djb microtech ltd
www.djb.co.uk

Projectiles
Energy
Timing

Items Supplied

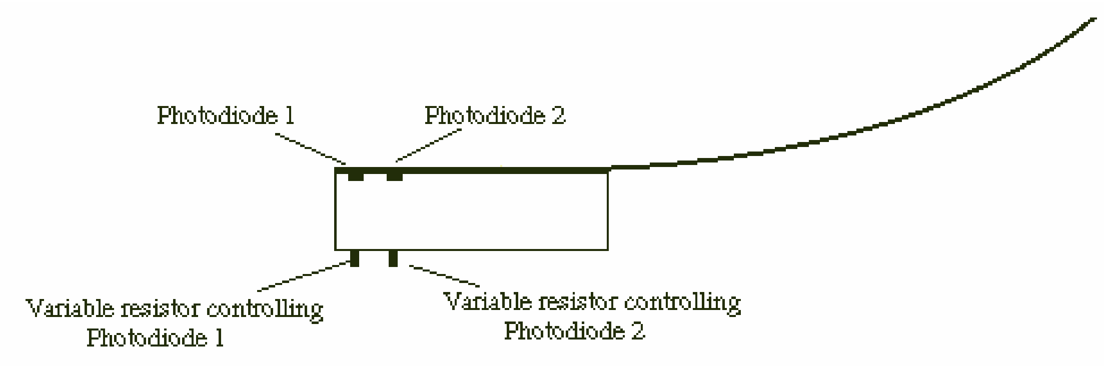
Your P.E.T. device is supplied with the following:
Ball Bearing
G Clamp

Additional apparatus required :

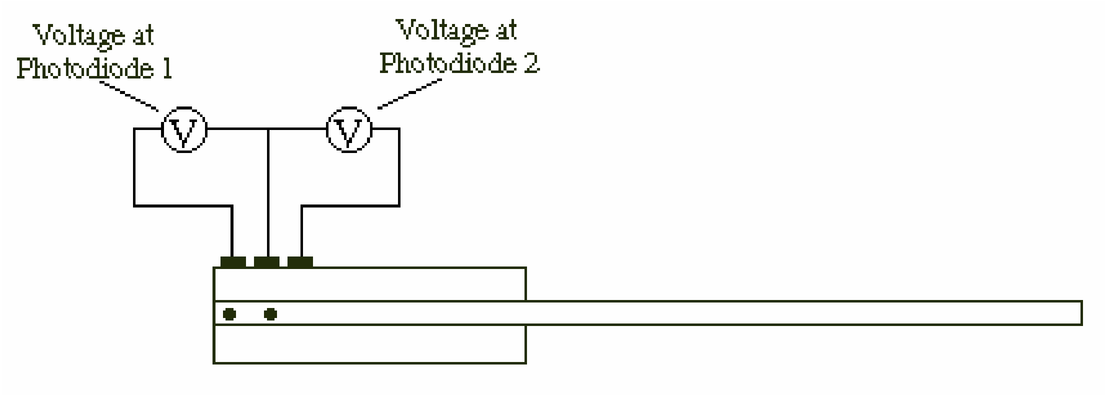
TSA or ALBA Interface and Logger
Timing Plate

How the Apparatus is used:

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. **Place a 12V, 24W car headlamp bulb approximately 75 cm above the photo-diodes It is strongly recommended that you work away from bright sunshine at the windows and ensure that no shadows are being cast which will affect the operation of the P.E.T. device.**
Place the P.E.T. device so that the label is facing you. Connect the cable to the socket at the back of TSA or ALBA and power the unit. The voltage at the photodiode furthest to the left (i.e. the edge of the track) is controlled by a variable resistor underneath – see figure below.



Connect a voltmeter to measure the voltage at photodiode 1 – see the figure below - and adjust the variable resistor using a screw driver, so that the voltage is between 2.0 and 2.5 V. While you are doing this it is important to keep the photodiodes pointing towards the light source – this is a little awkward at first but with care you will manage. In a similar way set the voltage on the second photodiode.



Checking that your P.E.T. device is set up properly.

