gravity at the same rate. Strictly speaking, such experiments must be conducted in a vacuum so that the force of air resistance does not affect the results. For relatively small, smooth bodies of considerable density, however, the error introduced by conducting such experiments in the atmosphere is quite small.

In any motion problem it should be apparent that three variables- distance, rate, and time- are involved. If the motion uniform, or if the concept of average velocity is used, the motion can be described by the simple equation

$$x=vt \tag{5.1}$$

where x is distance traveled in time t and v is the average velocity for the time interval t. When motion is non-uniform, that is, where velocity is changing, acceleration is said to take place. If the acceleration is uniform, as from a constant force such as the force of gravity, the acceleration can be defined as the average rate of change of velocity and it is given by the following equation:

$$a=\frac{(v_2-v_1)}{t} \tag{5.2}$$

where v_2-v_1 represents the change in velocity which occurs in time t. If a body starts from rest (i.e.,v=0) and is uniformly accelerated by a constant force for a time interval t, the total distance it will travel is given by the equation

$$x = \frac{1}{2}at^2 \qquad (5.3)$$

For the case of a body falling from a height h under the influence of the acceleration of gravity g, becomes

$$h = \frac{1}{2}at^2 \text{ and } v^2\text{-}v_o^2 = 2gh. \qquad (5.4)$$

3. EXPERIMENTAL PROCEDURE:

Preview

Use the Motion Sensor to measure the motion of a ball as it falls and bounces. Use the Xplorer GLX to record the motion and display and analyze the position a the ball. Use the position versus time graph to find the acceleration of the ball.

Procedure: GLX Setup

1. Turn on the GLX and open the GLX setup file titled **free fall.**
   -The Graph screen opens with a graph of Position (m) versus Time (s). The setup file is set to measure position at 40 Hz (40 measurements per second).
2. Connect the Motion Sensor to one of the sensor ports on the top end of the GLX as sown in figure 1. Put the range selection switch on the top end of the Motion Sensor to the 'far' (person) setting.

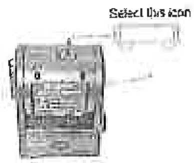


Fig. 1: Motion Sensor setting

Equipment Setup, as shown in figure 2;

1. Make sure that the floor is level. If it is not, put a hard flat surface on the floor and put pieces of paper or shims under the edges of the hard flat surface to level it.
2. Adjust the position of the Motion Sensor on the support rod so that the sensor is about 1.5 meters above the floor. Aim the sensor at the floor.

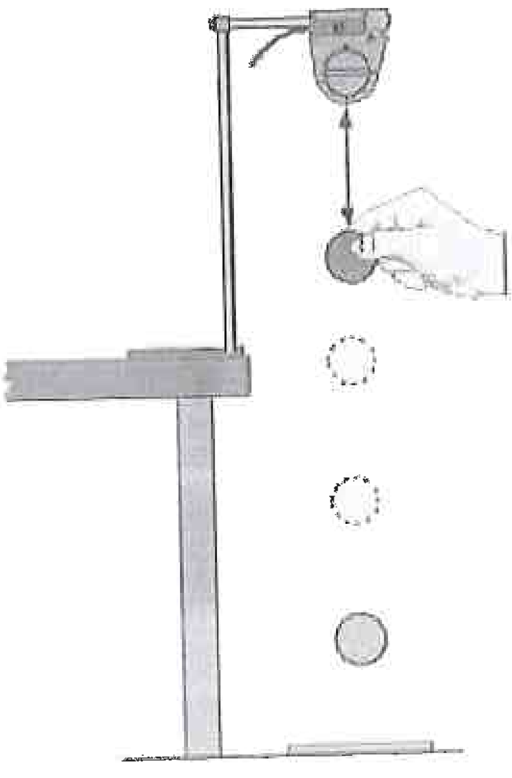


Fig. 2: Equipment setup

Record Data

1. Prepare to drop the ball so it falls straight down beneath the Motion Sensor. Hold the ball between your finger and thumb under the Motion Sensor no closer than 15 cm (about 6 inches) below the Motion Sensor.
2. Press Start to start recording data. Drop the ball. Let the ball bounce several times.
   -NOTE: Be sure to move your hand out of the way as soon as you release the ball.
3. After the ball bounces several times on the floor, press to stop recording data.

3. EXPERIMENTAL PROCEDURE:

1. Measure the masses of the large plastic ball and the golf ball. Enter the values in the Object Masses table on the Conclusion page.
2. Set the system up as shown in Figure 3. Either of the two plugs from the timer switch is plugged into the Photogate port on the Control Box. The second plug does not attach to anything. The telephone extension cord connects from the Control Box (Signal to Dropbox port) to the Dropbox. Plug the Motion Sensor into the 850 Universal Interface. Note that the Motion Sensor is not centered in the Motion Sensor Guard. This decreases the chance of a signal return off the guard cage.

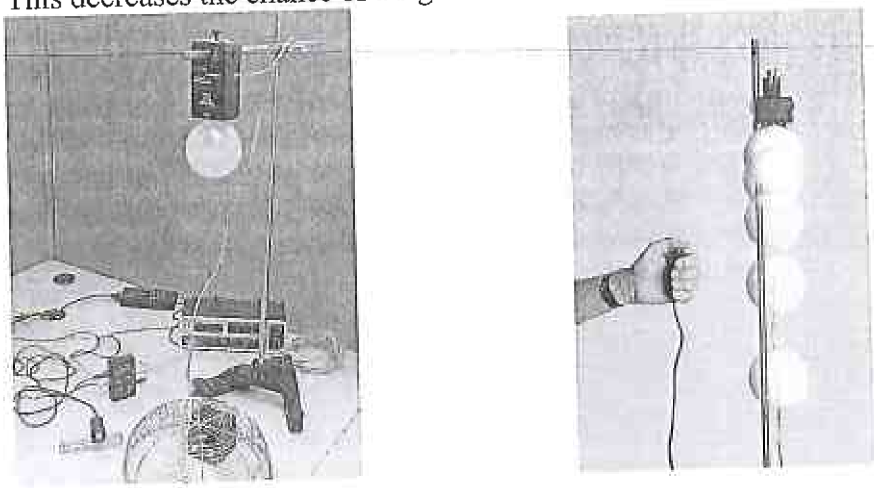


Figure 3: Setup

3. Plug in the AC adapter and connect to the Control Box.
4. Set the Motion Sensor to the cart position and turn the sensor to the 90^0 position so it points vertically upward.

Ball Setup:

5. Peel backing from Cellotape labels and attach washers to the large plastic ball and to the golf ball with Cellotape labels (See Figure 4).

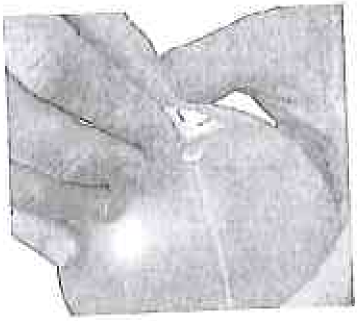
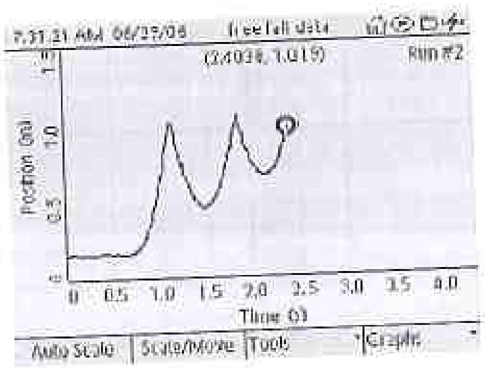


Figure 4: Attaching a washer to the drop object

6. Click RECORD. When the green light shows on the Motion Sensor, press the Timer Switch button to release the ball. Recording will stop when the ball gets below about 25 cm.
7. Examine the Falling Object Position curve. If you don't have a smooth curve, reposition the sensor slightly and repeat the run (use the Delete Last Run button at bottom of screen to delete any bad run).
8. Repeat steps 1-4 until you have three good runs: "falling ball 1", "falling ball 2", and "falling ball 3".

Analysis

1. Change the Graph screen to show position versus time. Press √ to activate the vertical axis menu. Press √ to open the menu.



2. Notice in the velocity plot that the velocity of the ball is positive part of the time (above the x-axis) and negative part of the time (below the x-axis). The Motion Sensor records motion away from it as positive and motion toward it as negative.
3. Use the right-left arrow keys to move the cursor to the point of the graph that is the beginning of one of the bounces.

4. Record the value of the slope in the Data Table. This is the value for the acceleration due to gravity on the falling object.

4. QUESTIONS

Data

'g' (slope of position versus square of time) = ________

1. How does your value for 'g' (slope of velocity versus time) compare to the accepted value of the acceleration of a free falling object (9.8 m/s2)?

$$\text{Reminder: percent difference} = \left| \frac{\text{accepted value - experimental value}}{\text{accepted value}} \right| \text{x100\%}$$

2. What factors do you think may cause the experimental value to be different from the accepted value?
3. What can be the sources of errors in your results?
4. Do you think that precise determinations of "$\vec{g}$" on an area might give some evidences for the underground resources at that location?
5. Do you expect any dependence in the value of "$\vec{g}$" on latitude and altitude of the location where the experiment is performed? Distance per interval= Δd: ...... (assumed to be 0.050 m)
6. A ball thrown vertically upward rises to a maximum height and then falls to the ground. What are the ball's velocity and acceleration at the instant it reaches its maximum height?
7. A professor drops one lead sinker each second from a very high windows.(a) How far has the first sinker gone when the second one is dropped? (b) Does the distance between the first and second sinker remain constant? Explain your answer.
8. The equation $v^2-v^2_o = 2gh$ was used to calculate the acceleration. Under what conditions is this equation valid? Are those conditions met in this experiment?
9. Could you use the relationship $\vec{F} = m\vec{g}$ to determine the force acting between the earth and the moon? Explain.

PHYSICS 1 LABORATORY
EXPERIMENT–5
CENTRIPETAL FORCE

1. PURPOSE

In this activity, students will use a Force Sensor and Photogate to discover the relationship of centripetal force, mass, (tangential) speed and radius for an object in uniform circular motion. Students will determine what happens to centripetal force as the result of changes in mass, speed, and radius.

2. THEORY

According to Newton's First Law, an object in motion tends to stay in motion in a straight line at a constant speed if there is no external net force applied to the object. An object undergoing uniform circular motion (motion in a circle at constant speed) must be acted on by a non-zero net force. That net force is called the centripetal force. It must point toward the center of the circle and have a constant magnitude given by:

$$F_c = mv^2/r \qquad (1)$$

Where m is the mass of the object moving in a circle, r is the radius of the circle, and v is the (tangential) speed of the object. For uniform circular motion, the tangential speed is given by:

$$v = 2\pi r/T \qquad (2)$$

where T is the time for one revolution.

Examples of centripetal force include the tension in a string attached to a can twirled in a circular path, the friction between the road and the tires of a car on an unbanked curve, or the force of gravity pulling a satellite toward the center of Earth as the satellite moves in a circular orbit.

3. EXPERIMENTAL PROCEDURE:

Setup:

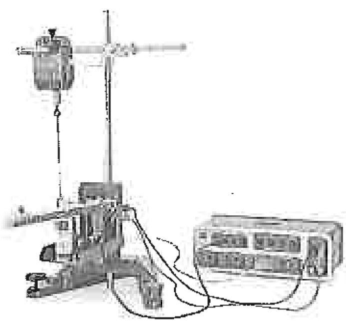


Figure 1: Complete Setup

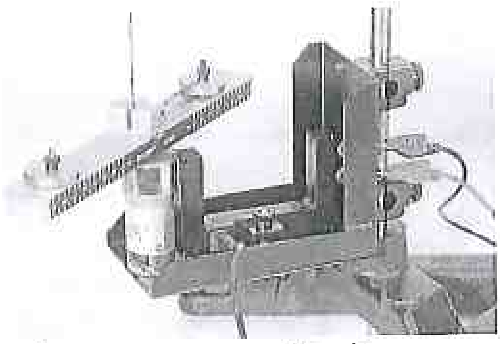


Figure 2: Photogate Attachment

1. **Attach the Photogate to the frame of the Centripetal Force Apparatus as shown in Figure 2.**
2. Attach the entire Centripetal Force Apparatus as low as possible to the 90 cm rod and base.
3. Attach the 45cm rod horizontally to the 90 cm rod with the multi-clamp.
4. Hang the Force Sensor from the horizontal rod.

5. Screw the Ball Bearing Swivel to the Force Sensor.
6. Use a metal clip to attach the low-stretch cable to the Swivel. Thread the other end of the cable through the plastic pulley and attach it to the sliding post by putting the loop over the post and attaching the mass above it. Note: between uses, it is important to store the cable in a manner that does not put kinks in it.
7. Plug the Photogate into Digital Channel 1 on the 850 Universal Interface. Plug the Force Sensor into any *Pasport* input.
8. Click open the Signal Generator at the left of the screen. On 850 Output 1, the Waveform should be DC with a DC Voltage of 4.0 V. Click the Off button to be sure the Signal Generator is off and connect the Centripetal Force Apparatus to OUTPUT 1 on the 850 Universal Interface with banana plugs. It is not important which plug on the Centripetal Force Apparatus attaches to the red output although it will affect the rotation direction. Careful: if the Signal Generator is not off, the arm will begin to rotate! Click the Signal Generator again to close it.
9. Level the base. This must be done carefully for good results. Remove the counterweight mass and put a level on the rotating arm as shown in Figure 3. Start with the arm parallel to the two leveling screws in the base as shown in Figure 3. There is some play in the rotating arm. Tip it up or down a bit by pushing on the end of the rotating arm away from the level. Adjust the leveling screws until the bubble moves about the same amount on either side of center when you rock the arm up and down as in Figures 4a & 4b. Now rotate the arm 90^0 and repeat changing both screws by the same amount. Then rotate back to the original position and re-level if necessary.
10. Attach a 5 g counterweight mass.
11. Remove the assembly that holds the moving mass (black plastic nut and bolt, silver nut and two pastic washers) and determine its mass. Click open the Calculator at the left of the screen and repace the 0.0038 value in line 7 your measured mass (in kg) for "m hold".
12. Re-attach the assembly to the rotating arm with one plastic washer below the arm and one above. Then the silver nut, tightened down enough to prevent tipping, but the assembly must slide freely. Then the cable loop (see Figure 5). Then use the black nut to attach 5 g of mass above the loop. The cable loop should be <u>below</u> the 5 g mass. It is shown incorrectly in Figures 1&2.

