Time — Speed — Acceleration

Mark 2 Manual

djb microtech ltd

Contents

Introduction

Welcome to Time - Speed - Acceleration (TSA). This manual is a comprehensive guide to the use of this versatile measuring instrument.

To obtain the best results from TSA work your way through each section of this manual. It won't take you long and it will give you an insight into the versatility of the instrument and its potential areas of application.

What can TSA Measure ?

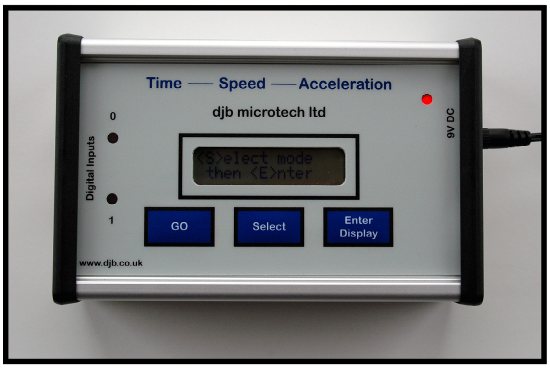
TSA can operate in a number of different modes.
It can :-

a) measure time intervals (4)
b) measure event times (8)
c) be used as a fast timer with a resolution of 10 µs
d) measure gap time
e) be used to develop the concept of acceleration (v1, v2, dt)
f) measure speed (4)
g) measure acceleration (2)

Power Requirements

TSA has been designed to run from a regulated plug top power supply, centre positive, set at 9V.

Getting familiar with TSA



Note that there are two digital inputs which are TTL compatible. Switches and light gates may be connected to these inputs. The inputs are also available at the DIN sockets. Light gates can be powered from these sockets.
To enable you to make some simple measurements connect a push switch between the red and black terminals of either digital input. Avoid using a toggle switch as this may cause switch bounce.

Time Interval

This mode measures the length of time a light beam has been cut or a switch closed and will be dealt with in most detail as all other modes are similar in operation.

- Switch on TSA,
- When prompted press the <S>elect button,
- Continue to press <S>elect and cycle through the modes. When you return to Time Interval press the <E>nter button.
- <S>elect how many readings you wish to make, For this first attempt <S>elect 1
- Now press <E>nter.
- The LCD displays <G> when ready. When you are ready to start the experiment press the GO button.

- The LCD displays "Waiting". TSA is now waiting for an event to happen so that it can start its internal clock.
- Close the switch (firmly) and then open it a short while later.
- The time interval will be displayed on the LCD.
- Press <G> to GO again and repeat the experiment.
- After you have repeated the experiment several times press <S>elect and again select Time Interval but this time set TSA to read 3 time intervals.
- Proceed in a similar fashion as before but note that the Waiting message is displayed until all 3 time intervals have been measured.
- To see all three time intervals, keep pressing <D>isplay.

If the displayed time intervals are unreasonably short then this is caused by switch bounce. The best thing to at this stage would be to replace the switch or use a light gate and cut the beam with your hand.

Important
An Event is simply a change in state of an input. To measure a time interval there must betwo events: the first one starts the internal clock and the second one stops it.

TSA has been designed so that the starting and stopping of its clock can be controlled from either input channel independently. For example an event on channel 1 can start the clock and the next event on channel 0 or channel 1 stops the clock.

All inputs are debounced. On shutting a switch the contacts tend to bounce very quickly, generating many events. To get round this problem the software waits for a few milliseconds after an event before returning to look at the inputs to see if another event has occurred. Note that the clock has not stopped and no error has been introduced in the timing. It does, however, limit the minimum time interval to the length of the debounce delay. The default debounce delay is set at 10 ms. A minimum time interval measurement of 10 ms should not impose too many restrictions on general classroom work. However for users having specialist requirements see the section on Changing the Debounce Delay.

The time interval is rounded to 3 decimal places.

Event Times

This mode is used to measure the time at which each event happened. Up to 8 events can be measured and the first event is displayed as happening at Time = 0.000 s.

The Event Timer is set up in an identical fashion to the the Interval Timer.

The Event Timer is the most verstile of all the modes offered. It can be used for many experiments in the study of motion — both linear and rotational. However it may place addition demands on the student e.g calculating the acceleration from 4 event times and a mask length is not recommended in a first level Physics course but would be excellent in promoting a deeper understanding in a second level course.