If the power to TSA/ALBA is on and you have just adjusted the photodiodes then re-power the unit. The red LED on the front of your P.E.T. device should come on. Run a ball bearing along the track and you should see the LED on the front of the P.E.T. device go off when it goes over the first photodiode and then come on again when it runs over the second photodiode. Alternatively you can watch the front of TSA/ALBA and you should see its LED pulse on then off. *You should only start an experiment when the LED on the front of your P.E.T. device is on.* If it is not on then cover each photodiode in turn until it comes on or re-power TSA/ALBA. If it still does not come on then your photodiode voltage level needs to be adjusted.
Be aware that shadows may trigger the photodiodes so it is best not to lean over the apparatus during an experiment.
Use a spirit level to ensure that the P.E.T. device is level after it has been clamped onto a table/bench.

Quick Setup

Once you understand how the P.E.T. device operates you might find this alternative method for setting up attractive. Connect the P.E.T. device to ALBA/TSA and power the unit. Now take a 12V, 24W bulb and mount it in a clamp stand above the photo-diodes. Adjust the height of the lamp so that the red LED is on and putting your finger over one of the photo-diodes causes the LED to go off then putting your finger over the other photo-diode causes the LED to come on again. Adjust the height of the lamp until this situation is obtained. If this does not work for you then the variable resistors on the base of the unit may be up against the end stop. If this is the case, looking directly at them, turn them fully anti-clockwise and then turn back 30-45 degrees. If you still experience difficulties then you must resort to using a voltmeter as outlined above.

How it Works

The two photodiodes are 2 ± 0.1 cm apart. When the leading edge of the ball bearing covers the first photodiode it causes an event and the clock in ALBA/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 2 cm the velocity at the end of the track can be calculated.

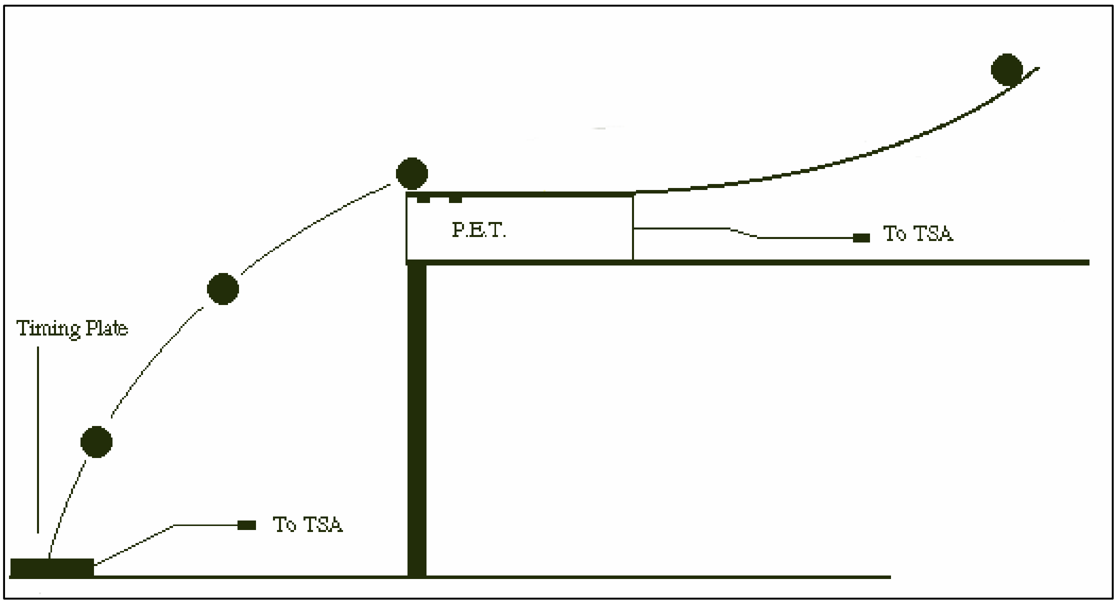
Possible Experiments/Investigations

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

It is hoped that teachers will select from the above a few experiments which are appropriate to their courses. Some guidance on performing these experiments follows:

Guidance on Experiments

A typical setup is shown below:



Definition of terms:
Release Height: this is to be interpreted as the vertical height the ball falls through before being launched from the end of the track.
Launch Height: this is the height from the end of the track to the top of the Timing Plate.
Before starting any of the experiments below :

- check that your P.E.T. device is operating properly for the light level in your lab.
- clamp the unit to a bench and support the end of the track using a clamp stand.