Figure 3: Level Placement

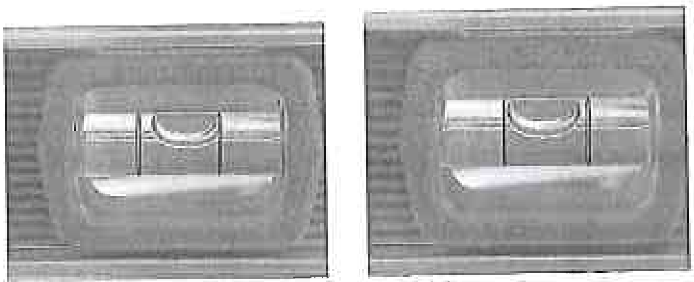


Figure 4a & 4b: Rocking the Bubble

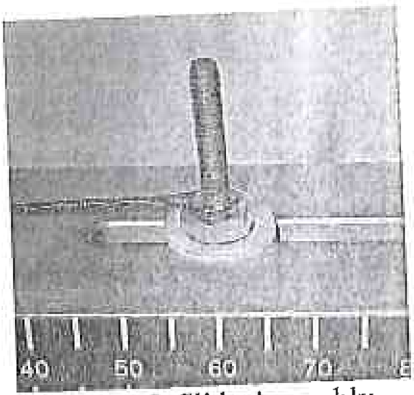


Figure 5: Slide Assembly

Setup C:

1. Now, adjust the height of the force sensor so that the 5g mass is about 10.0 cm from the center when there is just enough tension in the cable to straighten the cable. It is important that the force sensor be exactly above the center of the apparatus. To check this, pull on the mass to put tension in the cable. Then observe the cable from the front of the system to verify it is parallel to the 90 cm rod and measure the distance from the rod to the top of the string and to just above the pulley. Adjust the 45 cm rod holding the force sensor until the cable is parallel to the rod. Note that any time you change the position of the Force Sensor, you will have to repeat this step.
2. Pull the mass to tighten the cable to determine the actual radius to the nearest 0.1 cm. Although you can do this using the scale attached to the side of the apparatus, it is more precise to measure from the center of the mass to where the vertical cable is with a small ruler. Click open the Calculator at the left of the screen. In line 1, replace the 0.1 value (10cm) with the value that you actually measured. Click the Calculator again to close it.

Part-1 – Force vs Mass (Radius and Velocity held Constant)

1. Press the "ZERO" button on the Force Sensor. This should set the Force Sensor to zero since there should be no force on it at this point.
2. Click RECORD. Collect data for about 5 s and then click STOP to stop data collection. Mean speed and Mean Force should both be zero. If the Mean Force is not zero, record the value. It will help during the data analysis.
3. To avoid wobbling, tighten an identical mass (5 g here) to the opposite side of the rotating platform as a counterbalance so that it is as far from the center of the rotating platform as the distance you measured in step 2. This measurement need not be precise and it is sufficient to use the scale on the side of the apparatus.
4. Click on the Signal Generator at the left of the screen. Under the Output 1, set waveform to DC and the DC Voltage to 4.5 V. **Caution! The next step will cause the apparatus to begin rotation. Be sure it can do so without hitting anything or anybody.** Click the On button. After about 10 s, reduce the voltage to 4.0 V. Starting with a higher speed and then reducing it minimizes the frictional effects by positioning the mass at about the correct position before reducing the speed. Let it run for about 20 s to reach constant speed.
5. Press the RECORD button. Allow data collection to occur for approximately 10 seconds until the mean Values for Speed and Force are almost constant. Press the STOP button.
6. Click the Signal Generator Output 1 to Off. The rotation should stop.

7. In row 1 (5g row) of the Variable Mass table, enter the value of the Mean Speed into column 2 and record the Mean Force (ignore the minus sign) in column 3.
8. Increase the mass by 5.0 g (0.005kg).
9. Repeat steps 3-8 until you reach 30.0g of mass. Note that the mean speed should be about the same for all the runs.

Analysis-1: Force vs Mass

1. Observe the Force vs Mass Graph. The "Av Force" is the measured average force from the table on the previous page.
2. Click open the Calculator at the left of the screen and examine lines 1-7 to verify that "theory force" is calculated using Equation 1 from Theory. Note that the actual measured speed, "Av speed" from the Variable Mass table on the previous page is used to calculate "theory force". Since the speed is not quite constant, the "theory force" points are not quite linear. Click the Calculator to close it.
3. The mass sometimes hangs up a little causing an obviously bad "Av Force" point. You should repeat the run for any bad point and see if it improves. Enter the new run in the row below the 0.030 kg row of the Variable Mass table on the previous page.
4. Select the "Av Force" data by clicking in the Legend box or on a data point. Then click the black triangle by the Curve Fit tool in the graph toolbox and select Linear.

Part-2: Force vs Speed (Radius and Mass held Constant)

1. Keep the **30g** mass attached to the cable and the rotating platform.
2. Click on the Signal Generator at the left of the screen. Under the Output 1, set the DC Voltage to 5.5 V. **Caution! The next step will cause the apparatus to begin rotation. Be sure it can do so without hitting anything or anybody.** Click the On button. After about 10 s, reduce the voltage to 5.0 V. Let it run for about 20 s to reach constant speed.
3. Press the RECORD button. Allow data collection to occur for approximately 10 seconds until the mean Values for Speed and Force are almost constant. Press the STOP button.
4. In row 1 (5.0 V row) of the Variable Mass table, enter the value of the Mean Speed into column 2 and record the Mean Force (ignore the minus sign) in column 3.
5. Decrease the Signal Generator voltage by 0.5 V. Let it run for about 20 s to reach constant speed.
6. Repeat steps 3-5 until you reach 3.5 V.

Analysis-2: Force vs Speed

1. Observe the Force vs Speed^2 Graph. The "Ave F" is the measured average force from the table on the previous page.
2. Click open the Calculator at the left of the screen and examine line 8 to verify that "theory f" is calculated using Equation 1 from Theory. Click the Calculator to close it.
3. The mass sometimes hangs up a little causing an obviously bad "Ave F" point. You should repeat the run for any bad point and see if it improves. Enter the new run in the row below the 3.5 V row of the Variable Speed table on the previous page.
4. Select the "Ave F" data by clicking in the Legend box or on a data point. Then click the black triangle by the Curve Fit tool in the graph toolbox and select Linear.

Part-3: Force vs Radius (Mass and Time for one rotation held Constant)

1. Keep the **30g** mass attached to the cable and the rotating platform.
2. Enter the radius of the circle in column 1 of the Variable Radius table. Note that the initial radius is the same as before and is recorded in line 1 of the Calculator. After you enter it, the value should also show in the Radius box in the upper left.
3. Click on the Signal Generator at the left of the screen. Under the Output 1, set the DC Voltage to 5.0 V. **Caution! The next step will cause the apparatus to begin rotation. Be sure it can do so without hitting anything or anybody.** Click the On button. After about 10 s, reduce the voltage to 4.5 V. Let it run for about 20 s to reach constant speed.
4. Press the RECORD button. Allow data collection to occur for approximately 10 seconds until the mean Values for Speed and Force are almost constant. Press the STOP button.
5. In row 1 of the Variable Radius table, enter the value of the Mean Speed into column 2 and record the Mean Force (ignore the minus sign) in column 3.
6. Turn the Signal Generator Off. The rotation should stop.
7. Following the steps in Setup C, decrease the radius to about 8.5 cm. Measure the value of the radius to within 0.1 cm. Move the counterweight mass to about the same distance. Repeat steps 2-6.
8. Continue as above for radii of about 7 cm and 5 cm.

Analysis-3: Force vs Circle Radius

1. Observe the Force vs Radius, r, Graph. The "Ave Force" is the measured average force from the table on the previous page.
2. Click open the Calculator at the left of the screen and examine lines 9 & 10 to verify that "theo f " is calculated using Equation 1 from Theory. Note that the actual measured speed, "Ave speed" from the Variable Mass table on the previous page is used to calculate "theo f". Since the speed is not quite constant, the "theo f" points are not quite linear. Click the Calculator to close it.
3. The mass sometimes hangs up a little causing an obviously bad "Ave Force" point. You should repeat the run for any bad point and see if it improves. Enter the new run in the Variable Mass table on the previous page.
4. Select the "Ave Force" data by clicking in the Legend box or on a data point. Then click the black triangle by the Curve Fit tool in the graph toolbox and select Linear.

4. QUESTIONS

1. What can you conclude about the relationship between the centripetal force and mass? Explain how you know.
2. What can you conclude about the relationship between the centripetal force and tangential speed? Explain how you know.
3. What can you conclude about the relationship between the centripetal force and radius of the circle? Explain how you know.
4. Considering the answers to the first three questions, is Equation 1 from Theory valid. Careful…how can the relationship you saw in Question 3 agree with Equation 1?

5. Analyze the errors that could be made in all the measured quantities. What was probably the greatest source of error and why? Discuss how these errors could be avoided and how the experiment in general could be improved.
6. Discuss any trends that were noted in your analysis of percentage error for the different trials. Analyze the meaning of any observed trends or discuss the meaning of the lack of any trends.
7. Was the purpose of this lab accomplished? Why or why not? (Your answer to this question should be reasonable and make sense, showing thoughtful analysis and careful, thorough thinking.)
8. What would happen if you increased the circular motion!velocity? What would happen if you decreased the circular motion velocity? Try it.
9. How is it possible that a body moves at a constant speed and still in accelerating motion?
10. When a car is going around a circular track with constant speed, what provides the centripetal force necessary for circular motion?
11. What are directions of acceleration and net force if the speed of an object is changing while rotating in a circular motion?
12. If the period increases, does the centripetal force increase or decrease? If the radius increases, does the centripetal force increase or decrease?

PHYSICS 1 LABORATORY
EXPERIMENT–6
PROJECTILE MOTION

1. PURPOSE

The purpose of this experiment is to predict the horizontal range of a projectile shot from various heights and angles. In addition, students will compare the time of flight for projectiles shot horizontally at different muzzle velocities.

2. THEORY

The horizontal range, Δx, for a projectile can be found using the following equation:

$$\Delta x = v_x t \tag{1}$$

where v_x is the horizontal velocity (= the initial horizontal velocity) and t is the time of flight.

To find the time of flight, t, the following kinematic equation is needed:

$$\Delta y = \frac{1}{2} a_y t^2 + v_{y0} t \tag{2}$$

where Δy is the height, $a_y = -g$ is the acceleration due to gravity and v_{y0} is the vertical component of the initial velocity.

When a projectile is fired horizontally (from a height Δy), the time of flight can be found by rearranging Equation 2. Since the initial vertical velocity is zero, the last term drops out of the equation yielding:

$$t = (2\Delta y/a_y)^{1/2} = (-2\Delta y/g)^{1/2} \tag{2a}$$

When a projectile is fired at an angle and it lands at the same elevation from which it was launched, $\Delta y = 0$, and we may solve Equation (2) for t:

$$t = 2v_{y0}/g \tag{2b}$$

Subbing this into Equation (1) yields

$$\Delta x = 2v_x v_{y0}/g = (2v^2 \cos\emptyset \sin\emptyset)/g \tag{3}$$

where v is the initial speed of the projectile.

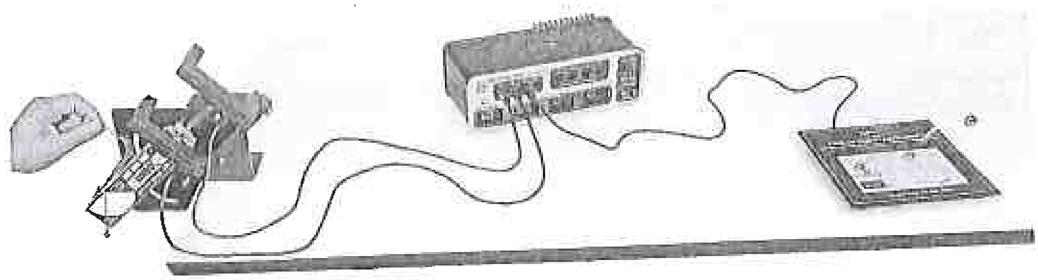
When a projectile is fired from a height, none of the terms drop out and Equation 2 may be rearranged as follows:

$$\frac{1}{2} a_y t^2 + v_{y0} t - \Delta y = 0 \tag{2c}$$

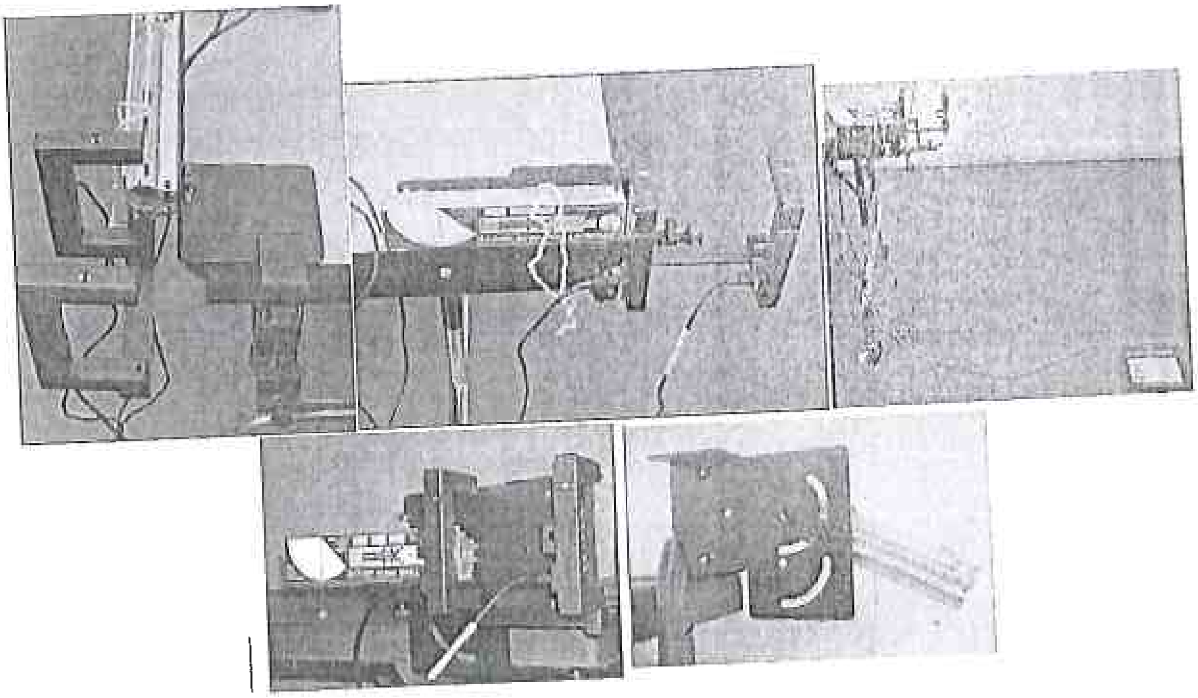
Equation 2c may be solved using the quadratic formula to find the time of flight, t. Equation 1 then yields the horizontal range.

