H28020 **Motion QED** **NFU452**

Introduction

What is Motion QED?

Motion - Quick and Easy Display, is a microprocessor based instrument which enables pupils to make measurements of:-

- time intervals
- speed
- acceleration
- event times
- average speed
- gap times

Where can it be used?

Most of the measurements which are made in elementary mechanics courses can be handled by Motion QED. In many standard experiments, this instrument is an alternative to the use of ticker tape or computers. It can be used in the laboratory with light gates or mechanical switches as inputs or if required it could be used outside the classroom.

Quick Start

Two introductory investigations are described later in these notes.

Power requirements

Motion QED runs from a laboratory power supply or a plug top power supply set to 12V - 15V A.C./D.C.. As Motion QED has two sockets for powering 12V light gates then the supply should be capable of delivering 0.5A to the load.

What can it do?

Motion QED accepts up to four inputs from light gates, mechanical switches, foil switches or any TTL switch.

Philip Harris Technical Support **0845 120 4520**

www.philipharris.co.uk **techsupport@philipharris.co.uk**

If you are using fewer than four inputs it does not matter which inputs are used. Motion QED can measure and display up to:-

- 4 time intervals
- 4 speeds
- 2 accelerations
- 8 event times
- 1 average speed
- 3 gap times

Note that Motion QED does not care if three speeds are measured on one channel and one speed on another. It can also handle coincident events on different channels.

Getting to know your Motion QED

Time Interval

This mode of operation is dealt with in greatest detail - the other modes operate in a similar manner.

This mode is used to measure how long it takes for a mask to cut a light beam. Power up your Motion QED using a suitable power supply set to 12 - 15V A.C./D.C.

Connect the lamp supply from Motion QED to a Unilab light gate (H27623) and the photodiode to input 1 (taking care with the polarity).

The input 1 LED should be on, indicating that the light beam is aligned. This is more important when the lamp and detector are not an integral unit.

After power up the user is offered <S>elect mode. Press the Select button and the Time Interval mode of operation appears.

Continue pressing the <S>elect button and step through all the different modes. Stop when Time Interval is displayed. Now press the Enter/Display button to display <S>elect number. Press the Select button until the display shows the number of readings =2 then press the Enter/Display button. If it helps, think of the Enter button as the <RETURN> key on a computer keyboard.

<G> when ready indicates that you should press the GO button.

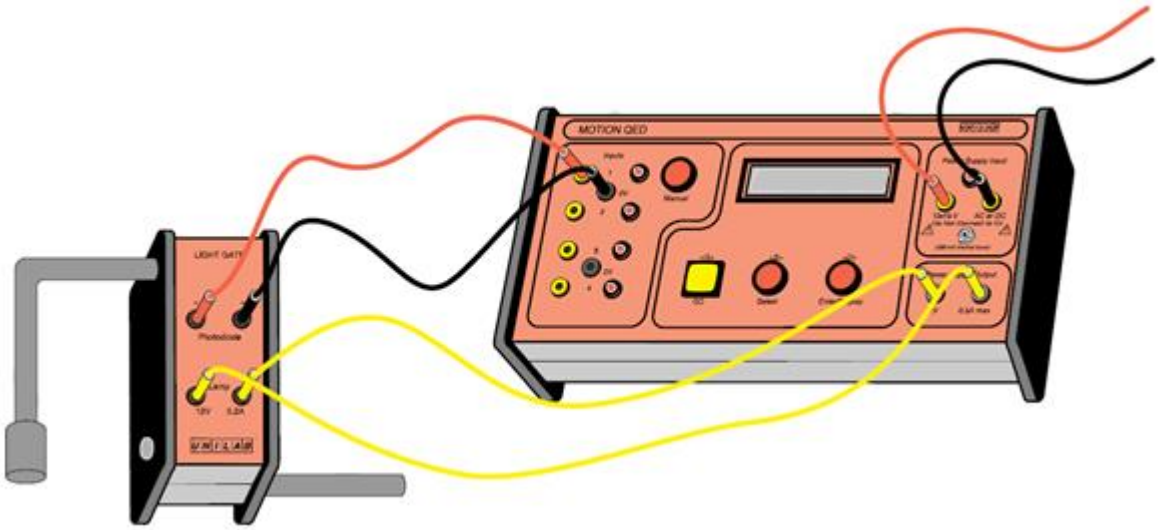
Block the light beam with a card for about five seconds and quickly remove the card - this is the first time interval. Note that Motion QED still displays waiting. Block the beam again and this time when the card is removed the message <D>isplay appears.

