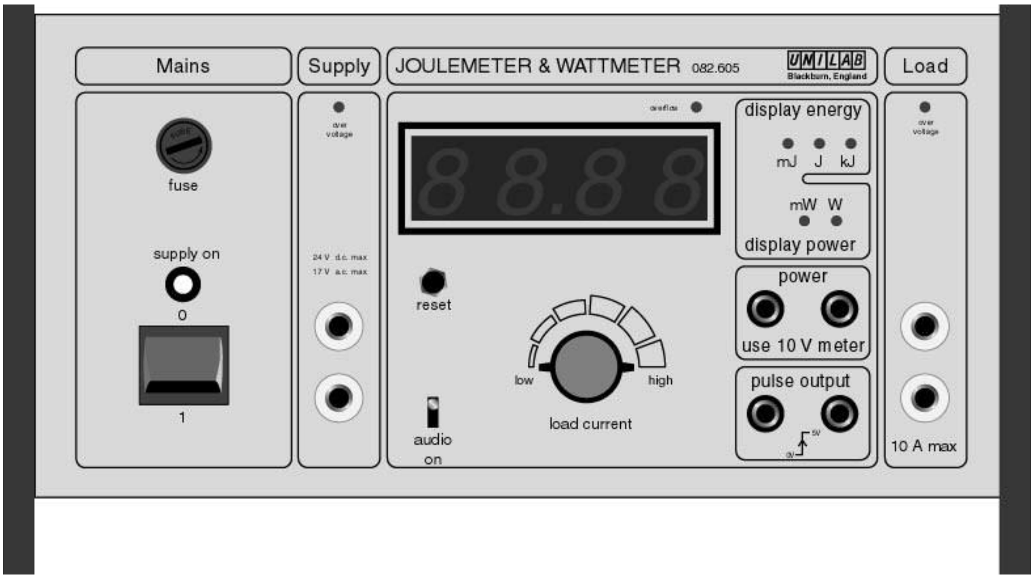
H28986 Joulemeter and Wattmeter NFU 381

The Joulemeter and Wattmeter, is intended for measuring energy used (in joules and kilojoules) and power (in watts) for a wide range of electrical and electronic devices, and is designed to replace the previous model whilst improving the performance and being easier to use.



Technical Information

Check the operating voltage rating label on the instrument

Mains input 240V 50Hz,Instrument fuse T100mA Mains plug 5A recommended.

Input characteristics
Input range for linear operation
0 to ±24V peak, d.c. or a.c. (sine wave 0 to 17V RMS)
Frequency range d.c. to 10kHz
Input resistance without load 125kΩ

Output characteristics
Output resistance on lowest range = 1kΩ
Output resistance on highest range = 10mΩ plus wiring resistance
No load current with supply p.d. = 10V 10/1.25 x 105 A = 80µA

Maximum ratings on each range
The maximum thermal ratings of the shunts are represented by the following current maxima:

low	200µA
	2mA
	20mA
	200mA
	2A
high	10A

Accuracy

5% of F.S.D. typically 2%

Dimensions

Approx. overall 275mm wide, 165mm deep, 165mm high

Weight 2.6 kg

Warnings

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

EMC

This equipment is Class A according to the EMC standard EN 55011 and is intended for use in a non-domestic environment only.
Do not open or remove covers or panels. Repairs and service may only be carried out by our repair agent, otherwise the warranty may be void.

Use only the 3-core mains cable supplied with the unit. If the mains cable is replaced, the rating of the replacement must be the same or better than the original.
The unit must be earthed at all times. The unit is earthed/grounded through the 3-core mains lead, so no additional earth connection is required.

The unit is protected by a T100mA mains fuse, accessible from the top panel. Switch off and disconnect from mains supply before replacing the fuse. To remove the fuse, use a small coin or broad flat blade screwdriver to turn the fuse holder by 90 degrees anticlockwise, then lift it out.

Always position the unit so that it can be disconnected from the mains, if an emergency arises.
This unit is intended for use in DRY conditions. Avoid spillage of water and other liquids on to the unit. If spillage occurs, disconnect the mains supply.
There is no specific requirement for insulation of external circuits as they cannot become hazardous live, as a result of connection to this unit. Limit the length of any connecting leads to 3 metres.
For your safety, this product should be used in accordance with these instructions; otherwise, the protection provided may be impaired. Risk of shock if the unit is opened. Use only the 3-core mains cable supplied with the unit.

Introduction

The Instrument is based on a solid-state current-voltage multiplier, the signal from which is used to drive an internal meter and so monitor the power dissipation in the load. Pulses are fed to an electronic counter at equal increments of energy dissipation in the load, providing a digital indication of the energy dissipated and to display the power dissipation in the load on an external meter.
The unit is mains-powered and its drain on the external low voltage supply is low enough to be neglected in most applications.
Power input to unit from supply = Power output from unit to load.
For more precise work or specialised applications, it is necessary to take into account the internal parameters of the unit and the nature of the supply and load.
The instrument is suitable for use up to 24V d.c., and 17V a.c. rms, up to a maximum frequency 10kHz, for any waveform.
Power dissipation is in the range 0 to 240W, nominally.