3. EXPERIMENTAL PROCEDURE:

Setup 1 – Muzzle Velocity, Time of Flight & Range



1. Slide the Photogate Bracket into the groove on the bottom of the launcher and tighten the thumbscrew.
2. Connect two photogates to the bracket (see photos below). Adjust the Photogate Bracket so the first photogate is as close to the launcher as possible without blocking the IR beam.
3. Attach the launcher to the launcher stand using the upper holes (see photo below).
4. Plug the photogate closest to the launcher into Digital Input 1 on the 850 Universal Interface. Plug the other photogate into Digital Input 2.
5. Plug the Time of Flight Accessory into Digital Input 3.
6. Choose one corner of a table to place the projectile launcher. Make sure a distance of about 3 meters is clear on the floor in the direction the ball will be fired.
7. Clamp the launcher to the corner of the table using a C Clamp (see photo below).
8. Using the attached plumb bob, adjust the angle of the launcher to 0°.



Note 1: Measuring angles

It is critical that you measure the angle carefully. An error of ½ degree will affect your results by several centimeters. You should be able to read the angles within 0.2 degrees. In Figure 2, the angle is 25.5^0. Does Figure 1 show 25.0^0 ? No! Notice that the line is not symmetric between the 24^0 and 26^0 marks. This angle should be read as 24.8^0. In Procedure 1, it is critical that the angle be exactly 0.0^0. In Procedures 2 & 3, it is not critical to exactly set the requested angle as long as you know what your exact angle is. For example, having 20.7^0 instead of 20.0^0 is fine as long as you know it is 20.7^0 and adjust the numbers in the table to reflect your actual angles.

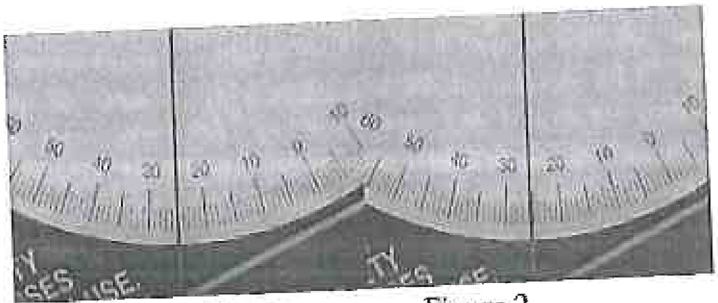


Figure 1 Figure 2

Procedure 1: Muzzle Velocity, Time of Flight & Range (Initial Speed and Time of Flight.)

1. Note the circle on the side of the launcher that says "Launch Position of Ball." This indicates the position of the ball when it leaves the spring and becomes a free projectile. From where on the circle should you measure the drop distance Δy? Hint: what part of the

ball strikes the floor? Is Δy positive or negative? From what part of the circle should you measure Δx? In addition, measure the spacing between the two photogates and verify that it is 10.0 cm. The program calculates the initial speed by assuming the photogates are separated by 10.0 cm and dividing by the time the ball takes to travel between the two gates.

2. Measure the drop distance, Δy, to the top of the Time of Flight Accessory and record it in the Initial Height line under the Data 1 tab.
3. Carefully adjust the launcher to fire horizontally. The protractor should read exactly zero degrees. You should try to set the angle within 0.2 degrees by making the string equidistant between the +1 and -1 degree hash marks on the protractor. You will not get good results if you are not careful when setting the angles. See Note 1.
4. Place the steel ball into the launcher and use the push rod to load the ball until the "3rd click" is heard.
5. Check to see that there is no one down range! Launch the ball by pulling straight upward on the string. Don't jerk. Observe where the ball hits the floor. Tape a small piece of tape to the floor to mark the spot. Place the Time of Flight Accessory above the piece of tape so the ball will strike it.
6. Click on the Record button.
7. Pull the launch cord on the launcher. Click the Stop button to stop recording.
8. Record the Initial Speed and the Time of Flight in the table under the Data 1 tab.
9. Repeat two more times.
10. If the launcher is only compressed to two clicks, will the Time of Flight be more, less, or the same as for 3 clicks? Think about it and write you answer in the appropriate place under the Data 1 tab.
11. Repeat steps 2-8 for 2 clicks and 1 click. Record your results in the table on Data 1.
12. Using your data and Equation 1, calculate the Δx distance to where the ball should strike the floor when the launcher is compressed two clicks. Record your value as the Predicted Range line on the Data 1 page. Drop a plumb line from the Launch Position of Ball circle and mark the position with a piece of tape. Measure a distance equal to Δx along a line between the piece of tape you just put on the floor and the one from step 4. Tape a piece of white paper to the Time of Flight apparatus and place it at your predicted impact point. Mark your predicted impact point with an X. Place a piece of carbon paper on top of the paper (face down). Launch the ball three times using the two click position. Turn in this paper as part of your lab report!

Data 1:

Initial Height (Δy) = __________

1. Will the Time of Flight for the two click position (horizontal fire) be more than, less than, or the same as the Time of Flight for the three click position? Explain your logic!

2. If your initial guess about what would happen (in the box above) was wrong, explain why the Time of Flight behaves the way it does!

Predicted Range for two click position = ____________
Time of Flight vs. Speed Table: # of Clicks, Initial Speed (Vin), Time of Flight (ToF)

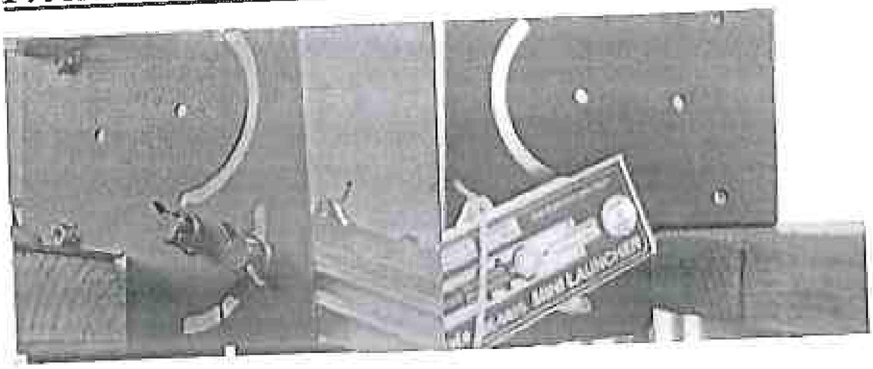
Analysis 1: Part 1:

1. Did the time of flight depend on the initial horizontal speed. What does this imply about the dependence of the vertical motion on the horizontal motion?
2. Use Equation 2a from Theory to calculate the time of flight.

   Predicted Time of Flight = ____________

3. How well does the Time of Flight calculated from Equation 2a agree with your experimental values. If they don't agree, what could explain the difference?
4. How well did your predicted range compare to the actual range? What does this show?
5. How would the horizontal range change if the muzzle velocity was doubled? Explain how you know.
6. How would the horizontal range change if the height from the ground was doubled? Explain how you know.
7. How would the horizontal range change if the mass of the ball was doubled? Explain how you know.
8. What effect are we able to ignore in this experiment? Explain.

Procedure 2: Launching at an angle on a plane



1. If you did Procedure 1, calculate the average initial speed in meters per second for 1 click horizontal fire, Vin from the Time of Flight vs. Initial Speed under the Data 1 tab. Record the average value in the second column (V1) of the Plane Range table (angle (Ang), horizontal speed (V1), corrected speed(V), predicted range(PRange), measured range(MRange)) on the Analysis 2 page in each of the first five rows. If you are doing this part of the experiment without doing Procedure 1, you will have to determine the speed for horizontal fire by performing Procedure 1, steps 3-8. You do not need the Time of Flight accessory.
2. Clamp the launcher to the edge of a table using a C clamp so that the ball launches from and lands at the same elevation (the bottom of the Ball Launch Position circle should be even with the top of the table (see photos above). Launcher should be as far back as possible on its track so the front holding screw points directly at the center of the Launch Position circle. That way the release height will not change when you change the angle.

3. Adjust the launcher for a launch angle of 45^0. Using the push rod, push the ball into the Launcher until the first click is heard. Using the string, pull back on the trigger. Note the location on the table where the ball lands.
4. Tape a sheet of blank paper at the location where the ball landed. Place carbon paper over the blank paper.
5. Load the Launcher. Launch the ball. Repeat two more times.
6. Use the tape measure to find the horizontal range from the Ball Launch Position circle to the center of the three shot pattern (just eyeball the center of the pattern).
7. Record the value of the horizontal range in meters into the Measured Range (MRange) column of the Range table in the 45^0 row on the Analysis 2 page. If your angle was not exactly 45^0, record the correct angle in the Angle (Ang) column.
8. Repeat the steps 3-7 for 25, 35, 55, 65 degrees.

Analysis 2: part 2;

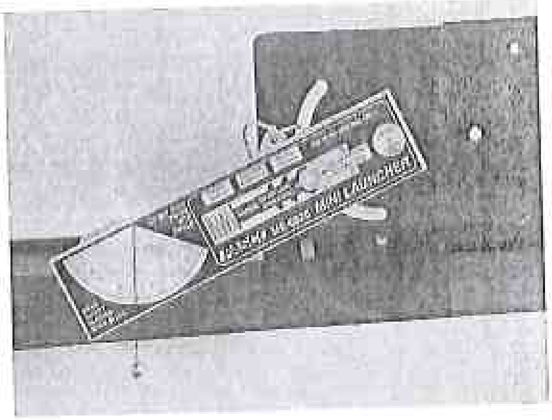
1. The third column in the Plane Range table shows the initial speeds (V_0) at various angles calculated from your measured initial horizontal speed. They are smaller because when the gun is tipped up by an angle θ, some of the energy from the spring goes into increasing the potential energy of the system instead of the kinetic energy of the ball. However, since you have probably not considered energy yet in your physics class, we have calculated the speeds for you. The formula is:

$$v^2 = (v_0)^2 - 2gs \sin \theta$$

where v = initial speed, v_0 = horizontal speed (measured), s = distance spring is compressed & θ is the angle of tip. s = 3.5 cm for 1 click, 4.8 cm for two clicks, and 6.3 cm for three clicks. Click open the calculator at the left of the screen and examine line 1 to verify that the value for V (Plane Range Table) is being calculated using this formula.

2. We now use Equation 3 to calculate the predicted range (PRange). Click on the Calculator and verify that the calculation in line 2 for PRange agree with Equation 3. Click the Calculator again to close it.
3. Compare your measured values to the predicted values for the range. Do they agree? Try to explain any differences.
4. The Angle vs. Range on a Plane Graph plots both the Measured Range vs. Angle and the Predicted Range vs. Angle on the same graph. Are they the same? Try to explain any difference.
5. Refer to your Angle vs. Range graph. What angle corresponds to the maximum range? Why isn't the graph symmetric about 45^0?

Procedure 3: Launching at an angle from a height



1. If you did Procedure 1 today, calculate the average initial speed in meters per second for 3 click horizontal fire, Vin from the Time of Flight vs. Initial Speed under the Data 1 tab. Record the average value in the second column (V3) of the Range table (angle(Angle), horizontal speed(v3), corrected speed(Vcor), time of flight (Tflight), theory range(TRange), experimental range(ERange)) on the Analysis 3 page in each of the first eleven rows. If you are doing this part of the experiment without doing Procedure 1, you will have to determine the speed for horizontal fire by performing Procedure 1, steps 3-8 for the 1 click position. You do not need the Time of Flight accessory.
2. Clamp the launcher to the edge of a table using the C Clamp so that the ball launches from a position above where it will land (see photo above). Launcher should be as far back as possible on its track so the front holding screw points directly at the center of the Launch Position circle. That way the release height will not change when you change the angle.
3. Adjust the angle of the launcher to -20°.
4. Note the circle on the side of the launcher that says "Launch Position of Ball." This indicates the position of the ball when it leaves the spring and becomes a free projectile. From where on the circle should you measure the drop distance Δy? Hint: what part of the ball strikes the floor? Is Δy positive or negative? From what part of the circle should you measure Δx? Measure the drop distance in meters. Click open the Calculator at the left of the screen and replace my value in line 4 with your value for Δy.
5. Drop a plumb line from the Launch Position of Ball circle and mark the position with a piece of tape. Measure the distance Δx from this mark for each angle.
6. Using the plunger, push the ball as far as possible into the Launcher. Make sure three clicks are heard. Using the string, pull back on the trigger. Keep track of the location on the floor where the ball lands.
7. Tape a sheet of blank paper at this location. Place carbon paper over the blank paper.
8. Load the Launcher. Take 3 shots. Measure Δx to the center (eyeball it) of the three shot pattern with the tape measure and record it in the Experimental Range column of the Range vs. Angle Table on the Analysis 3 page. If your angle was not exactly 45^0, record the correct angle in the Angle column.
9. Repeat for angle of -10°, 0°, 10°, 20°, 30°, 35°, 40°, 45°, 50°, and 60°.

Analysis 3: Launching at an angle from a height: part 3:

1. See the discussion of why the initial launch speed V3 is different than the horizontal launch speed under the Analysis 2 tab. Click open the calculator at the right of the screen and examine line 1 to verify that the value for Vcor (Range vs. Angle table) is being calculated correctly.
2. We now use Equation 2c from Theory to calculate the time of flight. Solve the quadratic equation for t and write your answer below. Click on the Calculator (lower left) and verify that the calculations for Tflight (the time of flight) agree with your result.
3. Verify that the calculations for the Theory Range (TRange) agree with Equation 1.
4. Compare your measured values to the predicted values. Do they agree? Try to explain any differences.
5. The graph plots both the Experimental Horizontal Range vs. Angle and the Theory Horizontal Range vs. Angle on the same graph. How well do the measured results compare to the predictions. What does this show? Explain any differences.

