Time Speed Acceleration Manual V3

Introduction

Welcome to Time - Speed - Acceleration. This manual is a comprehensive guide to the use of this versatile measuring instrument. There is an on-line copy of this manual in the Teachers section of our website.

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 (8)

d) measure gap time (1)

e) measure speed (4)

f) be used to develop the concept of acceleration (v1, v2, dt)

g) measure acceleration (2)

Getting Started

On the left hand side of TSA there are two digital input channels labelled 0 and 1. Each input can be via the DIN sockets or the 4mm sockets. Switches and light gates may be connected to these inputs. The DIN sockets are capable of supplying power to our light gates, sound switches etc.

Please note that no external voltage should be applied to the 4mm sockets.

Connect the 9V, 0.66A DC plugtop power supply supplied with TSA.

After the splash screen display you will see a screen which has the layout shown. Keep tapping the Select Button and explore the different modes. Stop when you get back round to the Interval Timer – do not press Enter just yet.

To try out the TSA, connect a djb Light Bridge or Light Gate to either of the digital inputs. If you do not have a Light Bridge or Light Gate then connect two 4mm leads to one of the digital inputs – touching the leads together should cause the LED on the front panel to go on.

In the next section a description of the Interval Timer is dealt with in most detail since other modes are very similar.

Time Interval

This mode measures the length of time a light beam has been cut or a switch closed. It is ideal for measuring the length of time a mask on a trolley takes to cut a light beam.

Select Interval Timer then tap Enter.

- Follow the instructions on the screen and select to measure one Time Interval by tapping the '1'
- Now tap the Enter button.
- When you are ready to start the experiment press the GO button.
- The screen displays "Waiting". TSA is now waiting for an event to happen so that it can start its internal clock.
- Move a card very slowly through the beam of your Light Bridge. The LED should switch off as the beam is cut then back on again as the beam is re-established. If you are using two wires connected to the 4mm sockets, instead of a Light Bridge, then touch them firmly together, pause, then separate them.
- The time interval will be displayed on the screen.
- Touch GO again and repeat the experiment.
- After you have repeated the experiment several times tap Select and again select Time Interval but this time set TSA to read three Time Intervals.
- Proceed in a similar fashion as before but note that the Waiting message is displayed until all three time intervals have been measured.
- To see all three time intervals, keep tapping Display.

Note: It is recommended that this mode should be restricted to times greater than 10ms.

Important

An Event is simply a change in state of an input. To measure a time interval there must be two 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 closing a switch connected to an input, the contacts tend to bounce very quickly, generating many events. To get around this problem the software waits for a few milliseconds after an event and 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, that can be measured, to the length of the debounce delay. The default debounce delay is set at 4ms. A minimum time interval measurement of 4ms should not impose too many restrictions on general classroom work. However, for users having specialist requirements see the section on Changing the Debounce Delay.

Similarly as in the Interval Timer mode it is recommended that this mode should be restricted to times greater than 10ms.

The time interval is rounded to three decimal places.

General Timer

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 input channel on which the event happened is displayed along with the time.

The General Timer is set up in an identical fashion to the Interval Timer. If you wish to measure two timing intervals then you would set the General Timer for 4 event times.

The General Timer is the most versatile 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 four 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.

Gap Timer

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 that 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. The trailing edge is ignored.
This mode could find application in the teaching of average speed — set two light gates a known distance apart and use Gap Time to measure the time for the trolley to travel this distance. This mode is also extremely useful in measuring 'g' by freefall where switch bounce could cause problems if you are using an electromagnet – see later in manual.

Fast Timer

The setup for this mode is similar to the General Timer.
This mode can be used to display a time interval between 10µs and 99,999ms. Trying to measure an interval larger than the maximum causes the error message "Too big" to be displayed.
The Fast Timer displays the time in microseconds up to 10000us and for times greater than that it displays in milliseconds to two decimal places. The fast timer should be used for times up to 150ms.
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. It also can be used with the Projectiles, Energy & Timing apparatus as well as the Energy Track. A maximum of eight Fast Times can be recorded.
**Important:** On selecting this mode the debounce delay is automatically set to zero and it is returned to its original value on exit.