Fast Timer

This mode can be used to display a time interval between 50 - 65535 µs. Trying to measure an interval larger than the maximum causes the error message "Too big" to be displayed.
This timer could be used to measure the time for sound to travel between two microphones and from this the speed of sound can be calculated.

Important

On selecting this mode the debounce delay is automatically set to zero and it is returned to its original value on exit.

Gap Time

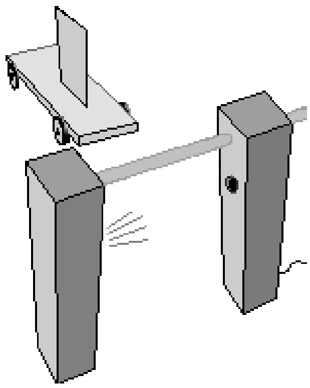
This mode is used to measure the time interval between events on different input channels. It is set up in a similar way to the Interval Timer. Only one Gap Time can be measured.

Consider a trolley with a mask running down a runway which has two light gates positioned on it. When the first light gate is cut the clock starts and when the second one is cut the clock stops. Gap time is different from Time Interval because here the events must happen on different channels.
The time displayed is the time for the leading edge of the mask to travel from one light gate to the next.
This mode could find application in the teaching of average speed — set two light gates a known distance apart and using Gap Time measure the time for the trolley to travel this distance.

If you require an accurate stop clock then connect a switch to each digital input —pressing one switch will start the clock and pressing the other will stop it. This will give a stop clock displaying to 1/1000 ths of a second and with a range of 0 - 999.999 s.

Speed

This mode is used to measure the speed of a vehicle as it passes through a light gate. If the mask is small then the measurement is a reasonable approximation to the instantaneous speed.



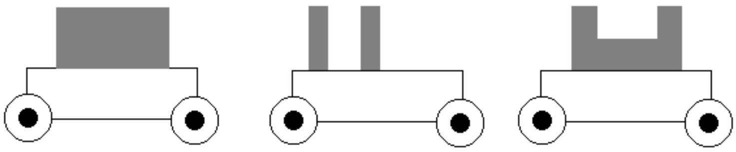
- <S>elect the Speed mode then press <E>nter.
- <S>elect the size of your mask in centimetres. Note that each time the <S> button is pressed the distance increments in 1 cm steps until 10 cm and then in 10 cm steps until 250 cm. Holding down the <S> button results in a rolling display.
- Press <E> to enter your mask size.
- Press <G> when ready.

Important

If very fast speeds are to be measured then the debounce delay must be changed to zero and bounce free switches used.

Acceleration

The setup for this mode is identical to Speed. However, there are several possible mask arrangements:-



Possible mask arrangements

Masks may be attached to the trolley with masking tape.
To measure an acceleration a single mask requires two light gates whereas a double mask requires only one light gate.
Where double masks are used then both sections must have the same width.

Acceleration Data

This mode is intended for developing the concept of acceleration. The user is presented with values of v1 and v2 from which they have to calculate the change in velocity. They are also given the time for the change in velocity. Using this data they can calculate the acceleration. Note that this mode does not display the acceleration. Once the student is familiar with the calculation of acceleration using the Acceleration Data mode they can switch to the Accleration Mode for investigative work.
The following notes may be helpful :
Suppose you use a light gate and a double mask with each leg d cm wide.
To calculate an acceleration you require 4 event times – t1, t2, t3 and t4.
Subtracting t2 - t1 gives the time for the first leg of the mask to cut the beam.
The velocity (v1) of the first leg can be calculated using d/(t2 - t1). This is an average velocity and it will have this velocity in the middle of the timing interval (t2 - t1) – for a constant acceleration.
Similarly the velocity (v2) of the second leg can be calculated using d/(t4 - t3). This is an average velocity and it will have this velocity in the middle of the timing interval (t4 - t3)

The change in velocity (v2 - v1) can now be calculated.
The time for the change between these two average velocities is:

(t2 - t1)/2 + (t3 - t2) + (t4 - t3)/2

The acceleration can now be calculated from

(change in velocity) / (time for change)

Changing the Debounce Delay

Switch bounce may cause problems when you are trying to measure events. Consequently a default debounce delay of 10 ms has been designed into TSA. This does NOT mean that there is an error of 10 ms in the timing. After an event, 10 ms will elapse before the inputs are again examined to await an event. During these 10 ms the switch should settle and stop bouncing. If an event happens during these 10 ms then it would be missed! In most school experiments a 10 ms debounce delay will not cause problems. However the user can change this delay in the range 0 - 50 ms.