4. QUESTIONS

1- What are the possible sources of error in this experiment?

2- For one of the trajectories, calculate the percentage error in v_0, R and t_R assume the percentage error in the measurement of time to be 10%.

3- Is $t_R=2t_H$? Why?

4- Is the displacement of the mass along the x-axis constant for each time interval? Why?

5- For a given initial velocity, what should be the angle θ to make R maximum?

6- Will a ball dropped from rest reach the ground quicker than one launched from the same height but with an initial horizontal velocity?

7- In projectile motion when air resistance is negligible, is it ever necessary to consider three-dimensional motion rather than two –dimension.

8- At what point in its path does a projectile have its minimum speed? Its maximum?

PHYSICS 1 LABORATORY
EXPERIMENT–7
NEWTON'S LAW

1. PURPOSE

Part 1: The purpose of this experiment is to determine how external forces influence an object's motion.
Part 2: The purpose of this experiment is to verify Newton's 2^{nd} Law for a one dimensional system. A measured force is applied to a low friction cart and the resulting acceleration is measured.

2. THEORY

The study of the causes of motion is called dynamics. The laws that govern the motion of an object were described by Newton in 1657- known as Newton's laws. The laws are physical interms of force and mass. Newton's first law describes what happens when the near force acting on an object is zero. In that case, the object either remains at rest or continues in motion with constant speed in a straight line. If the net force on an object is zero then the objects acceleration is zero. If $\Sigma\ \vec{F}=0$ then $\vec{a}=0$. And so the object remains at rest or at constant velocity. We used Newton's 1^{st} law in static, $\Sigma\vec{F}=0$.
"An object at rest will remain at rest. An object in motion will remain in motion."

Newton's second law describes the change of motion that occurs when a nonzero net force acts on the object. The original translation of **Newton's second law** was, *The alternation of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.* Elsewhere in the Principia Newton was clear that by "motion" he meant the product of the velocity and the mass. For the moment, it is sufficient to use Newton's identification of mass as the "quantity of matter". Then the second law:

The rate of change of momentum with time is proportional to the net applied force and is in the same direction:

$$\frac{\Delta(m\vec{v})}{\Delta t}=\sum\vec{F} \tag{7.1}$$

Where $\sum\vec{F}$ is the net force – that is, the vector sum of all forces acting on a body- and the change in the momentum $\Delta(m\vec{v})$ is in the direction of $\sum\vec{F}$.

In the majority of real situations, the mass of an object does not change appreciably, so the change in momentum is just the mass times the change in velocity. Then

$$\frac{\Delta(m\vec{v})}{\Delta t}=m\frac{\Delta\vec{v}}{\Delta t}=m\vec{a} \tag{7.2}$$

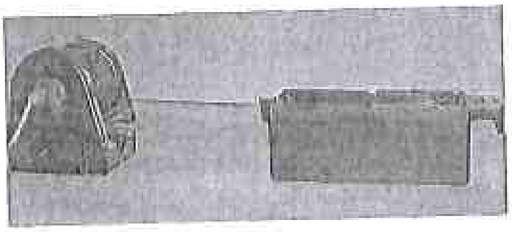
The rate of change in momentum of a body is proportional to the net force on the body. In equation from the 2^{nd} law states.

$$\Sigma\vec{F}=m\vec{a} \tag{7.3}$$

This leads to the definition of force interms of the acceleration of $\vec{a}$ mass

3. EXPERIMENTAL PROCEDURE: *Newton's 1st Law*

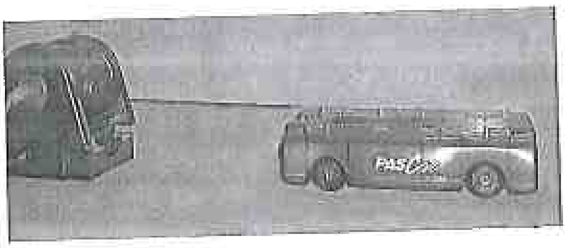
SET-UP : Part 1:



1. Connect the Motion Sensor to the 850 Universal Interface.
2. Make sure the switch on the top of the motion sensor is set to the cart position.
3. Adjust the alignment bar on the side of the motion sensor so that it points slightly downward.
4. Choose a Friction Tray that slides easily on the surface you are using (probably the plastic bottomed tray).

3.1. EXPERIMENTAL PROCEDURE: *Part 1: Newton's 1st Law*

1. Place the Friction Tray about 1 meter away from the Motion Sensor.
2. Press the RECORD button at bottom left of page.
3. Push and release the Friction Tray in the direction of the motion sensor. You want it to stop about 20 cm from the Motion Sensor. You want the Tray to move directly toward the Motion Sensor without rotating too much.
4. Press the STOP button to stop the data collection.
5. To erase data, click "Delete Last Run" on the lower right of the screen.
6. Examine the Velocity vs Time graph. Repeat the above steps, if necessary, until you have one nice data run. A few noise spikes won't hurt anything.
7. Click open Data Summary at the left of the page. Double click on the current run (probably Run #1) and re-label it Friction Tray.
8. Repeat for the Hover Puck and for the PasCar, making sure someone stops the object about 20 cm from the Motion Sensor. Label them Hover Puck and PasCar



Analysis: Part 1:

1. If all three runs don't show on the graph, click the Run Select icon on the graph toolbar (to allow viewing of multiple runs) and select all three runs using the black triangle by the Run Select icon.

2. The data from the Motion Sensor tends to be noisy due to missed position measurements, so it is worthwhile to smooth it some. Select the Friction tray run by clicking on its graph or the icon in the box at the lower right and adjust the Smoothing bar at the center of the graph toolbar for a smoothing of about 20. Repeat for the PasCar and Hover Puck data.
3. Click the Scale to Fit button at the left of the graph toolbar so the data fills the graph.
4. Consider the region after you have released the object. (a) Which of the three objects slowed the most each second? (b) Which slowed the least? Why
5. Refer to the graph on the Analysis page.

5.1. Consider the region after you have released the object.
   a. Which of the three objects slowed the most each second?
   b. Which slowed the least?
   c. Why?
   d. If all three objects began with the same speed on a uniform flat surface, which would go furthest before stopping? How could an object go further? Could an object never stop?

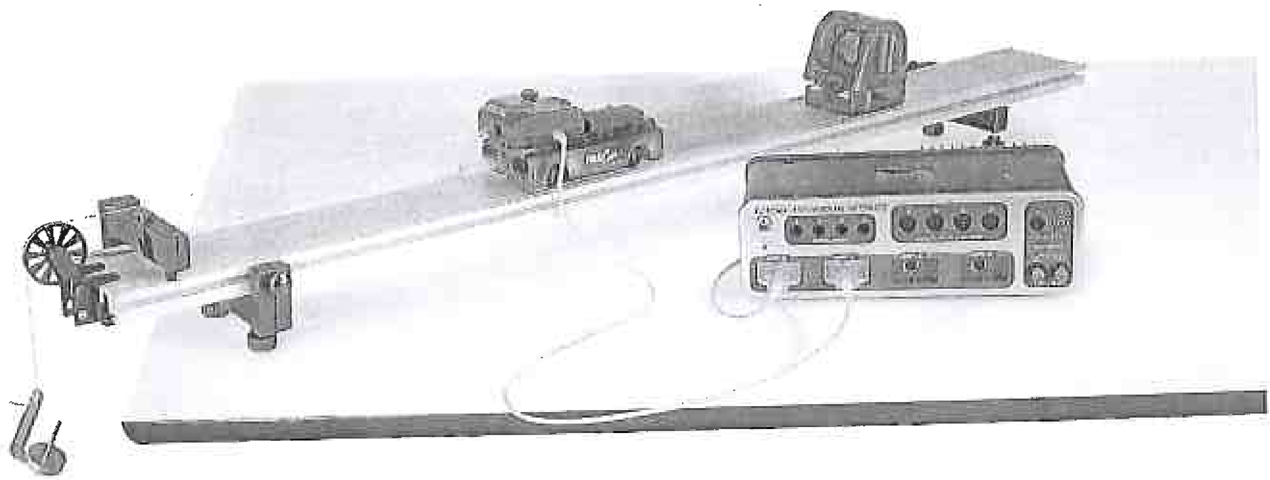
5.2. Do objects at rest remain at rest? Really? What about the Hover Puck? Why didn't it remain at rest? Why didn't the Friction Tray remain at rest?

5.3.Did the three objects move in a straight line?

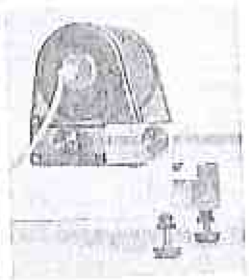
5.4.Try to re-state Newton's 1st Law in a more quantitative way than we did in the Theory.

3.2. EXPERIMENTAL PROCEDURE: *Part 2: Newton's 2nd Law*

SET-UP :



1. Connect the Motion Sensor to a PASPORT input on the 850 Universal Interface. Make sure the switch on the top of the Motion Sensor is set to "cart."
2. Connect the Force Sensor to a PASPORT input.
3. Using the long thumbscrew, attach the Force Sensor to the cart. Make sure the plunger on the cart is out before attaching the Force Sensor.
4. Use adjustable feet on both ends to level the track. Easiest is to use a spirit level, but can also use the motion of the cart. If using a spirit level, check the level both along

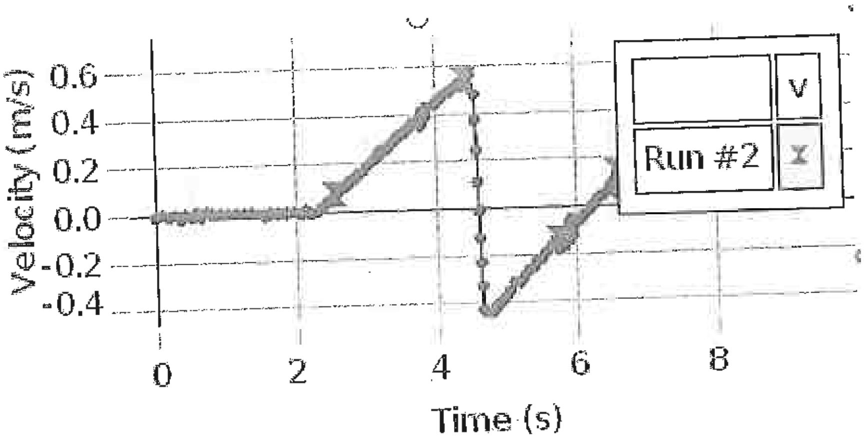


the track and perpendicular to the track.

5. Attach the Motion Sensor to the end of the track as shown at right. Adjust the alignment knob on the side of the Motion Sensor so that it points parallel to the track.
6. Clamp the pulley to the other end of the track. Place this end over the edge of the table. Attach the endstop to prevent damage to the pulley.
7. Place the Cart/Force Sensor assembly on the track.
8. Tie a loop in one end of a one meter length of string. Attach the notch of the mass hanger to the loop. Add 5 g to the hanger for a total of 10 g (including the 5 g hanger.) Tie a loop in the other end of the string and attach the loop to the hook of the Force Sensor. Hang the mass hanger over the pulley. Adjust the string so the mass is just above the floor when the cart plunger strikes the endstop.
9. Level (eyeball it) the string by adjusting the pulley.

***PROCEDURE A*:**

1. Remove the string from the Force Sensor hook and press the "ZERO" button on the Force Sensor. Then replace the string.
2. Pull the cart back as far as possible without allowing the mass hanger to contact the pulley.
3. Click RECORD and, after you see a green light on the Motion Sensor, release the cart.
4. Make sure the Force Sensor's cord does not impede the cart's motion. To do this, hold the cord with your hand at least 30 cm above the cart and keep your hand directly above the cart as it moves so the cord does not push or pull on the cart (see video at right.)
5. Click STOP after the cart strikes the endstop.
6. Examine Figure 1. It should look like the picture below. The region of interest is the accelerated region between 2.5 s and 4.5 s. If you see noise spikes in your data, try adjusting the angle of the Motion Sensor and moving all objects away from the track including yourself. Delete bad data runs by clicking on the Delete Last Run at the lower right of the screen. We need at least 0.5 s of clean data, but it doesn't matter if have noise at the end of the run since we can ignore that part of the data.



7. Click on the Data Summary button on the left toolbar. Double click on the run you just made in any box and re-label it 10 g Run 1. Click the Data Summary button again to close it.
8. Repeat the above steps 2-7 four more times using masses of 20 g, 30 g, 40 g, and 50 g on the end of the string. Label them 20 g Run 1, etc. *Do not repeat step 1!!!!*

ANALYSIS

1. Open the v Graph tab. On the toolbar at the top of the graph, click the black triangle of the Run Select tool, and select the "10 g Run 1". Click anywhere outside the black box to shut it.
2. Click the Selection Tool (graph toolbar) and drag the handles on the selection box to select the initial accelerated portion of the run where the data is clean (no spikes) and linear. Write down the time range you have selected. You will use this in step 9 below.
3. Click the black triangle in the Curve Fit Tool and select Linear. Click outside the black box to close it.
4. Record the slope (m) from the Linear Curve Fit box in line 1 of the "a1" column in the Acceleration Values table. You want a precision of 2 decimal places. You may adjust that using the Gear Icon in the Curve Fit box. First right click anywhere in the Linear box. Then (left) click on the Gear icon (Curve Fit Properties) and select 2 Fixed Decimals.
5. Click the Curve Fit Tool black triangle again and turn off Linear.
6. Click somewhere in the selection box (from step 2) to highlight the box and then click on the Remove Active Element Tool (graph toolbar).
7. Repeat the above steps for the "20 g Run 1", entering the acceleration in line 2, and so on for all five runs.
8. Open the f Graph tab. On the toolbar at the top of the graph, click the Run Select tool, and select the "10 g Run 1". Click anywhere outside the black box to shut it.
9. Click the Selection Tool and drag the handles on the selection box to select the same time range you selected in step 2 above.
10. Click on the Statistics tool (graph toolbar) to turn it on and then on the black triangle and select Mean. The mean value for the selected region should show on the screen. We want a precision of three decimal places here. To change the precision, click open Data Summary (left of screen), click on Force (below High Resolution Force Sensor), click on the Gear icon that appears, and choose 3 Fixed Decimals from the pop-up that appears. Although the data looks rather noisy, the average is well defined with a resolution of 0.002 N. Record the Mean value in the Force Values table on line 1 of the "f1" column. Ignore the minus sign which results from the fact that we are pulling on the force sensor.
11. Click the Statistics tool to turn it off.
12. Click somewhere in the selection box to highlight the box and then click on the Remove Active Element tool.
13. Repeat the above steps 8-12 for the "20 g Run 1", entering the force in line 2, and so on for all five runs.