Press the Enter/Display button to see the first result and press again to see the second.

Press the Enter/Display button to see the options now available:- <G> <S> <D>

<G> lets you go and make measurements of another two time intervals <S> lets you select a different option <D> lets you display the results again.

Experiment with the Display and GO options and when you have finished press the Select button for <S>elect mode.



Speed

This mode is used to measure the speed of a vehicle (max 99.99ms-1) as it passes through a light gate.

The light gate should be connected to an input - take care with the polarity. Select the Speed mode and Enter Select readings=1 and then Enter.

Now <S>elect the the size of your mask. The mask size increases in 1 cm steps up to 10 cm and then in 10cm jumps to 200cm.

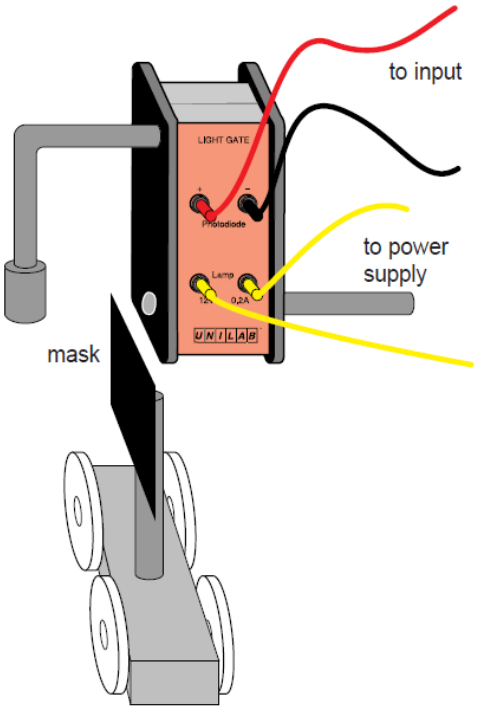
Enter a mask size of 4cm.

Press GO when ready.

For convenience use a card or your hand to block the light.

Press the Enter/Display button to display the results.

Press the Enter/Display button again to display the menu:- <G> <S> <D>.



Philip Harris Technical Support **0845 120 4520**

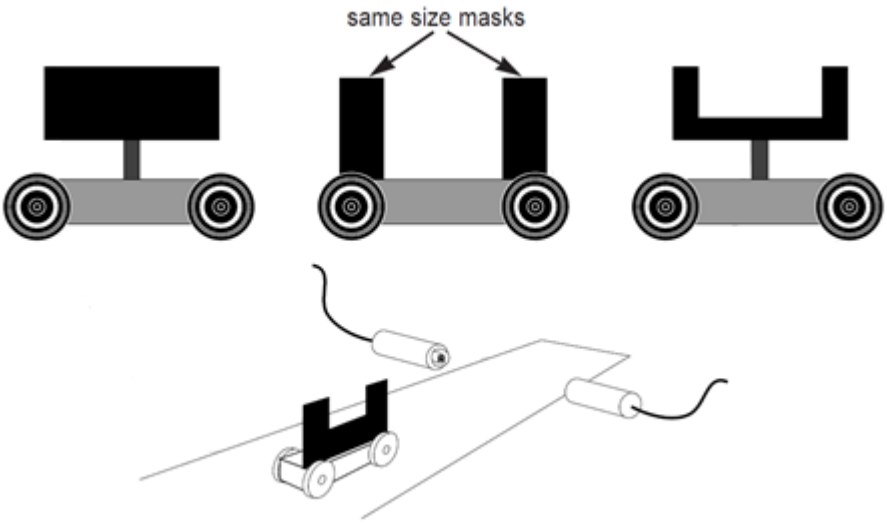
www.philipharris.co.uk **techsupport@philipharris.co.uk**

Acceleration
The setup for this mode of operation is identical to Speed.

Several types of mask arrangements are possible:

- a single mask with two light gates
- a double mask with a single light gate
- two single masks attached to a trolley passing through one light gate

It should be noted that the appearance of the units of acceleration as m/s/s is a restriction of the display.



9.81
The achievement of 9.81ms^{-2} should not be an end in itself. The understanding of the physics and the calculations which lie behind the answer are far more important.