To change the debounce delay

- <S>elect Change Debounce then press <E>nter.
- <S>elect to change the current value of the delay.
- Scroll through the values and <E>nter your required value.

If you are using switches as the inputs to TSA then do not set the debounce delay to zero unless these switches are hardware debounced.

Remember that for most work the default value of the debounce delay will be satisfactory. The default value of 10 ms is set at switch on.

Connecting Light Gates

The **djb microtech** Light Bridge connects directly to either DIN socket on TSA. The unit is free standing or may be held in a clamp stand. It also can be positioned upside down to measure the period of a simple pendulum.
Our free standing Light Gate Transmitter and Receiver are available for users wishing to operate with larger distances between the transmitter and receiver.

9.8

You have done your experiment to measure acceleration due to gravity and you don't get the magic number 9.8 — why not ? Where are the errors? Since the microprocessor inside TSA gives very accurate measurements of time, why are the results not perfect ?
Below are a number of suggestions which may help to minimize errors:-

- measure the size of the mask accurately,
- make a number of measurements with the mask inverted, i.e. the leading edge becomes the trailing edge,
- use a narrow parallel beam of light,
- drop the mask vertically,
- release the mask as close to the detector as possible in order to reduce the size of the shadow,
- release the mask from just above the detector in order to minimize possible air resistance effects.

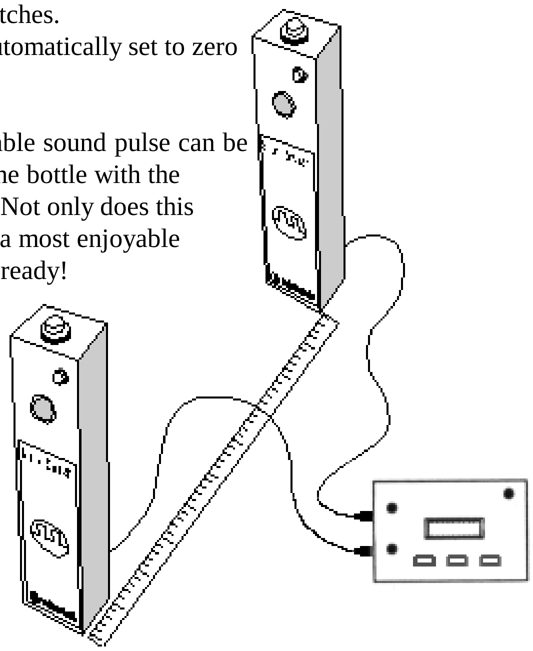
Measuring the Speed of Sound

TSA can be used to measure the speed of sound. A typical setup using **djb microtech's** Sound Switches is shown below.

It is important to adjust the switches to be as sensitive as possible. Users are referred to the instruction sheet supplied with the Sound Switches - this is available to download from the Teachers' Section of our website.

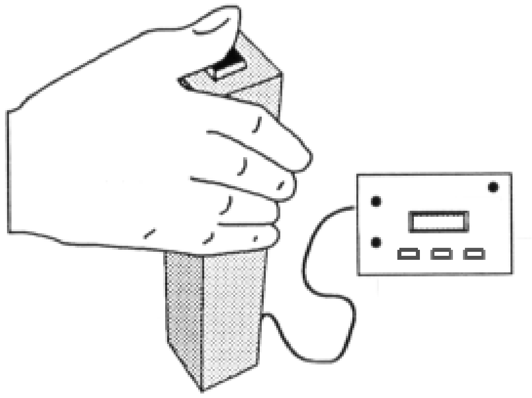
The speed of sound is calculated by measuring the distance between the sound switches and then using the Fast Timer to time how long it takes to travel between the switches.
Note that the debounce time is automatically set to zero when using the Fast Timer.

A suitably fast rising and repeatable sound pulse can be produced by hitting an empty wine bottle with the plastic handle of a screw driver. Not only does this fascinate the pupils but it can be a most enjoyable experience getting the apparatus ready!