PROCEDURE B

1. Add the compact mass onto the cart.
2. Repeat Procedure A except label the runs "10 g Run 2", etc.
3. Repeat the Analysis except enter the acceleration values in column "a2" and the force values in column "f2".
4. Find the mass in kilograms of the Cart and Force Sensor and the mass of the Cart and Force sensor plus the compact mass. This a bit tricky since we don't want to include the mass of the PasPort connector which was not part of the accelerated system. Do this like you did the acceleration runs, holding the wire so your hand is about 30 cm above the scale (with the PasPort connector in your hand) and you are not pushing up or down on the scale. If you are careful your measurement should be accurate to

within a gram or so. Enter your values below:

a. Cart mass = _________ kg

b. Cart mass + compact mass = _________ kg

Uncertainty:

It is valuable to estimate the uncertainties in this experiment. An easy way to do this is to repeat the "50 g Run 2" two more times and see how much the acceleration varies. Enter your extra two values under the v graph tab in lines 6 & 7 of the "a2" column.

What is your estimate of the uncertainty in the acceleration? Δa = ______ m/s^2

Questions:

1. Examine the graphs under the "f vs a graphs" tab. Graph 1 is the force (f1) versus acceleration (a1) plot for the cart and sensor. Graph 2 is the force (f2) versus acceleration (a2) for the cart with the compact mass added.
2. Do these graphs support Newton's second law? Explain your answer fully! Don't forget that there is some uncertainty here (Δa from Procedure B tab). Does it explain any deviations from what Newton would predict?
3. Would you expect the vertical intercept to equal zero? Is it? Explain.
4. What physical property does the slope of a Force v Acceleration graph represent? Hint: what are the units of the slope? Why are the slopes different? Explain.
5. How well do your slopes match what you should expect? They are probably both a little bit too large and the one with the compact mass added is probably somewhat worse. What could explain these differences?

4. DISCUSSIONS AND QUESTIONS:

1. Calculate the net force acting on the cart for each trial that you performed. The net force is the tension in the string (if friction is neglected), which can be calculated as:
$$F_{net}=(m_w m_c)/(m_c+m_w)$$
2. Also calculate the total mass that was accelerated in each trial: (m_c+m_w).
3. Graph the acceleration versus the applied force for cases having the same total mass. Graph the acceleration versus total mass for cases with the same applied force. What relationships exist between the graphed variables?
4. Calculated the theoretical acceleration using Newton's 2nd Law: $F_{net}=ma$. Compare the actual acceleration with the theoretical acceleration, determining the percentage difference between the two.
5. Discuss your results. In this experiment, you measured only the average acceleration of the object between the two photogates. Do you have reason to believe that your results also hold true for the instantaneous acceleration? Explain. What further experiments might help extend your results to include instantaneous acceleration?
6. Analyze the sources of error in the performance of the experiment.
7. If a loaded elevator weighs 3 tons, what force of tension in the hoisting cable (N) will be required it upward at a uniform rate of 6 m/s^2?

8. According to Newton's laws, an external force is needed to stop a car when brakes are applied. Where is this force and what is its origin?
9. A person on an upward-moving elevator is throwing darts at a target on the elevator wall. How should she aim the dart if the elevator has (a) constant velocity, (b) constant upward acceleration, (c) constant downward acceleration.
10. When a moving car is slowed to a stop with its brakes, what is the direction of its acceleration vector? Describe the path of a ball dropped by a passenger during the time the car is showing down.
11. A horizontal force acts on a mass that is free to move. Can it produce an acceleration if the force is less than the weight of that mass.

PHYSICS 1 LABORATORY
EXPERIMENT – 8
EQUILIBRIUM OF PHYSICAL BODIES AND THE PRINCIPLE OF TOROUES AND CENTER OF MASS

1. PURPOSE

To determine the conditions for equilibrium of a rigid body under the action of a system of coplanar parallel forces; to study the principle of moments and the center of mass.

2. THEORY

Gravity is a universal force; every bit of matter in the universe is attracted to every other bit of matter. So when the balance beam is suspended from a pivot point, every bit of the matter in the beam is attracted to every bit of matter in the Earth.

Fortunately for engineers and physics students, the sum of all these gravitational force produces a single resultant. This resultant acts as if it were pulling between the center of the Earth and the center of the mass of the balance beam. The magnitude of the force is the same as if all the matter of the Earth were located at the center of the Earth, and all the matter of the balance beam were located at the center of mass of the balance beam. In this experiment, you will use your understanding of torque to understand and locate the center of mass of an object.

Since the lines of action of the forces all passed through the same point, there was no turning effect on the body. Any unbalanced force would merely cause a linear acceleration. However, if a rigid body is acted upon by a system of forces which are not concurrent, there may result either a linear acceleration, or an angular acceleration (or both) unless the magnitudes, lines of action, and points of application of the forces are so chosen as to produce equilibrium. In this experiment you will investigate the interplay between forces and torques by examining all the forces acting on a body in physical equilibrium.

Moment: The turning effect of a force is called moment. The word torque is also used in this connection. The moment of a force is defined as the product of the force times the perpendicular distance from the axis of rotation to the line of action of the force. A moment is said to be clockwise (considered negative) if its effect would be to rotate the body clockwise and counter-clockwise (positive)

Rigid Body: A rigid body is one which will transmit a force undimished throughout its mass. The particles of a rigid body do not change positions with respect to one another. A rigid body is in equilibrium when both its linear acceleration and its angular acceleration are zero. The two conditions for equilibrium of a coplanar force system may be stated as follows.

First condition: The vector sum of all forces acting on the body must be zero. Mathematically,

$$\sum \vec{F} = 0 \tag{3.1}$$

Second condition: The algebraic sum of all moments about any axis (within or outside the body) must be zero.

$$\sum \vec{M}_p = 0 \tag{3.2}$$

where p may be any point in the plane of the forces, whether inside or outside the rigid body.

3. EXPERIMENTAL PROCEDURES

A-) Center of Mass:

1. Hang the balance beam from the pivot as shown in Fig.8.1. Use the inclined plane as a level and straight edge to draw a horizontal reference line. Adjust the position of the balance beam in the pivot so that the beam balances horizontally.

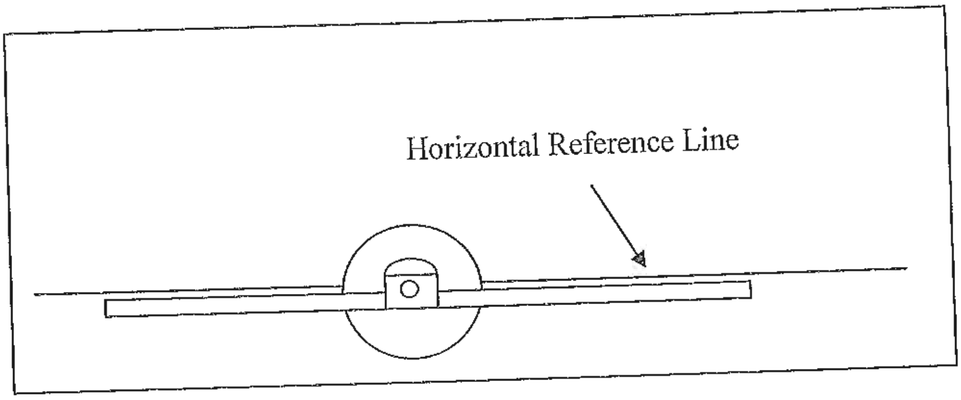


Figure 8.1: Equipment Setup

2. Since the balance beam is not accelerated, the force at the pivot point must be the equilibrant of the total gravitational force acting on the beam. Since the beam does not rotate, the gravitational force and its equilibrant must be concurrent force.
3. Think of the balance beam as a collection of many small hanging masses. Each hanging mass is pulled down by gravity and therefore provides a torque about the pivot point of the balance beam.
4. Attach a mass hanger to each end of the beam. Hang 50 grams from one hunger, and 100 grams from the other, as shown in Fig. 8.2. Now slide the beam through the pivot retainer until the beam and masses are balanced and the beam is horizontal. The pivot is now supporting the beam at center of the mass of the combined system (i.e. balance beam plus hanging masses).

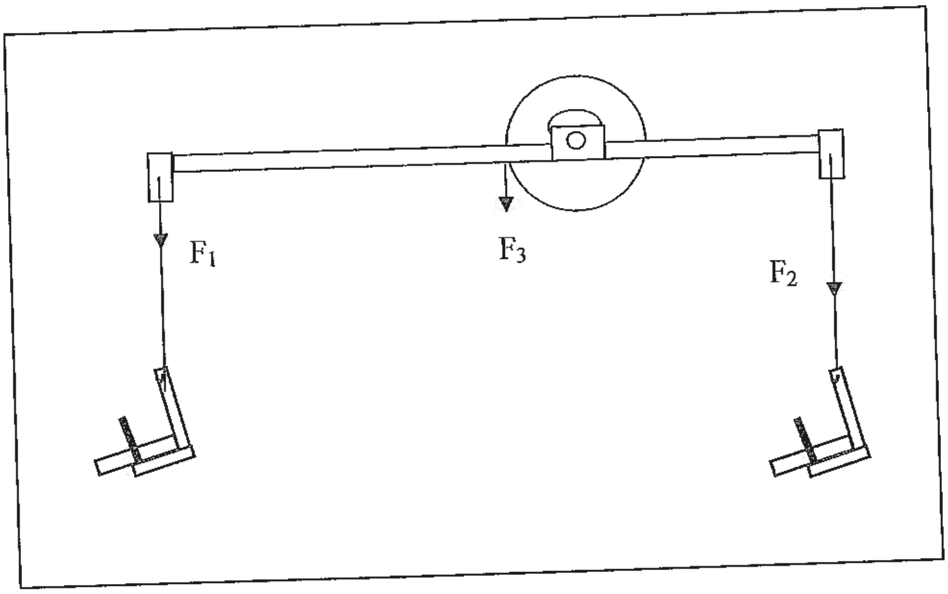


Figure 8.2: Torques and center of mass

5. Remove the 50 gram mass and mass hanger. Reposition the beam in the pivot to relevel the beam. Recalculate the torques about the pivot point.
6. Hang the planar mass from the holding pin of the degree plate as shown in Fig.3.3. Since the force of the pin acting on the mass is equilibrant to the sum of the gravitational forces acting on the mass, the line of the force exerted by the pin must pass through the center of the mass of the planar mass. Hang a piece of string with a hanging mass from the holding pin.
7. Tape a piece of paper to the planar mass as shown Fig.8.3. Mark the paper to indicate the line of the string across the planar mass. Now hang the planar mass from a different point. Again, mark the line of the string. By finding the intersection of the two lines, locate the center of mass of the planar mass.
8. Hang the planar mass from a third point.

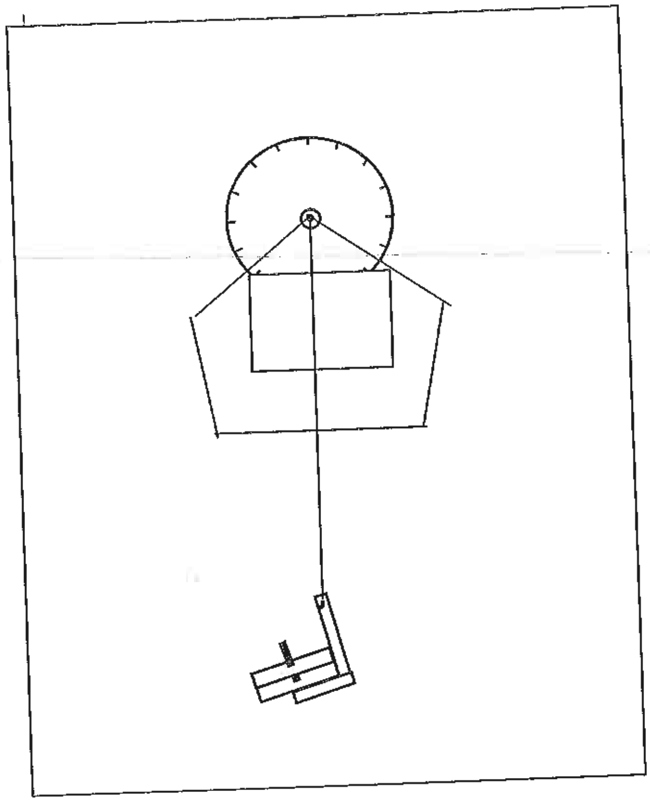


Figure 8.3: Finding the center of mass

B. Equilibrium of Physical Bodies:

1. Fig.8.4 shows three spaceships pulling on an asteroid. Which way will the asteroid move? Will it rotate? The answers to these questions depend on the total force and the total torque acting on the asteroid. But any force acting on a body can produce both translational motion (movement of the center of the mass the body in the direction of the force) and rotation. In this experiment you will investigate the interplay between forces and torques by examining all the forces acting on a body in physical equilibrium.

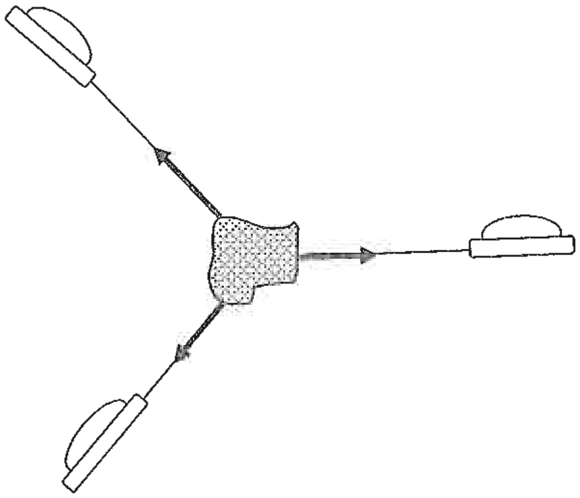


Figure 8.4: Non-Concurrent, Non-Parallel Forces

2. Using the technique described in part a, find the center of mass of the balance beam, and mark it with a pencil. Then set up the equipment as shown in Fig.8.5. (The retainer can be pulled from the pivot Mount and hung from the metal rings, as shown.) By supporting the balance beam from the spring balance, you can now determine all the forces acting on the beam. As shown in the illustration, these forces include:
   2.1. $\vec{F}_1$ – the weight of the mass M_1 (including the mass hanger and plastic retainer).
   2.2. $\vec{F}_2$ – the weight of mass M_2 (including the mass hanger and plastic retainer).
   2.3. $\vec{F}_3$ – the weight of the balance beam, acting through its center of mass.
   2.4. $\vec{F}_4$ – the upward pull of the spring balance (minus the weight of the plastic retainer).
3. Fill in Table 8, listing M (the masses in grams), $\vec{F}$ (the magnitude of the forces in newtons), d (the distance in millimeters from the applied force to the point of suspension), and τ (the torques acting about the point of suspension in newtons x millimeters). Indicate whether each torque is clockwise (cw) or counterclockwise (ccw).