It is assumed that bench/table surface is horizontal. If it is felt necessary to check this then use a spirit level.

At the start of every experiment the red LED on the P.E.T. device must be on.

On the following pages are typical results from a few experiments – please note ALBA/TSA only gives the times in the tables, other quantities are measured or calculated.

Experiment 1 –Release height and launch velocity

- Set TSA to the Fast Timer mode. In this mode TSA can only measure two events and the debounce time is automatically set to zero. If you are using ALBA then use the Fast Timer set to measure two events with zero debounce time.
- Place the ball bearing on the track and measure the release height.
- Release the ball and find the time for the ball bearing to cover the 2 cm between the photodiodes. Now calculate the launch velocity using distance/time. Repeat for different release heights.
- Draw a graph of launch velocity against release height and determine the relationship.

Typical results:

Release Height (m)	Time (s)	Launch Velocity (m/s)
0.21	0.014	1.43
0.44	0.01	2.0

Experiment 2 - Potential and kinetic energy

- Find the mass of the ball bearing or alternatively you may simply call it one unit..
- Set TSA to the Fast Timer mode. In this mode TSA can only measure two events and the debounce time is automatically set to zero. If you are using ALBA then use the Fast Timer set to measure two events – note that the debounce time is automatically set to zero.
- Place the ball bearing on the track and measure the release height. Release it and find its speed at the bottom of the ramp. Calculate the E_p and E_k in each case and compare them.

It should be noted that some of the initial potential energy will be changed to rotational kinetic energy as the ball bearing rolls down the track.
Typical Results:

Release height = 0.44 m, Mass of ball = 1 unit

Release Height (m)	Time (s)	V_H(m/s)	E_P	E_K
0.21	0.014	1.43	2.06	1.022
0.44	0.01	2.0	4.316	2.0

Some potential energy has been lost to sound, heat and rotational kinetic energy.

Experiment 3 - Launch height and time of flight.

For this experiment you will need the Timing Plate. In this experiment the ball bearing is always released from the same height above the bench but from different height of benches. In reality the different bench heights could be obtained by mounting the P.E.T. device on a wooden board then place the board at various heights. A certain amount of preparatory work will be required here to produce a workable and safe experimental setup.

- ALBA/TSA should be set to measure three events with zero debounce time. When the ball bearing hits the Timing Plate it produces a pulse. Subtracting the time of the second event from the third gives the time of flight. Pupils, depending on their previous knowledge, may be unaware that the time of flight is independent of the launch speed and therefore the release height is perceived as a variable which they should keep constant.
- If sufficient heights are used then draw a graph of Launch height / Time of flight. If desired , a value of 'g' could be extracted from the data.

Typical Results:

Launch Height (m)	t1 (s)	t2 (s)	Time of Flight (s)
0.88	0.014	0.443	0.429
1.00	0.01	0.467	0.457
1.40	0.01	0.550	0.540

Experiment 4 - Release height and time of flight.

For this experiment you will need the Timing Plate. In this experiment the ball bearing is released from different heights above the bench and the corresponding time of flight noted.

- Use the Event Timer mode in ALBA/TSA and set it to measure three events.
- Place the ball bearing on the track and measure its release height.
- When the ball bearing hits the Timing Plate it produces a pulse. Subtract the time of the second event from the third event and find the time of flight.
- Repeat for different release heights.

Typical Results:

Release Height (m)	t1 (s)	t2 (s)	Time of Flight (s)
0.21	0.014	0.443	0.429
0.44	0.009	0.437	0.428

Experiment 5 - Calculation of 'g'.

In this experiment it is assumed that the pupils have a knowledge of the equations of motion, in particular $s = ut + ½at^2$ and that they are aware that the time of flight is independent of the horizontal launch speed.

- ALBA/TSA should be set to measure three events with zero debounce time.
- When the ball bearing hits the Timing Plate it produces a pulse. Subtract the time of the second event from the third and obtain the time of flight.
- The time of flight is the same as the time it takes to fall the vertical height from the track on the P.E.T. device to the top of the Timing Plate. Measure this height.
- Substitute your values for s and t in the above equation (u=0) and calculate a value for 'g'.