Speed of Sound using **djb microtech's** Sound Switches

Measuring Reaction Time

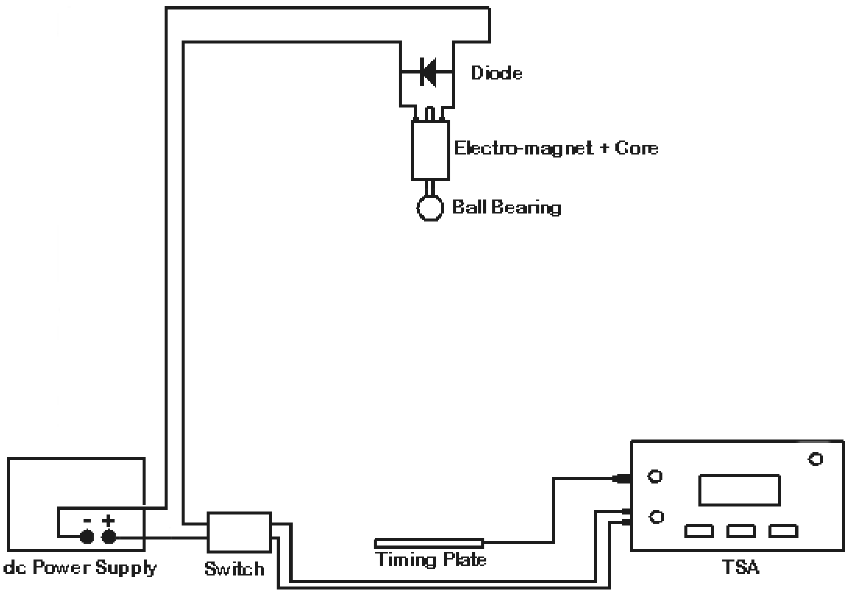


In this experiment we use two Reaction Timer Switches. One student presses their switch which causes a red LED to come on and start the clock. The other student, whose reaction time is being measured,presses their switch as soon as they see the LED light up. This stops the timer.

- Connect the DIN plug from each Reaction Timer Switch to the DIN sockets on TSA.
- Switch on TSA.
- Press the switch connected to channel 0 and check that LED 0 illuminates on TSA.
- Repeat for channel 1.
- Select Gap Time using the Select button on TSA. Note that when using the Gap Timer the software waits for an event on one channel and then waits for another event on the other channel. Hence any switch bounce is ignored.
- Press the GO button when ready.
- A pupil, who is the starter, presses their switch when ready. Another pupil whose reaction time is being measured presses their switch immediately the red LED comes on.
- Press GO to repeat the experiment.

The Falling Ball Experiment

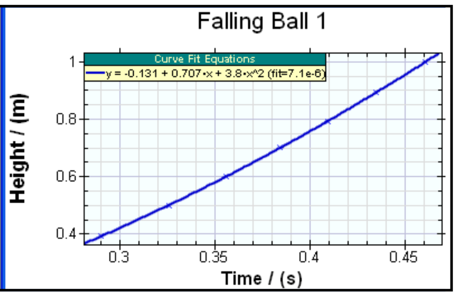
A little care is required in performing this experiment.



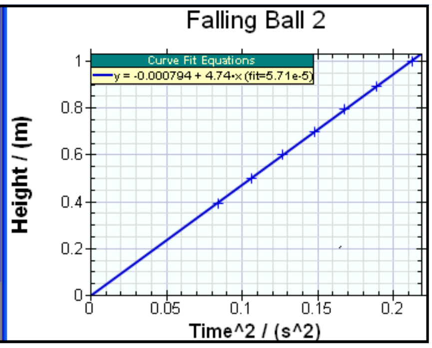
The switch used is a double pole, single throw - djb code A1-1035.00. Adjust the power supply so that the ball bearing is just held by the electro magnet. In this way any residual magnetism effects will be kept to a minimum.
The leads should be long (about 1 metre) to keep the switch and electro-magnet a good distance from TSA. If this is not done then magnetic effects may cause spurious triggering.
The diode used is a general purpose one - typically a 1N4001 would do nicely.
Set TSA up to measure the Gap Time. When the switch is moved to the off position the ball is released and the timer starts because there is a change in state of an input. The Timer now looks at the other input and waits for a change in state caused by the ball bearing hitting the timing plate.
An alternative method for carrying out this experiment is now available and it uses the Falling Ball Release Mechanism - it removes the requirement for an electromangnet.
See our website www.djb.co.uk/ppm_falling_ball_release.html