Guidance on selecting the appropriate timer is given in Appendix 1.

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.

- Select the Speed mode then press Enter.
- Select the size of your mask in centimetres. Note that each time the '+' button is pressed the distance increments in 1 cm steps until 10 cm and then in 10 cm steps until 300 cm. Holding down the '+' button results in a rolling display.
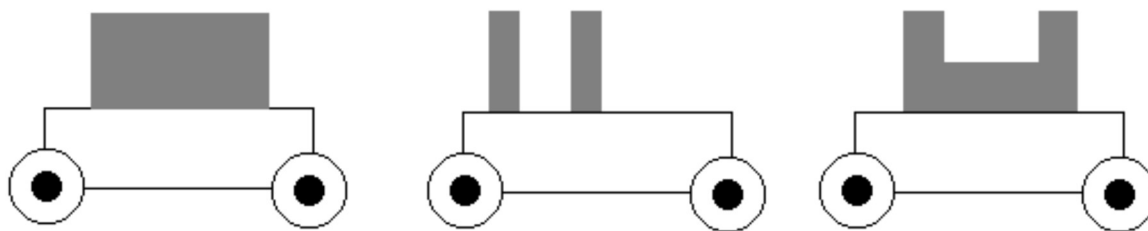- Enter your mask size.
- GO when ready.
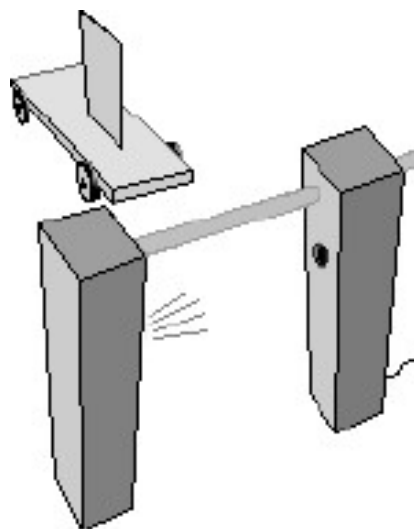
Important

If very fast speeds are to be measured then the debounce delay must be changed to zero. Bounce-free switches or light gates must be used.

Acceleration Data and Acceleration

The setup for these modes is identical to Speed. However, there are several possible mask arrangements:

Masks may be attached to the trolley with masking tape or Blu Tack.

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. In addition, they must be a whole number of centimetres.

The Acceleration Data 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, the acceleration can be calculated. 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 Acceleration Mode for investigative work.

In the Acceleration mode, only the acceleration is displayed. The setup is identical to the Acceleration Data mode.

The following notes may be helpful:

Suppose you use a light gate and a trolley with a double mask and each leg of the mask is 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)

Important Note: If you want to measure the acceleration due to gravity then it is strongly recommended that you drop a single mask through two light gates. Using a double mask will give less accurate results. A 1mm variation in length between the two legs of the mask results in a surprisingly large change in acceleration.

Changing the Debounce Delay

Switch bounce may cause problems when you are trying to measure events. Consequently a default debounce delay of 4 ms has been designed into TSA. This does NOT mean that there is an error of 4 ms in the timing. After an event, 4 ms will elapse before the inputs are again examined to await the next event. During these 4ms the switch should settle and stop bouncing. If an event happens during these 4 ms then it would be missed! In most school experiments a 4 ms debounce delay will not cause problems. However the user can change this delay in the range 0 - 100 ms.

To change the debounce delay
- Select Change Debounce then tap Enter.
- Scroll through the values and Enter 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 4 ms is set at switch on. If you change the debounce time then the new value will remain until the unit is switched off or another value is entered.

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. This enables large objects to cut the beam e.g. radio controlled cars, bikes … Note that the Light Gate Receiver operates using infrared. This means that the unit is unaffected by ambient light and therefore will operate satisfactorily near a window.

Note that using a laser to obtain a large distance between transmitter and receiver will not work.