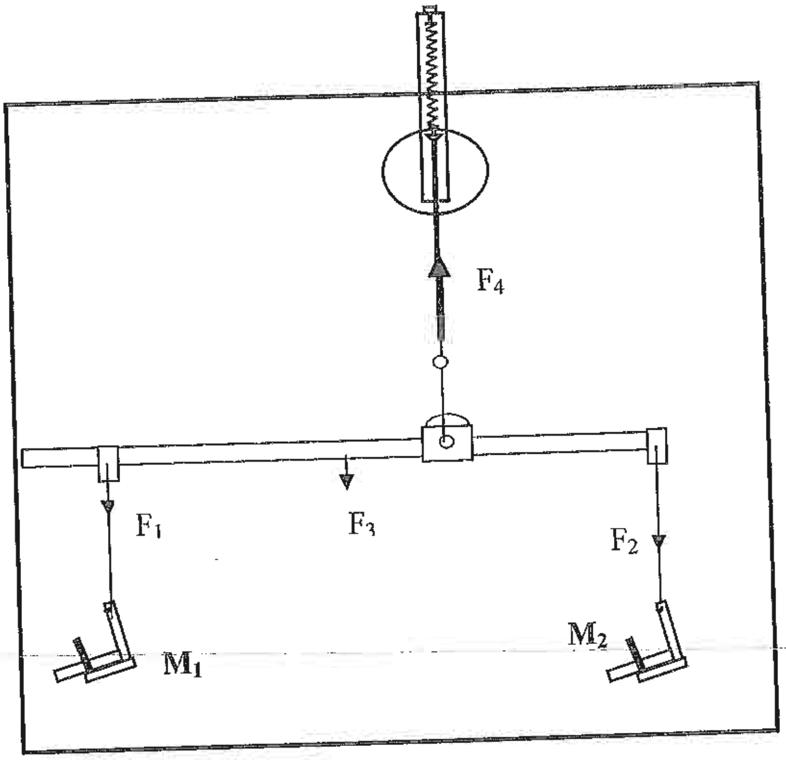


Figure 8.5: Equipment Setup

4. In measuring the torques, all distances were measured from the point of suspension of the balance beam. This measures the tendency of the beam to rotate about this point of suspension. You can also measure the torques about any other point, on or off the balance beam. Using the same forces as you used in Table 8.1 above, remeasure the distances, measuring from the left end of the balance beam as shown in Fig. 8.6. Then recalculate the torques to determine the tendency of the beam to rotate about the left end of the beam. Record your data in Table 8.2. As before, indicate whether each torque is clockwise (cw) or counterclockwise (ccw).

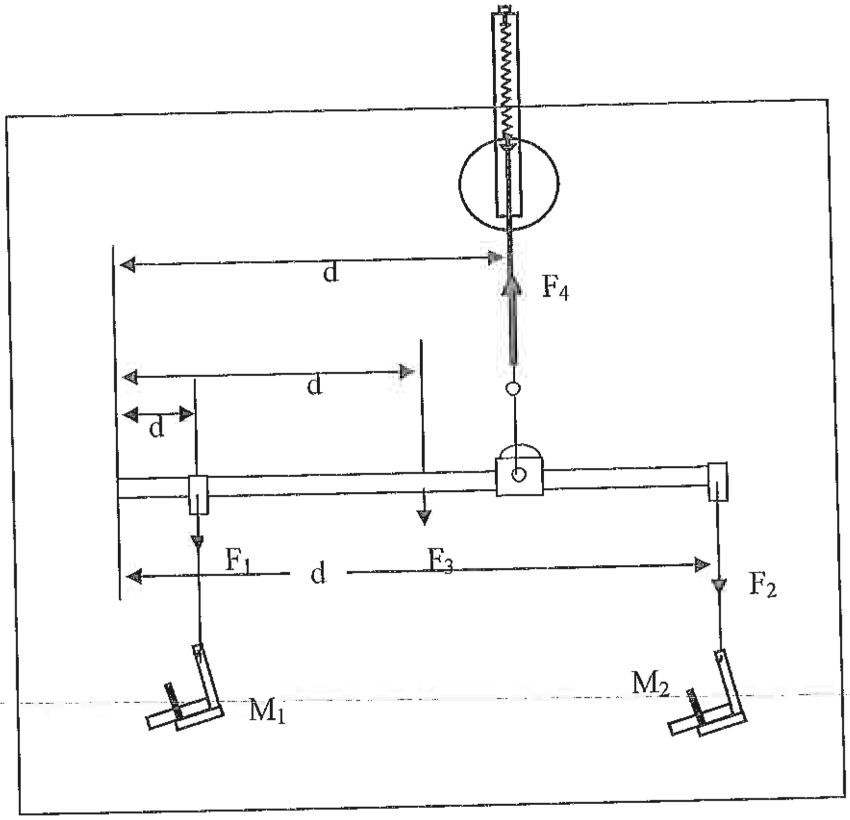


Figure 8.6: Changing the origin

5. Use a pulley and a hanging mass to produce an additional upward force at one end of the beam (You may need to use tape to secure the string to the beam, to avoid slippage). Adjust the positions of the remaining hanging masses and the spring balance on the beam until the beam is balanced horizontally.

4. DISCUSSIONS AND CONCLUSIONS

A-) Center of Mass:

1. Why would the balance beam necessarily rotate if the resultant of the gravitational forces and the force acting through the pivot were not concurrent forces?
2. What is the relationship between the sum of the clockwise torques about the center of mass and the sum of the counterclockwise torques about the center of mass? Explain.
3. Calculate the torques, τ_1, τ_2, and τ_3 provided by the forces $\vec{F}_1$, $\vec{F}_2$, and $\vec{F}_3$ acting about the new pivot point, as shown in Fig.8.2. Be sure to indicate whether each torque is clockwise (cw) or counterclockwise (ccw).
4. Are the clockwise and counterclockwise torques balanced?
5. Are the torque balance according to the experimental procedure part five?
6. Does the line of the string pass through the center of mass according to the experimental procedure part seven and eight?
7. Would this method work for a three dimensional object? Why or why not?

B. Equilibrium of Physical Bodies:

1. Calculate and record the sum of the clockwise and counterclockwise torques. Are the torques balanced?
2. Calculate the sum of the upward and downward forces. Are these translational forces balanced?
3. On the basis of your answers to questions 1 and 2, what conditions must be met for a physical body to be in equilibrium (no acceleration)?
4. Calculate and record the sums of the clockwise and counterclockwise torques. Are the torques balanced according to the data taken experimental prcedure part three ?
5. Are all the forces balanced, both for translational and rotational motion? Diagram your setup and show your calculations on a separate sheet of paper for experimental procedure part four.
6. From the data taken in this section, verify the first condition of equilibrium. Be sure to display your results in such a way tht your prof will be clear.
7. From the data taken in this section and using the second condition, determine the force contributed by unknown mass. Use the fulcrum as the center of moments. Compare this calculated result with the actual weight of the object. Do your results verify the principle of moment ?
8. Compare your experimental results with the calculated results and Express the percent error, accepting the calculated results as being correct.

5. QUESTIONS

1. Discuss the sources of error in the experiment. List and give a brief discussion of at least three structural components or machine components which are examples of a system of coplanar parallel forces in equilibrium.
2. What is meant by a rigid body?
3. What is the definition of the moment of a force?
4. State the two conditions for equilibrium of a rigid body acted upon by a system of coplanar parallel forces.
5. A large beam is to be supported by columns of steel at either end. The beam will support a floor on which heavy machinery is to be permanently installed. Is it necessary that the steel support columns be of equal strength? Explain.
6. Give several examples of a body that is not in equilibrium, even though the resultant of all the forces acting on it is zero.
7. A ladder is at rest with its upper end against a wall and the lower end on the ground. Is it more likely to slip when a man stands on it at the bottom or at the top? Explain.
8. Do a center of mass and the center of gravity coincide for a building? For a lake? Under what conditions does the difference between the center of mass and the center of gravity of a body become significant?
9. Explain, using forces and torques, how a tree can maintain equilibrium in a high wind.

Table 8.1: Data table

M_1	F_1	d_1	τ_1	M_2	F_2	d_2	τ_2	F_3	d_3	τ_3	F_4	d_4	τ_4

Table 8.2: Data table

M_1	F_1	d_1	τ_1	M_2	F_2	d_2	τ_2	F_3	d_3	τ_3	F_4	d_4	τ_4

PHYSICS 1 LABORATORY
EXPERIMENT – 9

WORK AND ENERGY

1. PURPOSE

The purpose of this activity is to compare the total work done on an object to the change in kinetic energy of the object.

2. THEORY

For an object with mass, m, that experiences a constant net force F_{net} over a displacement $\Delta x = x_f - x_0$ parallel to the net force (see Figure 1), the total work done is:

$$W_{Total} = F_{net} * \Delta x$$

The net force is the vector addition of all forces acting on the object during the displacement. If the net force varies during the displacement, then the total work done is calculated as an integral:

$$W_{TOTAL} = \int_{x_o}^{x_f} F_{net} dx .$$

This integral is equal to the area under the curve on a force versus position graph (see Figure 2).

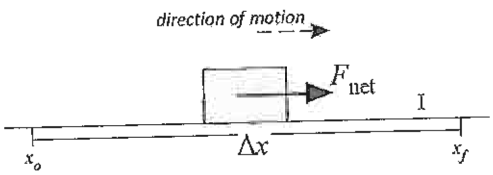


Figure 1: Force producing work

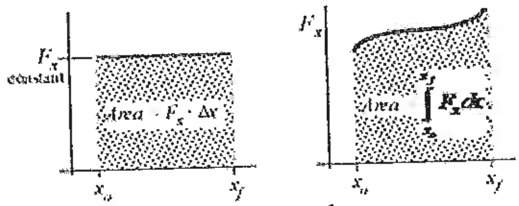


Figure 2: Area under a curve

According to the Work-Energy Theorem, a change in kinetic energy can only be produced if work is done. The work done must be the combined effort of all forces involved (the net force), that is, the change in kinetic energy is given by the *total* amount of work done. This yields the Work-Energy Theorem:

$$\Delta K = K_f - K_0 = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_0^2 = W_{Total} = \text{Area under F vs x curve.} \qquad \text{Eq. (1)}$$

3. EXPERIMENTAL PROCEDURES

Setup:

1. Level the track. Use a spirit level if available or just use the motion of the PasCar on the track. If a spirit level is available, check level along the track and perpendicular to it.
2. Attach the High Resolution Force Sensor to the Discover Collision Bracket and attach the bracket to the track as shown in Figure 4.
3. Attach a track Endstop in front of the hook on the Force Sensor (see Figure 4) to protect it from being struck by the PasCar. The Endstop should be about 1 cm from the hook (closer than shown in Figure 4).
4. Attach the Motion Sensor to the other end of the track. Tilt the sensor down slightly.
5. Connect the Force Sensor and the Motion Sensor to the PASPORT inputs on the 850 Universal Interface.
6. Choose one of the long weak springs from the Dynamics Track Spring Set. Attach the spring to the Force Sensor hook with a string threaded through the hole in the Endstop so that the spring is about 5 cm from the Endstop.
7. Attach the other end of the spring to the upper hole in the PasCar with a piece of string so there is about 20 cm of string between the spring and the car (the car, not the plunger). Attach to the end of the PasCar with the plunger and make sure the plunger is out.

Procedure: *(graph Speed of Pascar vs Position)*

1. Mass the PasCar. Mass one of the long springs (they are all about the same). Record both values in Question 3c on the Conclusions page. Click open the Calculator at the left of the screen. In line 1, replace the mass (0.2558) with the mass (in kg) you measured for the PasCar. Close the Calculator by clicking on it.
2. Push the ZERO button on the Force Sensor.
3. Start with the cart not attached to the string and about 15 cm from the Motion Sensor. Click RECORD. When the Motion Sensor green light comes on, gently push the cart away from the Motion Sensor and release it. The recording will stop automatically as the PasCar reaches 70 cm from the Motion Sensor.
4. Click the Scale to Fit icon on the graph toolbar. Examine the Velocity versus Position plot. If it is noisy (sudden variations in speed), make sure there is nothing around the track to reflect the signal from the Motion Sensor and/or vary the tip angle of the sensor. Repeat the run until it is reasonably clean. Delete unwanted runs using the Delete Last Run button at the bottom of the screen.
5. If there were no friction, the speed should remain constant, but the car clearly slows. We can compensate for this by tipping the track up slightly so a small component of the weight acts down the track and exactly cancels the frictional force. Screw down the leveling feet nearest the Motion Sensor by a couple of turns to increase the height of that end. Repeat steps 3 and 4 until the speed of the cart remains roughly constant as it move down the track. Use the Delete Last Run button at the bottom of the screen to delete each run except the last showing the speed as constant. Click open Data Summary (right of screen), double click on the Run you kept and re-label the run as "Calibrate Run". Close Data Summary by clicking on it.
6. Attach the cart to the spring and pull the cart until it is about 15 cm from the Motion Sensor. This should stretch the spring by about 35 cm.

7. Click RECORD. Once the Motion Sensor green light turns on, release the cart. The recording will stop automatically. If the data is too noisy, delete it and run again. Some bad points won't hurt.
8. Click open Data Summary and re-label this run as "Weak Spring".
9. Replace the weak spring with one of the strong springs and repeat steps 6-8, labeling the run as "Strong Spring".