Typical Results:

Release ht (m)	Launch ht (m)	t1 (s)	t 2 (s)	Time of Flight (s)
0.21	0.88	0.014	0.443	0.429
0.44	0.88	0.009	0.437	0.428

The above readings give values of 'g' as 9.56 m/s^2 and 9.65 m/s^2.

Experiment 6 - Launch velocity and range.

- Set ALBA/TSA to measure 2 event times using the Fast Timer mode (note TSA can only measure two event times in this mode).
- Select your first release height and do a 'dummy' run to find out where to position the Timing Plate so that the ball bearing hits it near the middle. Now do the experiment and carefully measure from the point where the ball bearing hits the Timing Plate to a point vertically below the end of the track – use a plumb line to help you.
- Calculate the horizontal launch velocity using distance/time where the distance is 2 cm.
- Repeat the experiment using different release heights.
- If sufficient results are obtained then draw a graph of Range/Launch velocity.

It might be interesting to ask the pupils what they would have to do to double the range of a projectile. Then ask what the release height would have to be to double the launch velocity.

Typical Results:

Release ht (m)	Launch ht (m)	t1 (s)	V_H=d/t1	Range (m)
0.21	0.88	0.013	1.54	0.66
0.44	0.88	0.009	2.22	0.83

Experiment 7 - Comparison of experimental and theoretical time of flight.

In this experiment it is assumed that the pupils have a knowledge of the equations of motion, in particular $s = ut + \frac{1}{2}at^2$ and that they are aware that the time of flight is independent of the horizontal launch speed.

- ALBA/TSA should be set to measure three events with zero debounce time.
- When the ball bearing hits the Timing Plate it produces a pulse. Subtract the second event time from the third and find the time of flight.
- The time of flight is the same as the time it takes to fall the vertical height from the track on the top of the P.E.T. device to the top of the Timing Plate. Measure the vertical height through which the ball falls.
- Using the above equation ($g=9.8\ m/s^2$ and $u=0$) calculate the theoretical time of flight. Calculate the percentage error in the measured value.
- The experiment may be repeated for different launch heights.

Typical results are:

Launch height = 0.88 m.
Using the equation $s= \frac{1}{2}at^2$ the calculated time to fall 0.88m is 0.424 s.
From the table in Experiment 6 the measured time to fall 0.88m is 0.429 s

Release ht (m)	Launch ht (m)	t1 (s)	t2 (s)	Time of Flight (s)
0.21	0.88	0.013	0.443	0.430
0.44	0.88	0.009	0.437	0.428

Experiment 8 - Comparison of experimental and theoretical range.

In this experiment it is assumed that the pupils have a knowledge of the equations of motion, in particular $s = ut + \frac{1}{2}at^2$ and that they are aware that the horizontal component of velocity is constant throughout the flight.

- Set ALBA/TSA to measure 2 event times using the Fast Timer mode (note TSA can only measure two event times in this mode).
- Select the release height and do a 'dummy' run to find out where to position the Timing Plate so that the ball bearing hits it near the middle. Now do the experiment and carefully measure from the point where the ball bearing hits the Timing Plate to a point vertically below the end of the track – use a plumb line to help you.
- Using the above equation ($g=9.8\ m/s^2$ and $u=0$) calculate the theoretical time of flight and multiply this by the horizontal velocity (2cm/time) to find the theoretical range. Note that the vertical height is from the top of the Timing Plate to the launch point on the P.E.T. device.
- Calculate the percentage error in the measured value of the range.
- The experiment may be repeated releasing the ball bearing from different points on the track.

Typical Results:

Release ht (m)	Launch ht (m)	t1 (s)	t2 (s)	Time of Flight (s)	V_H=d/t1	Measured Range (m)
0.21	0.88	0.013	0.443	0.430	1.54	0.66
0.44	0.88	0.009	0.437	0.428	2.22	0.83

With a horizontal launch velocity of 1.54 m/s and a time of flight of 0.430 s this gives a theoretical range of 1.54 x 0.430 = 0.66 m. The measured value was 0.66m.

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djb microtech ltd, Delfie House, 1Delfie Drive, Greenock, Scotland, PA16 9EN
Phone/Fax: 01475 786540, Email: info@djb.co.uk, Website: www.djb.co.uk