9.8

You have done your experiment to measure acceleration due to gravity by dropping a double mask through light gates 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,
- 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 Reaction Time
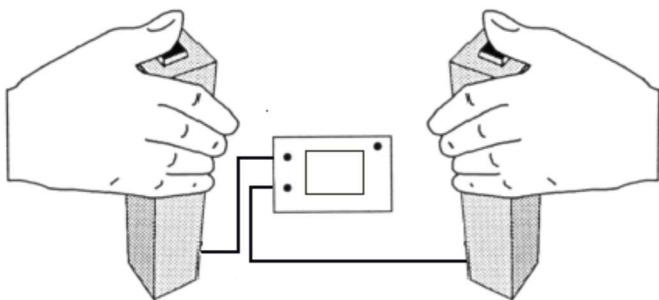
In this experiment we use two Reaction Timer Switches. One student presses their switch which causes an LED to come on and start the clock. The other student, whose reaction time is being measured, presses their switch as soon as they see the LED light up. This stops the timer.

- 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 Timer. Note that when using the Gap Timer the software waits for an event on one channel and then waits for the second 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 as soon as the LED comes on. Note that if the pupil whose reaction time is being measured,' jumps the gun' then the starter must press their switch and the result is ignored.
- Tap GO to repeat the experiment.

One of the switches can be replaced with our **foot switch**. This will lead on nicely to discussions on stopping distances in cars.

For further investigative work you could replace one of the switches with a Sound Switch. If a loud sound is made in front of the Sound Switch then the reaction time using sound can be measured and compared with previous results

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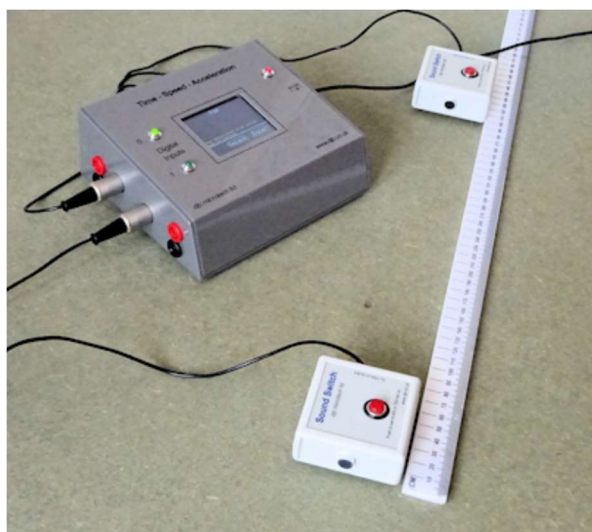
TSA can be used to measure the speed of sound. A typical setup using djb **microtech's** Sound Switches is shown.

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 sound to travel between the switches. The speed is then calculated using v=d/t. Once pupils understand how the speed is obtained then it can be measured directly. This done by setting the debounce time to zero (see Changing the Debounce Delay) then using the Speed mode.

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!

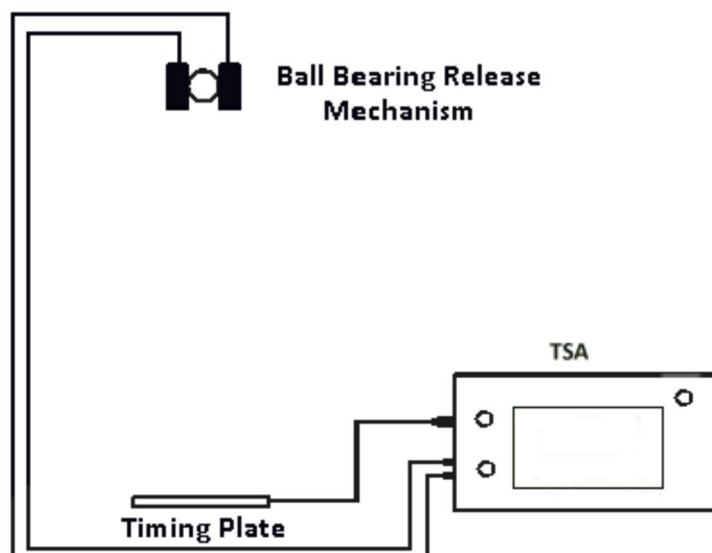## The Falling Ball Experiment ('g' by freefall)

Select the Gap Timer mode. When the release mechanism is opened electrical contact is broken and the clock starts because there is a change in state at 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.