Typical Results from Falling Ball Experiment

notes	Time s t	Height m s	Use Data Points
1	0.461	1.00	use
2	0.434	0.89	use
3	0.409	0.79	use
4	0.384	0.70	use
5	0.356	0.60	use
6	0.326	0.50	use
7	0.289	0.39	use



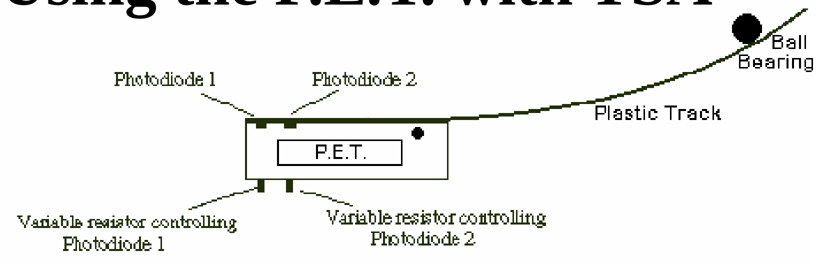
notes	Time s t	Height m s	Time^2 s^2 t2
1	0.461	1.00	0.212
2	0.434	0.89	0.189
3	0.409	0.79	0.167
4	0.384	0.70	0.147
5	0.356	0.60	0.127
6	0.326	0.50	0.106
7	0.289	0.39	0.084



The slope of the s/t^2 graph is a/2 and the results from this experiment give a value of the acceleration due to gravity as 2 x 4.74 i.e. 9.48 m/s^2.

The above tables and graph were obtained using the ALBA software, a version of which is freely available to download from www.djb.co.uk.

Using the P.E.T. with TSA



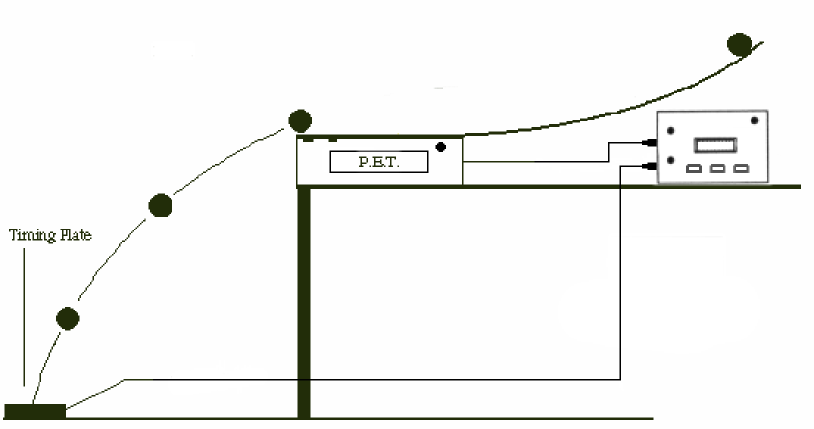
The Projectiles, Energy & Timing (P.E.T.) device consists of a flexible plastic track connected to a box containing two photo diodes mounted 20mm apart at the very end of the track.
The P.E.T. device allows pupils to investigate numerous aspects of motion including energy conversion, projectiles, and 'g'.
Before using your P.E.T. device you will have to adjust it so that the photodiodes switch properly for the light level in your lab. A full description on how to do this is given in the P.E.T. manual - a copy of which can be downloaded from the Teachers' Section on our website. Your attention is drawn to the Quick Setup which is by far the easiest way of ensuring that your P.E.T. is working properly.

The two photodiodes are 20 ± 1 mm apart. When the leading edge of the ball bearing covers the first photodiode it causes an event and the clock in TSA is started. The trailing edge of the ball bearing is ignored. When the leading edge cuts the second photodiode another event is created and the time on the clock is noted.
Knowing the time to cover the 20 mm the velocity at the end of the track can be calculated. To measure the horizontal launch velocity use the Fast Timer in TSA. Do not use the Event timer as its resolution is not nearly as good as the Fast Timer.