Description
The front panel of the instrument contains the following:

- Input terminals - under Supply, yellow.
- Output terminals - under Load, yellow.
- Power sockets – marked 'power' - connect a 10V meter, red and black, observe the polarity.
- Pulse sockets - marked 'pulse output' - red and black, observe the polarity.
- Range switch - marked 'load current' - six position, low to high.
- Display switch – to the right of the display – to display energy or power.
- Audio on/off switch – does not switch off the over current warning.
- Reset – below the display.
- Warning LEDs - over voltage in the Supply section, over current in the Load section, overflow above the display.

Basic Operation

Output to load
The polarity of the output is determined by the polarity of the input.

Energy measurement (Joulemeter)
Select 'display energy'. The counter increments in proportion to the rate of energy dissipation in the load. The repetition rate of the audio bleep corresponds to changes in one of the digits. Which digit depends on the range switch setting.
A separate counter may be connected to the 'pulse output'. It must be able to count positive going 5V pulses.

Power measurement (Wattmeter)
Select 'display power' and connect a 10V moving coil meter to the power sockets, observing the polarity.

Suitable meters include:
The Basic Student meter with a 5V/10V d.c. Multiplier, or an Easy-Read Digital Meter with the 20V d.c. Attachment.

Use of ancillary meters
This section refers to meters used in the external circuit and does NOT apply to the meter connected to the 'power' sockets. This should always be a 10V d.c. moving coil meter.

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The joulemeter/wattmeter measures the total power dissipation in the load, including that of any meters connected in the load circuit.

The instrument records the product of the simultaneous values of current and potential difference (voltage across the load) at every instant.

Moving iron meters record effective values of current and p.d. and so, in d.c. and a.c. resistive circuits, give readings consistent with those of the joulemeter/wattmeter.

Moving coil meters, however, record average values and when they are used the nature of the supply must be taken into consideration as follows:

1. 'Pure' d.c. sources, e.g. accumulator, dry battery: the meter readings represent effective values.
2. Mains-driven d.c. power supplies (full-wave rectified):
   a) Unsmoothed. Both current and voltage readings must be multiplied by 1.11 to obtain effective values.
   b) Smoothed. The degree of smoothing, and hence the approximation to pure d.c., often depends on the current drawn by the load.
3. a.c. Sources:

A.C. shunts and multipliers fitted to moving coil meters provide full wave rectification. They are usually adjusted to record effective values for sinusoidal waveforms. Where current transformers are incorporated, shunts are calibrated at frequencies of 50 - 60Hz. Meter readings DO NOT necessarily represent effective values for other waveforms or widely different frequencies.

Initial procedure

Switch on the instrument and allow a short time for transient counts to die away, then reset the display.

Connect the load and the supply. For energy measurement it is often convenient to include an on-off switch in the supply circuit.

Select the appropriate ‘load current’ setting (if known) otherwise set up the experiment to use the maximum current, set the ‘load current’ to high, then turn the load current knob down until the over current LED lights, then turn back one step.

If the over current LED lights during an experiment, turn the ‘load current’ control to a higher setting, or change the experiment setup.
Move the display switch to show energy or power, this may be done at any time without affecting the readings. If both energy and power are required, connect a 10V moving coil meter to the power sockets.

Note:

1. Changing the <+">load current<-"> setting, immediately resets the meter.
2. If spurious counts are to be avoided, the mains switch on the instrument should NOT be used to start or finish a reading.
3. Within the limits of accuracy of the instrument slight drift may occur, giving rise to occasional counts or slight offset to the wattmeter zero.
4. If earthed supplies and measuring equipment are used, care must be taken to ensure that short circuits do not occur as the lower Supply socket, the black power and black pulse sockets are connected inside the unit.

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Display operation
When the instrument is reset, the display may be set to say '0.000', (depending on load current setting), if the reading goes above '9.999', the format "rolls over" to '10.00'. If the reading continues to above '99.99', the overflow LED lights and the reading becomes '00.00'. In general only one "rollover" or movement of the decimal point is allowed, before the overflow operates.
The meter will continue measuring the energy after an overflow but the leading digit and leading zeros are not seen. If the reading over-flows a second time the display shows " - - - - " and the instrument stops measuring until the reset button is pressed.

Beep frequency
The sounder will beep each time the **second least significant** digit in the display changes, i.e. second from the right, (provided the switch is on), except when a rollover has occurred in which case the beep happens when the least significant digit changes.

Reading the external power meter
The external power meter shows a direct reading of the power being consumed in the range 0 - 10V. For example, if the digital display is reading a power dissipation of
40.00mW then f.s.d. on the external meter would represent 100mW and the reading of 4.0 will have to be multiplied by 10 to give 40mW.

Over voltage warning
If the maximum voltage is exceeded the Over voltage LED will light. Reduce the voltage immediately and REPEAT the experiment or there will be errors.