The value of 'g' can be calculated using the equation:
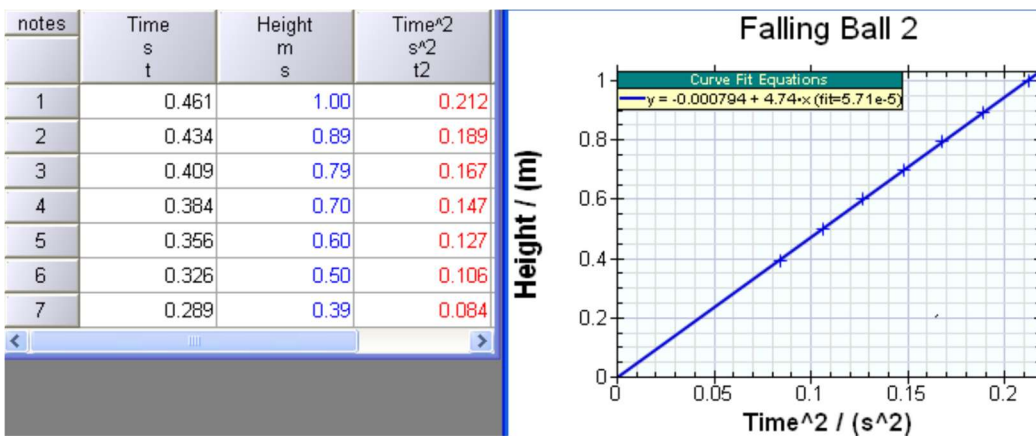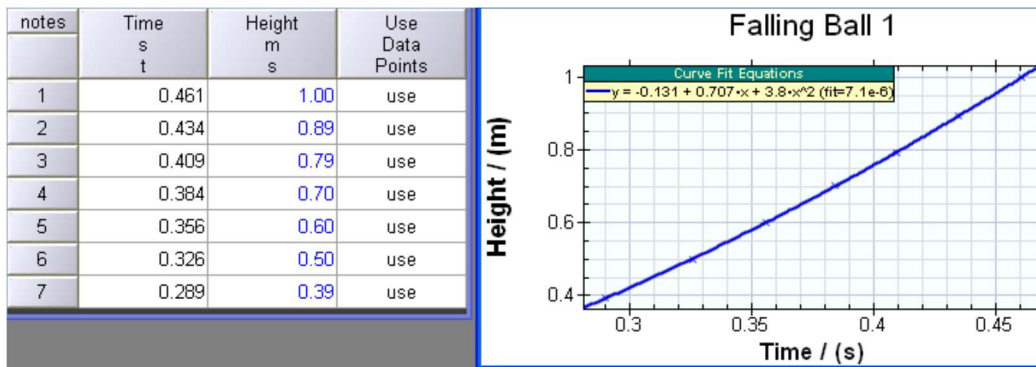
$$s = \tfrac{1}{2}\ gt^2$$

Alternatively the ball can be dropped from different heights and a table built of heights and times. Drawing a graph of displacement against time squared gives a straight line with a gradient of g/2

Typical results for this experiment are shown on the next page.

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

Falling Ball 1

Curve Fit Equations
$y = -0.131 + 0.707 \cdot x + 3.8 \cdot x^2$ (fit=7.1e-6)

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

Falling Ball 2

Curve Fit Equations
$y = -0.000794 + 4.74 \cdot x$ (fit=5.71e-5)

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 = 9.48 m/s^2.