There is a number of simple steps which the user can take to ensure minimum error:

- use a parallel beam where possible
- use a large mask – recommended minimum is 4cm
- minimise the shadow effect by dropping the mask close to the detector
- drop the mask vertically
- drop the mask from just above the detector in order to minimise air resistance effects

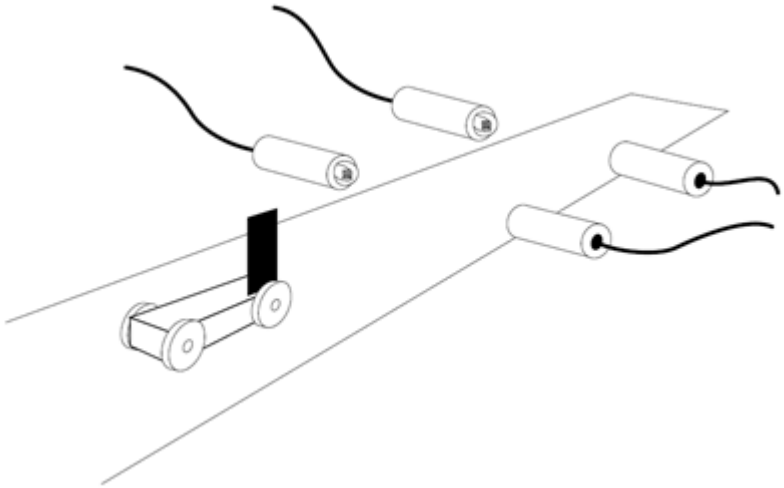
Event Timer
This mode is used to measure the time at which an event happened.

For the purpose of this document an event is defined as a change in state of an input. When a single mask cuts a light beam there are two events, one for the leading edge and one for the trailing edge.

The Event Timer facility is set up in an identical manner to Time Interval, by <S>electing Event Timer.

The Event Timer option is potentially the most powerful option which Motion QED offers.

From the event times all the other quantities can be calculated e.g. time intervals, gap times, speed, momentum, acceleration etc. All event times are measured from event 1 which is at time = 0.



Average Speed
This option is used to measure the average speed of a vehicle as it travels between two light gates. The time used in the calculation is the time for the leading edge of the mask to travel between the light gates. The information on the trailing edge is not used.

This option is set up in a similar manner to Speed, except that only one average speed can be measured.

Place two light gates on a runway and connect them to any inputs. The maximum separation of the light gates is restricted to 200cm.

Release a trolley with a single mask and display the average velocity.

Gap Times

This option is used to measure the time to travel between light gates. Up to three gap times can be measured.

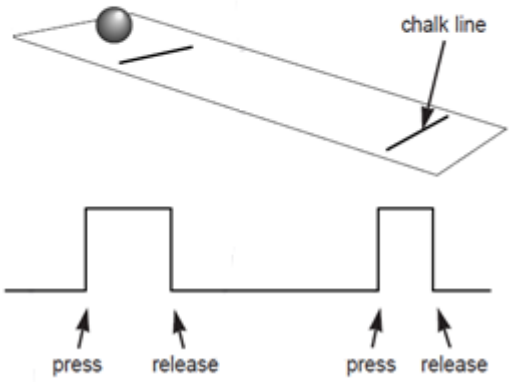
The time displayed is the time for the leading edge of a mask to travel from one light gate to the next light gate. The option is set up in a similar manner to Time Interval.

The Manual Button

This button is connected internally to input 1 and can be used instead of a light gate to measure average speed.

The manual button can be used to measure time interval but it should be noted that the push in of the button is one event and the release of the button is another event.

Philip Harris Technical Support 0845 120 4520
www.philipharris.co.uk techsupport@philipharris.co.uk



Suppose there was a start and finish chalk line on a bench and a ball bearing was rolling down the bench.

Press and release the Manual button when the ball bearing crosses the start line and similarly at the finish line. The average speed can then be displayed.

The manual button can be used in conjunction with light gates.
To measure Average Speed place a light gate connected to input 2 at the first chalk line and have your finger on the Manual button while watching the second chalk line. Release the ball bearing then press and release the Manual button when the ball bearing crosses the second line.

Taking it outdoors

Provided that you do not wish to use light gates or drive any external circuitry, Motion QED will give several hours of operation from a 9 volt 6F100 (PP9) battery.