Possible Experiments/Investigations

- Height and launch velocity
- Potential and kinetic energy
- Launch height and time of flight.
- Release height and time of flight
- Calculation of 'g'
- Launch velocity and range.
- Comparison of experimental and theoretical time of flight.
- Comparison of experimental and theoretical range

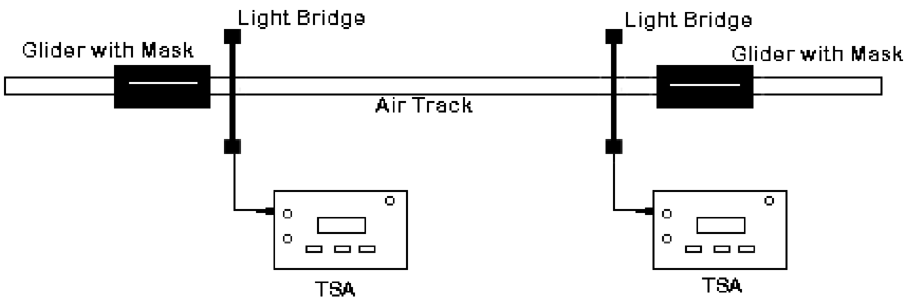
Time of Flight



To measure the time of flight then you must position the Timing Plate so that the ball bearing leaves the end of the plastic runway and hits the plate.
TSA must be set up to measure three Event Times. Subtracting Event Time two from Event Time three gives the time of flight.
Note: If you wished the horizontal launch velocity and the time of flight you would have to do this in two steps releasing the ball bearing from the same place each time. This is because the Fast Timer measures only two events and the resolution of the EventTimer is not sufficient for timing over the 20mm.
The results of numerous experiments are given in the P.E.T. manual which can be downloaded from the Teachers' Section of our website.

Measuring Momentum

Consider the situation where you wish to show the conservation of linear momentum at an elastic collision between two equal masses. The simplest way of carrying out this experiment is to set up two TSAs and two Light Bridges.



Do a trial run to show that each light bridge will be cut twice. Set up each TSA to measure two velocities. The data simply falls out in front of the students with the minimum of calculation being involved. Once the basic operation is understood different masses can be used.

Portability

Using our PP3 Battery Lead it is possible to operate TSA without a laboratory power supply. This could lead to interesting experiments being tackled outside the laboratory.

The current drain of TSA with a **djb microtech** Light Bridge connected is < 25mA.

It is quite possible to operate TSA with a Unilab light gate with a large 9V battery but this will place a much heavier demand on your battery. This problem can be circumvented by using a '6 pack' AA cell holder instead of a large 9V battery.

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Teaching with TSA

TSA is a very powerful and easy to use instrument which produces answers quickly. However, before pupils have access to this instrument they should have a basic understanding of the Physics principles involved e.g.

- speed = distance/time
- acceleration = change in velocity/time for the change

Once the basics are understood and pupils can operate TSA confidently then they can start investigating and exploring their world:-

- Do heavier objects have a greater acceleration?
- Is the acceleration up and down the slope the same ?
- What is the effect of the type of surface on the final speed ?
- How is the acceleration of a radio controlled car affected by battery usage ?

Additional ideas for using TSA are on our website at **www.djb.co.uk**.

Technical Information

Plug top supply voltage 9-12 V DC - centre positive.
Digital inputs protected to 15 V.
Digital inputs protected against reverse polarity.
The two digital inputs are TTL compatible i.e.

0 - 1 V (approx.) is logic 0
3 - 5 V (approx.) is logic 1.

With a Light Bridge connected the input is held high.
The red LED is off when an input is taken low.

Time Intervals and Event Times have been rounded to three decimal places.
With the debounce delay set to zero the minimum time between events is < 50 µs.
Speeds have been rounded to 2 decimal places.
The error in the Fast Timer is between -0.02 ms and +0.01 ms
The maximum Time interval is 999.99 s.
The maximum time between events is 999.99 s.
The Gap Time range is 0 — 999.999 s.

Associated Equipment

From **djb microtech ltd**:-

Light Gate cable for Unilab Slave Light Gate B1-1000.40
Light Bridge B1-1000.35
Light Gate Receiver B1-1000.30
Light Gate Transmitter B1-1000.25
DPST Switch for 'g' by free fall A1-1035.00
Reaction Timer Switches B1-1000.10
Sound Switches B1-1000.05
Timing Plate B1-1000.16
Projectiles, **E**nergy and **T**iming apparatus B1-1000.12