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

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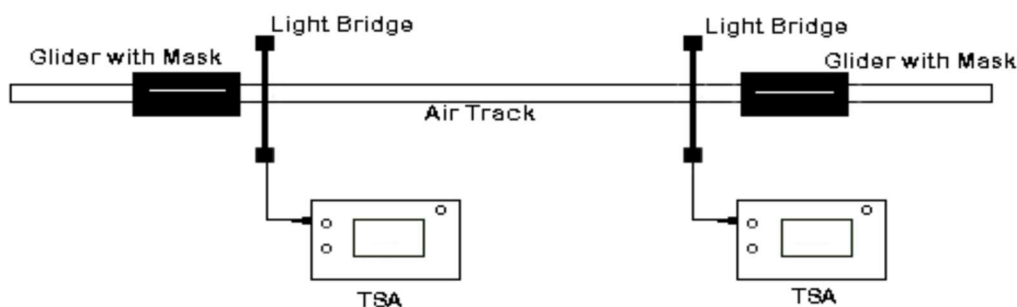
Do a trial run to show that each light bridge will be cut twice. Set up each TSA to measure two velocities. The data simply falls out in front of the students with the minimum of calculation being involved. Once the basic operation is understood, gliders of different mass can be used.

The Energy & Projectiles Track
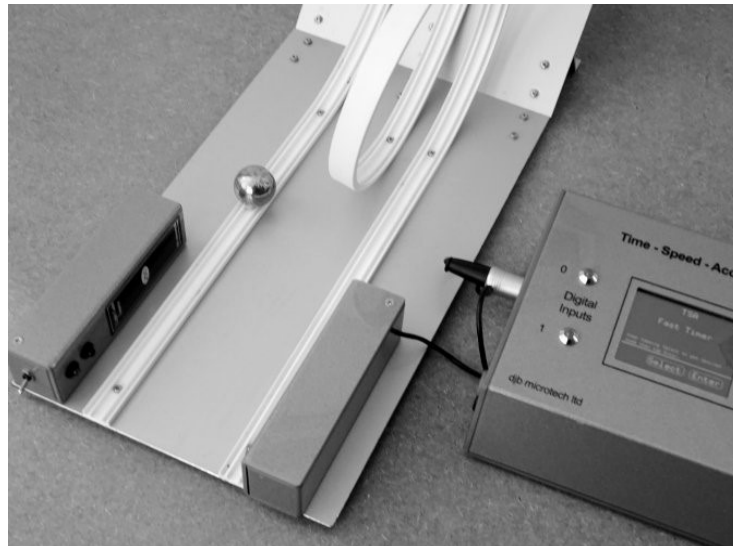
The Energy Track comprises two plastic tracks that run down a fixed slope and then along a horizontal section. A ball bearing placed on the slope will run down it and cut a light gate at the end of the track.

The numbers on the slope are the vertical heights in centimetres above the top of the horizontal track. This makes it very easy for students to accurately determine potential energy. A one inch diameter ball bearing has its centre in line with the centre of the light beam, making the setup very straight forward. Using TSA in the Fast Timer mode the time (in ms) for the ball bearing to cut the beam at the end of the track can be measured and hence the velocity calculated. If the track is placed at the end of a bench then, with the addition of our Timing Plate, projectiles can also be studied.

Many experiments are possible:

- comparison of potential energy with linear kinetic energy - see table below
- comparison of potential energy with linear kinetic energy + rotational kinetic energy
- minimum potential energy required for ball to loop the loop
- comparison of speed of ball bearing at the end of both tracks when released from the same height
- comparison of time of flight of projectile with calculated time
- comparison of theoretical projectile range with actual range
- calculation of 'g'

notes	ht cm h	time ms t	velocity m/s (A) v	v^2 (m/s)^2 (A) v2	Ep mJ (A) Ep	Ek mJ (A) Ek	Er mJ (A) Er	Etotal mJ (A) Et
1	10.5	21.44	1.18	1.40	69.2	47.0	18.8	65.8
2	10.5	21.33	1.19	1.42	69.2	47.5	19.0	66.5
3	10.5	21.27	1.19	1.43	69.2	47.8	19.1	66.9
4	12.5	19.38	1.31	1.72	82.4	57.5	23.0	80.6
5	12.5	19.50	1.30	1.70	82.4	56.8	22.7	79.6
6	12.5	19.48	1.30	1.70	82.4	57.0	22.8	79.7
7	14.5	18.11	1.40	1.97	95.5	65.9	26.4	92.3
8	14.5	18.12	1.40	1.96	95.5	65.8	26.3	92.2
9	14.5	18.07	1.41	1.98	95.5	66.2	26.5	92.7
10	16.5	16.77	1.51	2.29	108.6	76.9	30.7	107.6
11	16.5	16.80	1.51	2.29	108.6	76.6	30.6	107.2