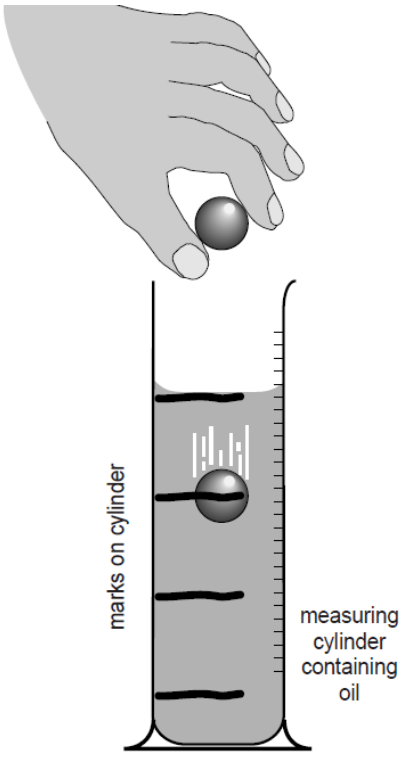
Teaching considerations

It is very easy to use a sophisticated device like Motion QED to acquire answers quickly. However, care must be taken to ensure that the Physics concepts are firmly established before letting pupils have free access to such a device e.g.

- if pupils are measuring average speed do they know that it is the total distance travelled divided by the total timetaken?
- If pupils are measuring acceleration do they know how to calculate it from first principles?

Once the basic concepts are understood then Motion QED becomes a very powerful investigative tool and is ideal for handling “what if…?” situations:

- what if the slope was increased?
- what if a heavier ball bearing was used?
- what if it was a rougher surface?



Philip Harris Technical Support 0845 120 4520
www.philipharris.co.uk techsupport@philipharris.co.uk

Possible Applications

In addition to the traditional experiments there are countless situations where Motion QED could be used and the list below is just a few suggestions:-

- Using Event Times and the manualbutton the terminal velocity of a ball bearing in oil could be investigated. Note that as the ball bearing passes the first marker the button should be pressed and then released as it passes the next marker.
- Using Time Interval and the manual button to measure the period of a pendulum. This demands skilful pressing of the manual button when measuring four periods - remember that the release of the button is also an event.
- Investigation of acceleration and angle of slope.
- Investigation of acceleration on slopes of different material.
- Investigation of the motion of radio control and wind up cars.
- The traditional impulse experiment of the force on a football being kicked is greatly simplified as Motion QED is capable of measuring the duration of the kick and the time the ball takes to
- cut a light beam.
- Use the Event Timer with 4 foil switches on long leads. Pupils should run or cycle through the switches and hence calculate their acceleration.
- Investigate the acceleration of a toy electric train when different masses are in the wagons.
- Investigate the speed of a toy electric train as the voltage is reduced.
- Measure the average speed of a worm as it moves away from a light source.
- Measure reaction time. Set up Motion QED with a push switch on input 2.
- Select Gap Times and one reading. The person whose reaction time is being measured should press the manual button as soon as the LED changes state.

Technical Information

Accuracy

Factors which contribute to errors are:-

- non-parallel light beams
- shadows from the mask
- variation of switch-on speeds of photo-diodes
- crystal frequency variation with temperature
- software rounding of numbers when doing arithmetic
- incorrect measurement of mask
- masks not cutting light beams at right angles

Switch Debounce

When mechanical switches are closed the contacts bounce open and close many times.

This type of situation must be eliminated and consequently a debounce delay of just under 3ms has been built into the software. This means that when an event occurs on an input line the software will let 3ms elapse before it again looks at the inputs. (Note that the clock is still running and hence the timing is still accurate). As a result of the debounce delay, time intervals < 3ms cannot be measured.

Philip Harris Technical Support 0845 120 4520
www.philipharris.co.uk techsupport@philipharris.co.uk

Other Manufacturer's Light Gates
Care should be taken if operating other manufacturer's light gates.
Check that the lamp operates at 12V before connecting to the 12V lamp supply from Motion QED. If the lamp does not operate from 12V then use a separate
power supply.

Specification
Supply voltage = 12 - 15V a.c./d.c. when driving lamps (note that unit will operate from a 9V PP9 battery when not driving an external load)

Input impedance = > 1M½

Maximum input voltage = 50V

Lamp supply = 12V, limited to 0.5A, shortcircuit protected

Maximum display time = 99.99s

Debounce delay = 2.629ms

Minimum measured time interval = 3ms manual button operates on input 1 only

Summary of Calculations

Time Interval
The time interval is calculated as the time between the leading edge and the trailing edge of a mask cutting a light beam.

The speed is the average speed of a vehicle as it passes through a light beam. If the mask size is small then the speed is approximately an instantaneous speed. It is calculated by dividing the mask size by the time interval (as defined overleaf).