Analysis: *(graph: Force vs Position; table: Position & Work)*

1. In the Work vs Position table, click the top of each column and select "Weak Spring".
2. On the graph click the black triangle by the Run Select icon and select "Weak Spring". Click the Selection icon and use the handles on the selection box that appears to move the left side of the box to a point before the data starts. Move the right side of the box to .20 m.
3. Click the Area icon on the graph toolbar to turn on the Area tool. The Area given on the graph is the area under the curve inside the selection box. Recall that 1 N*m = 1 J. Also recall (from Theory) that the area under the curve is equal to the work done by the spring on the PasCar. If the Area does not have 3 decimal places, click open Data Summary, go down to High Resolution Force Sensor, click on Force, click on the Gear icon that appears to the right of Force, go down to Numerical Format and change the number of Fixed Decimals to 4 and then back to 3.
4. Note that in the Work vs Position table all the Position values within the selection box on the graph are highlighted in yellow. In the first row enter 0 for the work (W) done by the spring since the spring has done no work on the car until the car moves. Then scroll down to the last highlighted position (~0.20 m) and record the Area from the graph into the work (W) column.
5. Drag the right side of the selection box to 0.25 m. Scroll down to the last highlighted position (~0.25 m) and record the Area from the graph into the work (W) column. Repeat for each 0.05 m until 0.70 m.
6. Click anywhere in the selection box to highlight it. Click the Delete Active Element icon. Repeat the above process for the "Strong Spring".

Work vs Energy: (graph: K.E. and Work vs Position)

1. Click the Run Select icon to allow multiple runs, click the the black triangle by the icon and select both Strong Spring and Weak Spring. The kinetic energy (KE) and work (W) curves should be shown for both springs. Click on the Scale to Fit icon.

4.QUESTIONS:

1. Click the Run Select icon to allow multiple runs, click the the black triangle by the icon and select both Strong Spring and Weak Spring. The kinetic energy (KE) and work (W) curves should be shown for both springs. Click on the Scale to Fit icon.

2. Why do the graphs start off steep (at small positions) and then become less steep?

2. What effects could decrease the translational kinetic energy of the cart?
   a. We compensated for friction at a speed that was probably quite a bit lower than the final speed in the spring run. If there was more friction at high speed, how could you detect it in your graph. Do you see any evidence of uncompensated friction?
   b. The wheels of the cart are rotating, which means that the pieces of the wheel have a higher speed than the cart and thus more kinetic energy. How will this affect the amount of translational kinetic energy available to the cart?
   c. The spring has mass and is moving. Does it get some of the kinetic energy? During the acceleration, one end of the spring is at rest and the other is moving at the same speed as the car. Application of calculus shows that the kinetic energy of the spring is given by: $K_{spring} = (1/6)m_{spring} v_{cart}^2$.

4. How well do the curves agree with Equation 1 from Theory?

PHYSICS 1 LABORATORY
EXPERIMENT – 10

CONSERVATION OF ENERGY

1. PURPOSE

A car is started from rest on a variety of shapes of tracks (hills, valleys, loops, straight track) and the speeds of the car at various points along the track are measured using a photogate connected to a Smart Timer. The potential energy is calculated from the measured height and the kinetic energy is calculated from the speed. The total energy is calculated for two points on the track and compared.

The height from which the car must be released from rest to just make it over the loop can be predicted from conservation of energy and the centripetal acceleration. Then the prediction can be tested on the real roller coaster. Also, if the car is released from the top of the hill so it easily makes it over the top of the loop, the speed of the car can be measured at the top of the loop and the centripetal acceleration as well as the apparent weight (normal force) on the car can be calculated.

2. THEORY

The total energy (E) of the car is equal to its kinetic energy (K) and its potential energy (U).

$$E = K + U \qquad (1)$$

$$K = \frac{1}{2}mv^2 \qquad (2)$$

where m is the mass of the car and v is the speed of the car.

$$U = mgh \qquad (3)$$

where g is the acceleration due to gravity and h is the height of the car above the position where the potential energy is defined to be zero.

If friction can be ignored, the total energy of the car does not change. The Law of Conservation of Energy is stated as

$$E = \text{constant} \quad \Rightarrow K_{initial} + U_{initial} = K_{final} + U_{final}$$

3. EXPERIMENTAL PROCEDURES : ***LOOP PROCEDURE***

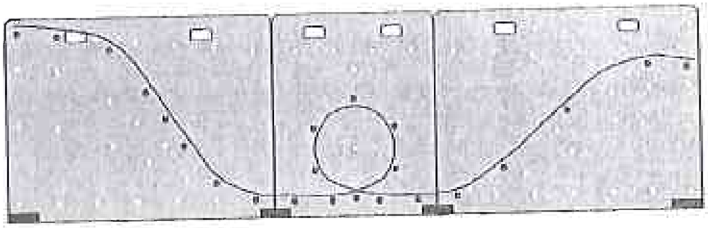


Figure 1: Loop Setup

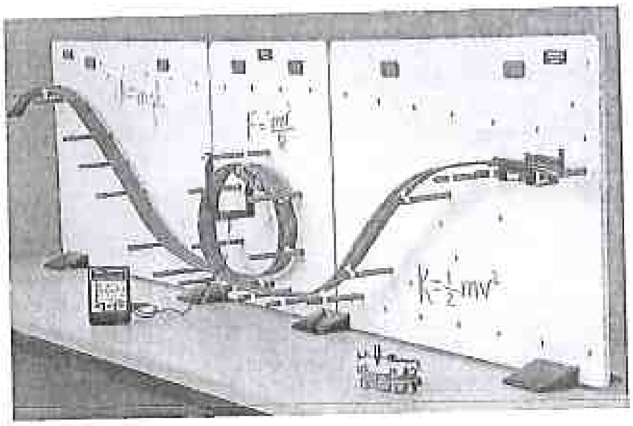


Figure 2: Photogate Position

1. Configure the track as shown in Figures 1 and 2. Attach a photogate at the top of the loop. Also put the catcher on the end of the track to keep the car from going off the end of the track.
2. Put a peg in the center of the loop. Place the Mini Car at the top of the loop. Mark on the position of the center of mass of the car on the white board. Measure from the center of the center peg to the center of mass of the car at the top of the loop (see Figure 3).

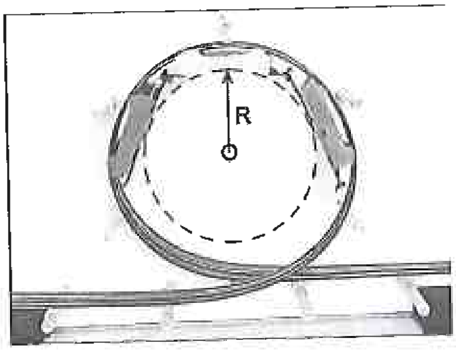


Figure 3: Loop Radius

3. Measure the distance from the center of mass of the car at the top of the loop to the table.
4. Using Conservation of Energy, predict the minimum height from which the car can be released on the left end of the track so the car will just make it completely over the loop.
5. Draw a horizontal line from the top of the circle you drew for the loop to the left part of the track. Measure from this line to mark the starting position calculated in Part 4.

6. Place the center of mass of the car at the marked predicted position and release it from rest.
7. Place the 50g mass on the car and repeat steps 1 through 6 above.

QUESTIONS

1. Does the car make it over? If not, why not? If so, does it just make it or did you start too high?
2. Once you have determined the release position where the car will make it over the loop, observe and mark the highest position reached on the right side of the track. In theory, where should this position be? How far above or below is this position from the horizontal line drawn in Part 5? Use the loss in height from the starting position to calculate the percent energy lost.

$$\%EnergyLost = \frac{LossOfHeight}{StartingHeight}$$

3. Calculate the initial total energy of the car.
4. Calculate the final total energy of the car.
5. How much energy is lost? Where does it go?
6. How does increasing the mass of the car change the total energy?
7. How does increasing the mass of the car change the speed of the car at the bottom?
8. Does the car lose a greater percentage of its energy when it has the extra mass or not?
9. How fast would the car have to go to cause the normal force to be zero at the top of the hill? How high would the car have to start to make this happen?
10. Which car has the greater speed at the right end of the track? How does energy conservation explain the result?
11. Which car reaches the end of the track first? Why?

PHYSICS 1 LABORATORY
EXPERIMENT – 11

IMPULSE

1. PURPOSE

A cart runs down a track and collides with a Force Sensor equipped with either a clay bumper, spring bumper, or magnetic bumper. The cart experiences a variable force during the time of the collision, causing it to change its velocity. In this experiment, the relationship between momentum, force, and impulse will be explored.

To determine the change in momentum (impulse), the speeds before and after the collision are measured using a photogate. This photogate is also used to trigger the beginning of data collection for the Force Sensor. To confirm the impulse, the force versus time is plotted and the impulse is determined by finding the area under the curve.

2. THEORY

According to Newton's Second Law,

$$\vec{F} = \frac{\overrightarrow{dp}}{dt} \qquad (1)$$

where F is the force on an object, p is the momentum of the object, and t is time. Rearranging and solving for the impulse (Δp) gives

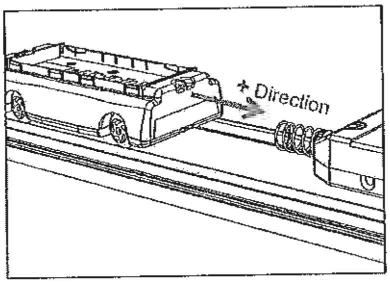


Figure 1. Definition of the Positive Direction

$$\overrightarrow{\Delta p} = \vec{p_f} - \vec{p_i} = \int \vec{F} dt \qquad (2)$$

where the momentum is $\vec{p} = m\vec{v}$.

$$\overrightarrow{\Delta p} = m\vec{v_f} - m\vec{v_i} \qquad (3)$$

and

$$\int \vec{F}dt = \text{Area} \quad (4)$$

Area is the area under the F versus t curve.

Note on Positive Direction:

We define the positive direction for the velocity to be toward the Force Sensor. See Figure 1.We define the positive direction for the velocity to be toward the Force Sensor. The force of the cart on the force sensor is positive but the force of the force sensor on the cart is negative. See Figure 1.

3. EXPERIMENTAL PROCEDURES : *Set-Up*

1. Put the force sensor and bracket on the end of the track. See Figure 2.
2. Put the photogate on the track. Position it just far enough away from the force sensor so the flag on the cart will pass through the photogate before the cart hits the bumper on the force sensor (see Figure 2). The photogate is used to measure the incoming and outgoing speeds.

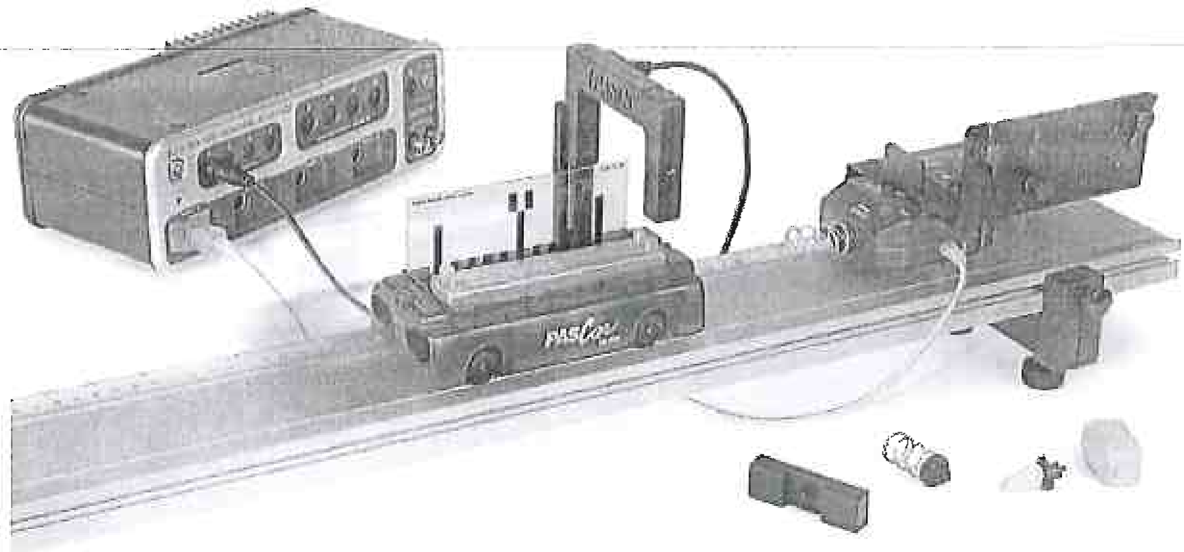


Figure 2. Complete Setup for the Spring Bumper

3. Plug the photogate into Channel 1 and plug the force sensor into Channel P1 on the interface.
4. Put the weak spring bumper on the end of the force sensor.
5. Put an endstop approximately in the middle of the track. This will be the starting point of the cart for every run.
6. Mount the photogate flag in the cart with the double-flag up. Set the position the photogate in the vertical direction so the photogate will be blocked by the double flag.
7. Force Calibration
    a. Put the force sensor on a rod stand so the hook is facing downward.
    b. Press the zero button.
    c. In PASCO Capstone, create a digits display with the force on it.
    d. Hang a 500 gram mass on the hook. Record for a couple of seconds.
    e. Use a scale to find the exact mass of the 500 g mass.
    f. The reading on the force sensor should be "mg". Open the calculator and

multiply the force measurement by the ratio of mg over the force reading on the digits display.

8. In PASCO Capstone, set up a table with one column with the velocity in it. Create a graph of Calibrated Force vs. time.

Procedure

1. Measure the mass of the cart with the flag and record it here.
2. Set the sample rate for the force sensor to 5 kHz. Press the Zero button on the top of the force sensor while nothing is touching it.
3. Compress the cart's plunger to its first position. Place and hold the cart plunger against the endstop.
4. Begin data recording, then hit the plunger release on the top of the cart using a mass bar.
5. After the cart collides with the bumper on the force sensor and passes back through the photogate, recording will automatically stop.

Analysis

1. Record the initial and final velocities for each trial in Table II. Note: Make sure the signs of the velocity follow the convention that positive is toward the force sensor.
2. On the Force versus Time graph, find the area under the curve to determine the impulse from the moment just before the collision to the moment just after the collision for each trial. You may have to make a selection, particularly with the clay bumper because the cart sticks to the bumper. Record each value in Table II.
3. Calculate the change in momentum Δp using the velocities for each trial and record the resulting values in Table II. Show a sample calculation.