Table of results showing Ep, Ek and Er

Note that if the leading edge of the ball is placed at the 20cm mark on the scale then the centre of mass is a little higher. Further information is in the product notes http://www.djb.co.uk/pdfs/Physics%20pdfs/Energy%20Track.pdf

Portability

Ideally TSA should be operated using the 9V DC plugtop power supply supplied with TSA. However, it can be operated using our a '6 pack' AA cell holder (http://www.djb.co.uk/ppm_battery_box.html). Rechargeable batteries are recommended as the current drain is significant due to the demands of the screen.

Teaching with TSA

TSA is a very powerful and easy to use instrument that 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?
- Does acceleration up and down the slope have the same magnitude?
- 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/m_teachers.html.

Technical Information

Plug top supply voltage 9V DC - centre positive.

The current drain of TSA with no external devices connected is 82mA.

Maximum current that can be supplied to external devices e.g. Light Bridge should be restricted to less than 100mA.

There is an internal resettable fuse rated with a trip current of 600mA.

Digital inputs protected against accidental reverse polarity. Note that external voltages should not be connected to the digital inputs.

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.

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 10 ms.

Speeds have been rounded to 2 decimal places.

The uncertainty in the Fast Timer from 0 to 10000us is ±2 and for times greater than this the uncertainty is ±1ms.

The shortest time between changes in state of the inputs using the Fast Timer is 10us.

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

Light Bridge B1-1000.07
Light Gate Receiver B1-1000.30
Light Gate Transmitter B1-1000.26
Reaction Timer Switches B1-1000.10
Foot Switch, B1-1000.09
Sound Switches, B1-1000.06
Timing Plate, B1-1000.16
Release Mechanism , B3-1120.00
Energy and Projectiles Track, B1-1000.50
Battery Box for TSA/ALBA, B1-1000.22

Appendix 1 – Selecting the Appropriate Timer

TSA has 4 timing modes and the notes below give guidance on which mode to select.

Interval Timer: measures the time between events 1&2, 3&4, 5&6 and 7&8. It is suitable for use with gliders on air tracks and a vehicle on a runway. Resolution is 1/1000 th of a second and there is an uncertainty of ±1 in the last digit.

General Timer: Use this mode when you require to know the actual times at which the events happen. It also gives information on the channel the event happened. It is suitable for use with gliders on an air track, vehicles on a runway, momentum investigations and general purpose timing. Resolution is a millisecond with an uncertainty of ±1 in the last digit.

Gap Timer: Consider the situation where you have a trolley with a single mask on a sloping runway which has two light gates. You want to measure the time to go between the light gates. When the trolley cuts the first beam two events will be recorded - the leading and the trailing edges of the mask. Similarly when it cuts the second beam. You are not interested in the trailing edge times. In the Gap Timer mode the software waits until one of the inputs has changed state and as soon as that happens it starts the clock and then it looks at the other input and waits for a change in state which stops the clock. The trailing edge plays no part in the timing.
The resolution is a millisecond with is an uncertainty of ±1 in the last digit
The Gap Timer mode is especially useful if you have any mechanical switches connected. If a switch is used to start the timing then it is possible that many events will be generated due to switch bounce. The Gap Timer mode would ignore all the bounces.

Fast Timer: The Fast Timer displays the time in microseconds up to 10000us and for times greater than that it displays in milliseconds to two decimal places. Both ranges have an uncertainty of ±2 in the last digit. The fast timer should be used for times up to 150ms. It can be used for Speed of Sound and projectile experiments.
It is important that all inputs to TSA are bounce free. This means that mechanical switches should not be connected to TSA when used as a Fast Timer.