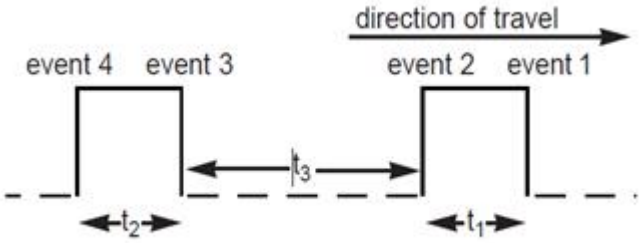
Event Times
An event time occurs when an input changes state. It should be noted that it does not matter which input is being used. If three event times were being measured then all three events could be on the same input or the first event could be on input 2, the second on input 1 and the third on input 4.

Average Speed
The average speed is calculated by dividing the time between two light gates (switches) by the time that it takes the leading edge of a mask to go from the first light gate to the second one. Note that the size of the mask is irrelevant provided it is smaller than the separation of the light gates.

Gap Times
The gap time is calculated by measuring the time for the leading edge of a mask to go between two light gates. Using four light gates, QED gives three gap times.

Acceleration

Consider a trolley with a single mask on a runway with two light gates. Motion QED calculates the average speed of the trolley as the trolley cuts each beam. Each average speed will occur in the middle of the time that it takes for the mask to cut the light beam. The total time between each speed is calculated as shown below.



$$v_1 = \frac{\text{mask size}}{t_1}$$

$$v2 = \frac{\text{mask size}}{t_2}$$

$$\Delta_t = \frac{t_1}{2} + \frac{t_2}{2} + t_3$$

$$\text{acceleration} = \frac{v_2 - v_1}{\Delta_t}$$

Associated Equipment

C51501 to C51719 4mm leads
H30592 Phototransistor
H31509 Light Source
H27623 UNILAB Light Gate (Slave)
432.100 Linear Air Track and Accessories Kit
432.101 Air Blower for Air Track
H10465 Lockmaster Power Supply
H10453 Bench Power Supply
C50636 Plug Top Power Supply

Quick Start

An investigation using Motion QED

When a vehicle "runs away" down hill, it seems to go faster and faster.
1) Is this true? If it has run twice as far, will it be going twice as fast?
2) Does it matter how heavy the vehicle is? Does a bus accelerate down a hill faster than a Mini?
3) Does it matter how steep the hill is? Our intuition says Yes!
You need to test these possibilities, one at a time, in a fair and repeatable way.

Set up the track with one end about 5cm higher than the other. It must be marked accurately every 10cm, preferably using a permanent marker.

You will need a toy vehicle, and a 12 - 15V power supply for the Motion QED.

The three buttons marked:
<G>o
<S>elect and
<D>isplay/Enter
are used to select and control the QED's operation.

Motion QED also has a button marked Manual, you will use this facility first, before adding light gates.
Press Select until the word "events" is displayed. Press Enter/Display. Press Select until the number 4 is displayed.
Press Enter.

QED now displays <G>o when ready. Press Go. QED is waiting for "events".

Slowly press and release the Manual button. Press and release it again. The display changes to <D>isplay.

Pressing Enter/Display now shows you the times for the four events you input, with 0.000 as the first. Note that each press and each release of the button is one "events".

When <G> <S> <D> are displayed, you have the choice:
Go allows you to do the same measurements again
Select lets you select a different type of measurement
Display displays the measurements again for the last experiment.

Select Event timing and select 6 events.
Press Enter. Press Go.
QED is waiting for the Manual button to be pressed and released three times.
Ask another student to release the vehicle at the top of the track. Watch the vehicle. Press and release the Manual button as the front of the vehicle reaches each marker.

You may need to try this a few times to practise!

Use the times and distances to produce a graph. How do you know the vehicle is accelerating? Is the acceleration constant?

The same method can be used to time a ball rolling down a ramp, with suitable markings.

You can even check the speed of cars on a stretch of road, once the road has been safely marked in some way.

Lampposts could provide suitable markers, if you are viewing the road from some distance away. NOTE: you must be able to find the distance between the lamposts SAFELY!