Spring and Magnetic and Rubber Bumpers

1. Replace the weak spring bumper with the clay bumper. Shape the clay into a long protrusion so the clay will take a long time to collapse during the collision. Repeat the procedure and the analysis.
2. Replace the clay bumper with the magnetic bumper. Be sure that you place the photogate far enough back from the magnetic bumper so the speed is recorded before the cart's magnets start to be repelled by the magnets on the force sensor. Repeat the procedure and the analysis.
3. Replace the magnetic bumper with the rubber bumper. Be sure that you place the photogate so the speed is recorded right before the cart hits the rubber bumper. Repeat the procedure and the analysis.

4. Questions

1. How do the three different Force vs. Time graphs compare?
    a. Which had the highest maximum force?
    b. Which had the longest time of impact?
    c. Which had the greatest impulse?
    d. Which had the greatest change in momentum?
    e. Explain why the shapes of the curves are different.

2. How does the impulse from the clay compare to the impulse from the magnets? Why?
    a. Compare the initial velocities of the cart for the clay and magnetic bumpers.
    b. Compare the final velocities of the cart for clay and magnetic bumpers.
3. How is the momentum of the cart before and after the collision related? Was energy lost in the collision? If so, where did the energy go? Kinetic Energy is $K=1/2\ mv^2$. Calculate the kinetic energy before and after the collision.
4. Summarize the differences and similarities of elastic, inelastic, and completely inelastic collisions. Include the numerical results for the impulse for each of the bumpers and the percent differences.
5. How do the measured values for impulse compare to the calculated values for change in momentum? What are some factors that may have caused error in your measured values, and how could these have been avoided?

PHYSICS 1 LABORATORY
EXPERIMENT – 12

CONSERVATION OF MOMENTUM

1. PURPOSE

Elastic and inelastic collisions are performed with two dynamics carts of different masses. Magnetic bumpers are used in the elastic collision and Velcro® bumpers are used in the completely inelastic collision. In both cases, momentum is conserved.

2. THEORY

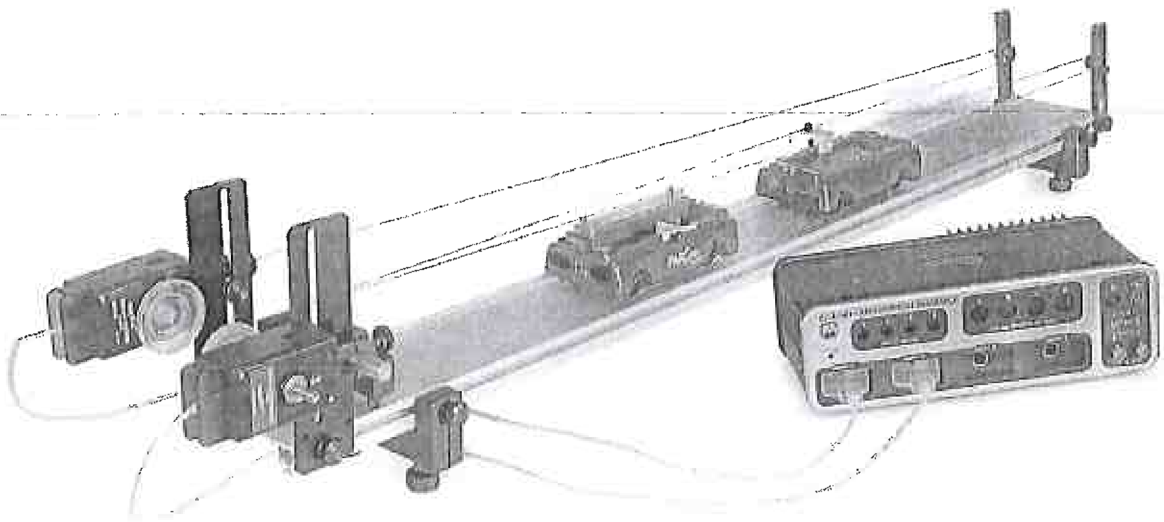


Figure 1: Setup

Cart velocities are recorded using two Rotary Motion Sensors connected to the carts by string wrapped around pulleys. This measurement method adds very little friction to the experiment and, since the velocities are continuously monitored, any deceleration due to friction can be measured. The total kinetic energy before and after the collision is also studied.

The momentum of a cart depends on its mass and velocity.

$$P=mv \tag{1}$$

The direction of the momentum is the same as the direction of the velocity. During a collision, the total momentum of the system of both carts is conserved because the net force on the two-cart system is zero. This means that the total momentum just before the collision is equal to the total momentum just after the collision. If the momentum of one cart decreases, the momentum of the other cart increases by the same amount. This is true regardless of the type of collision, and even in cases where kinetic energy is not conserved. The law of conservation of momentum is stated as

$$\vec{P}_{\text{Total Before Collision}} = \vec{P}_{\text{Total After Collision}} \quad (2)$$

The kinetic energy of a cart also depends on its mass and speed but kinetic energy is a scalar. The total kinetic energy of the system of two carts is found by adding the kinetic energies of the individual carts.

3. EXPERIMENTAL PROCEDURES: *Setup*

1. Level the track using the leveling screws on the track feet. When you place a cart at rest on the track, give it a little push in each direction. It should not accelerate in either direction.
2. Use the balance to find the mass of each cart. Include the string bracket on each cart.
3. Use one red and one blue cart so it is easy to distinguish between the carts. Attach a line of thread to each cart using the string bracket (see Figure 3). Run the thread over the largest pulley on the Rotary Motion Sensor (Figure 4a) and then over the small pulley on the other end of the track (Figure 4b), then return to the string bracket on the cart. The thread should not be too tight; just tight enough so the Rotary Motion Sensor pulley will turn when the cart moves.

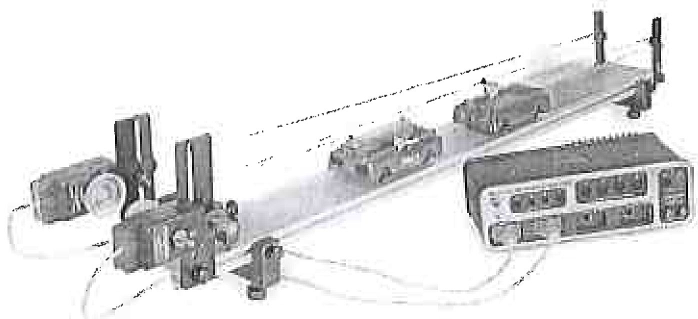


Figure 2: Complete Setup

Figure 3: Connecting thread to the cart

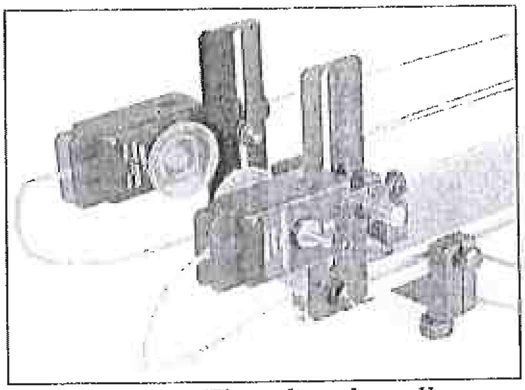


Figure 4a: Threading the pulleys

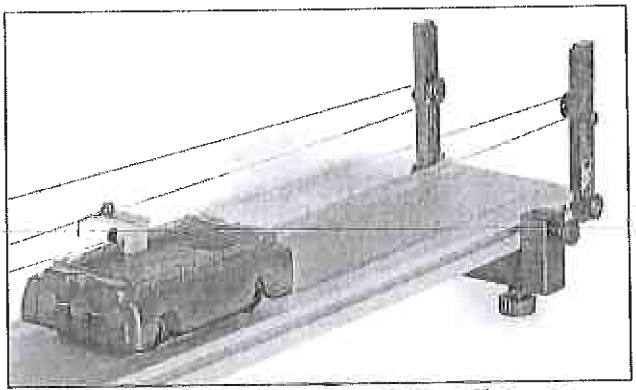


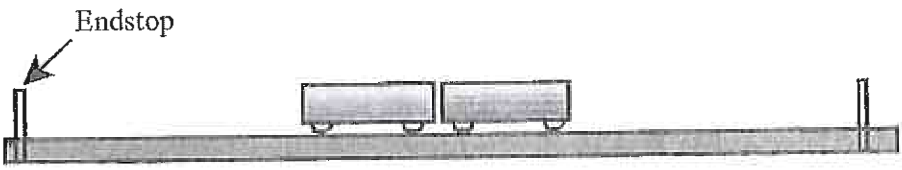
Figure 4b: Threading the pulleys

4. Plug the Rotary Motion Sensor attached to the red cart into Channels P1 on the 850 interface and plug the Rotary Motion Sensor attached to the blue cart into Channels P2 on the interface.
5. Create a graph of velocity vs. time, putting both the Red Cart Velocity and the Blue Cart Velocity on the same vertical axis.
6. Checking the signs of the velocities: The goal is to have the velocities of both carts be positive to the right.
    a. Start recording and push the red cart to the right, toward the blue cart.
    b. If the velocity of the red cart is negative, remove the 3-step pulley from the red cart's Rotary Motion Sensor and turn the Rotary Motion Sensor upside down and put the 3-step pulley back onto the Rotary Motion Sensor.
    c. Push the blue cart to the right, away from the red cart.
    d. If the velocity of the blue cart is negative, remove the 3-step pulley from the blue cart's Rotary Motion Sensor and turn the Rotary Motion Sensor upside down and put the 3-step pulley back onto the Rotary Motion Sensor.

Procedure

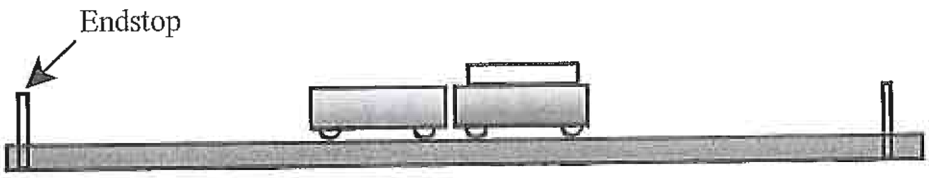
I. Explosions

A. Equal Mass Carts



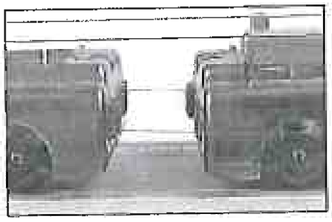
1. Depress the plunger on one cart to position #2. Does it matter which cart has its plunger depressed? Place the two carts in contact with other in the center of the track.
2. Start recording and tap the trigger release to launch the carts. Hitting the trigger with a mass bar works well.
3. Stop recording before either cart reaches the end of the track.
4. On the velocity vs. time graph, find the velocity of the red cart just after the explosion. It may be helpful to expand the graph, to see just that area you are interested in.
5. Repeat step 4 to find the velocity of the blue cart after the collision.

B. Unequal Mass Carts



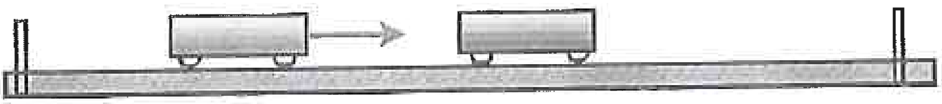
Use the balance to find the mass of two mass bars, and then place them both in the blue cart. Repeat steps 1 through 5 of part A.

II. Completely Inelastic Collisions



Velcro® Bumpers for Inelastic Collisions

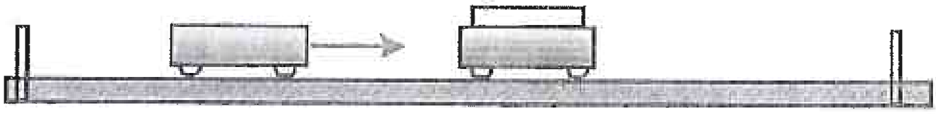
A. Equal Mass Carts



1. Place the red and blue carts at rest on the track as shown above, with the Velcro® bumpers facing each other.
2. Start recording and give the red cart a push toward the blue cart.
3. Stop recording before either cart reaches the end of the track.

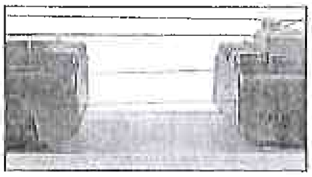
4. On the velocity vs. time graph, find the velocity of the red cart just before and just after the collision. It may be helpful to expand the graph, to see just that area you are interested in.
5. The initial velocity of the blue cart is zero and its final velocity is the same as the red cart because they stick together.

B. Unequal Mass Carts



1. Place the two mass bars in the blue cart.
2. Repeat the procedure from Part A.

III. Elastic Collisions



Magnetic Bumpers for Elastic Collisions

A. Equal Mass Carts

1. Place the red and blue carts at rest on the track, with the magnetic bumpers facing each other.
2. Start recording and give the red cart a push toward the blue cart.
3. Stop recording before either cart reaches the end of the track.
4. On the velocity vs. time graph, find the velocity of the red cart just before and just after the collision. It may be helpful to expand the graph, to see just that area you are interested in.
5. The initial velocity of the blue cart is zero. Find the final velocity blue cart.

B. Unequal Mass Carts

1. Place the two mass bars in the blue cart.
2. Repeat the procedure from Part A.

Analysis

1. Calculate the initial and the final momentum for each cart for each of the collisions.
2. Calculate the percent difference between the total initial momentum and the total final momentum for each collision.

$$\%difference = \frac{p_{before} - p_{after}}{p_{before}} x100\%$$

3. Calculate the initial and the final kinetic energy for each cart for each of the collisions.
4. Calculate the percent of the total kinetic energy lost for each collision.

IV. Total Momentum and Total Energy

1. Create these calculations in PASCO Capstone:

$p_{total}=m_1 v_1+m_2 v_2$, $KE_{total}=KE_1+KE_2$, $KE_1=1/2*m_1 v_1^2$, $KE_2=1/2*m_2 v_2^2$

v_1=[Red Velocity, Ch P1(m/s), ▼],v_2=[Blue Velocity, Ch P2(m/s), ▼],

m_1= mass of Red cart, m_2= mass of Blue cart

2. Graph p_{total} vs. time and add a second plot area for KE_{total} vs. time.
3. Examine the graphs to see what happens before, during, and after the collisions. Look at each type of collision and record your observations.

4. QUESTIONS:

In general, what did you learn about conservation of momentum and kinetic energy in different types of collisions?

1. Was momentum conserved for all types of collisions?
2. Was total velocity conserved for all types collisions?
3. Was energy conserved for all types of collisions? What happens to the initial kinetic energy that is lost in a collision?