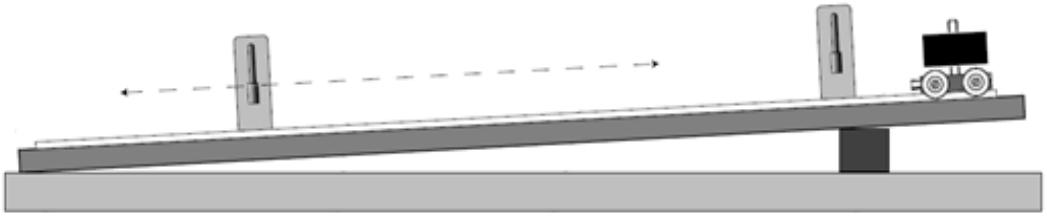
version H28020.15.11

Quick Start

Using Motion QED with Light Gates

Light gates are connected using long 4mm leads.
To avoid confusion use yellow for the power, red and blue for the Inputs 1, 2, 3 and 4.
Motion QED needs a 12 to 15V power supply.
Test the light gates by interrupting each one with a finger. The LED on the light gate, and the LED on the QED should indicate the "events".

Fit a 10cm card interrupter to the vehicle.
Check that it will pass through the light gates.



Arrange the light gates 40cm apart, with space for the vehicle to run 10cm before it passes through the top light gate. This gives it chance to accelerate and give you an INITIAL velocity.

Press Select until Speed is displayed.
Press Enter/Display.
Press Select to get 2 readings. PressEnter/Display.

Press Select repeatedly to set the mask size to 10cm. Press Enter/Display.
Press Go. QED is waiting. Release the vehicle.
When <G> <S> <D> are displayed, press Enter/Display to see the two measurements of speed.

Record the two speeds.

When <G> <S> <D> are displayed again:
Go allows you to do the same measurements again
Display displays the measurements again for the last experiment
Select lets you select a different type of measurement.

Adjust the separation of the light gates to 50cm. Press Go. Release the vehicle again.

Record the two speeds.

Continue in this way for different separations of the light gates. Now try to answer question 1 (previous page).

Another way to use QED in this experiment, is to measure the acceleration directly.
Press Select until Acceleration is displayed. Press Enter/Display. Select 1 reading. Press Enter/Display. Press Select repeatedly to set the mask size to 10cm. Press Enter/Display. Press Go. QED is waiting. Release the vehicle.

version H28020.15.11

When <G> <S> <D> are displayed, press Enter/Display to see the measurement of acceleration.

Repeat the measurement of acceleration to check that it is reliable.

Now investigate questions 2 and 3 (previous page) by making adjustments to the mass of the vehicle and the angle of the ramp.

Warnings

For your safety, this product should be used in accordance with these instructions, otherwise the protection provided may be impaired.

Periodic testing

Check the mains lead and plugs at both ends for any damage.

Periodically check the earth bonding and insulation, by performing a Portable Appliance Test (**PAT**). Most schools and local authorities have a regular schedule for such testing.

Check the action of the electronic cutout, by short circuiting the power supply output (check dc and ac outputs separately) using a short 4mm plug lead.

Check that the fuse in the mains plug (5A recommended) and the two fuses (active and spare) in the IEC socket on the back panel are all of the correct rating.

Disposal of Waste Electrical and Electronic Equipment (WEEE)

Do not dispose of this product with household waste

- For the proper treatment , recovery and recycling please take this product to an appropriate collection point.
- If you are unsure where this is, contact your Local Authority
- By disposing of this product correctly you will be providing positive help to the environment.

Warranty, repairs and spare parts

The Motion WED is guaranteed for a period of one year from the date of delivery to the customer. This warranty does not apply to defects resulting from the action of a user such as misuse, improper wiring, any operations outside of its specification, improper maintenance or repair, or unauthorized modification.

Our liability is limited to repair or replacement of the product. Any failure during the warranty period should be referred to Customer Services.

In the event of a fault, apart from replacing the instrument fuse in the IEC socket, the power supply should be referred to the Philip Harris recommended repair agent.

Please contact Customer Services or techsupport@philipharris.co.uk for advice

Instructions for authorized service technicians

Ensure that any replaceable mains cord is of the correct rating.
Ensure that all earth conductors and protective earth bonding is maintained after service work.
Please refer to the detailed service procedures, safe servicing and continued safety – contact techsupport@philipharris.co.uk for advice.
For any manufacturer specific parts please refer to our recommended repairer.
Please refer to product specific risks that may affect service personnel, the protective measures and verification of the safe state after repair.

Supplier details

Philip Harris Education, 2 Gregory Street, Hyde, Cheshire SK14 4RH

Orders and Information Tel: 0845 120 4521
Fax: 0800 138 8881
Repairs Tel: 0845 120 3211

E-mail: techsupport@philipharris.co.uk

Website: www.philipharris.co.uk

version H28020.15.11