Over current warning
If the maximum current allowed in any range is exceeded the Over Current LED will light, the buzzer will sound continuously and the display will show " - - - - ". Reduce the current then press the reset button to clear the display and start measuring.

Typical applications
The following notes only outline the experiments that may be performed using the new instrument. The experiments will be expanded in the fully revised version of these notes.

Mechanical and Electrical Energy
Apparatus:
Joulemeter/Wattmeter
Friction calorimeter with electric heater
Long cord
Thermometer 0 to 50˚C
Newtonmeter 0 to 100N Power
supply 12V a.c. or d.c.

Procedure:
Record the initial temperature of the metal cylinder. Apply a constant force, F, to rotate the calorimeter, using the cord and newtonmeter, pulling the cord a measured distance, X. Record the highest temperature reached. Calculate the temperature rise and the mechanical energy supplied = F x X= W joules.

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Cool the cylinder to its original temperature and supply the same amount of heat electrically, using the heater measured via the joulemeter. Again record the temperature rise and compare the results.

Further applications:
Simple determinations can be made of the efficiency of electromechanical systems:
1. An electric motor raising a known weight through a measured distance.
2. A falling weight driving a generator and lighting a lamp. Note that the final kinetic energy of the weight may be significant.

Suitable components:
Motor/Generator unit
Lineshaft unit
Lamp unit
Power supply, 6V d.c.

Specific Heat Capacity
Apparatus:
Joulemeter/Wattmeter
Immersion Heater 12V 42W
Aluminium Block, 1kg
Copper Block 1kg
Steel Block 1kg
Thermometer -10° to +110°C Power supply, 12V 5A d.c. or a.c.

Procedure:
Record the initial temperature of the aluminium block.
Heat the block for about five minutes and measure the electrical energy supplied, W. Record the final temperature allowing for thermal lag, i.e. note the highest temperature reached after the heater is switched off.

Repeat the procedure for the other blocks (which have the same mass), supplying the same amount of energy each time, measured by the joulemeter.

The experiment is intended to provided a quantitative illustration of specific heat capacity, with a minimum of calculation. With suitable refinements, more precise determinations are possible.

Further applications:
1. Simple electrical determinations can be made of specific latent heats of fusion and vaporisation.
2. In all standard methods of electrical calorimetry, the joulemeter replaces ammeter, voltmeter and clock, with the advantage that current and p.d. need not remain constant during the experiment.

Potential Difference as Energy per Unit Charge

Apparatus:

Joulemeter/wattmeter

Variable resistor/rheostat 0 to 10Ω, 1A rating Meters

1A d.c. and 5V d.c.

Digital stopclock

Source of smooth d.c. variable 0 to 6V d.c. e.g. 25V Variable OR Beaver Power Supply.

Procedure:

Adjust the supply voltage and the load resistance, R, to give a current, I, of 1A at a p.d. of 1V. Measure the energy, W, dissipated in a convenient time, t. Repeat the procedure for other values of p.d. each time adjusting the load resistance to give a current of 1A.

Note:

1. The experiment is intended as a simple illustration of the relationship between p.d., charge and energy. It should not be taken to establish this relationship.
2. The voltmeter is connected in the load circuit to avoid measurement of the potential drop across the joulemeter.

Further applications:

The circuit can also be used to demonstrate

1. W = I V t
2. P = I V
3. P = I2R

Effective Values of an alternating current.

Apparatus:

Joulemeter/wattmeter

10V d.c. meter instead of 1mA d.c. meter.

Resistor, 10kΩ

Oscilloscope

10V d.c. meter

10V a.c. meter

Source of smoothed d.c. 9V 1mA, e.g. PP3 battery or variable, smoothed power supply Source of a.c. and unsmoothed d.c. (full wave rectified) 0 to 12V 1mA

Procedure:

Set the oscilloscope input to d.c. (or ‘direct’) and the time base to 10ms.

Connect the d.c. meter, switch to the smooth d.c. source and measure the applied p.d. with both the meter and the oscilloscope. Record the power, P, dissipated in the load. Connect the a.c. meter, switch to the a.c. source and adjust the applied p.d. to give the same power dissipation. Measure the effective p.d. on the meter and the peak p.d. on the oscilloscope. Repeat the procedure with the unsmoothed (full wave rectified) d.c. source, using the d.c. meter to measure the average p.d. and the oscilloscope to measure the peak p.d.

The effective value of an alternating current is the value of that steady current which would dissipate energy at the same rate as the alternating current. In resistive circuits:

effective current I_{EFF} = root mean square current, I_{RMS}

similarly $V_{EFF} = V_{RMS}$

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An oscilloscope records the peak value of a p.d., Vo

Further applications
The circuits can be used to determine r.m.s. and half cycle average values of nonsinusoidal waveforms. For frequencies other than 50 - 60Hz, the frequency response of the voltmeter may be significant.

The 'form factor' of the waveform can be obtained from

F = r.m.s. value/half cycle average value

Maximum Power and Internal Resistance

Apparatus:
Joulemeter/wattmeter
10V d.c. meter instead of 1mA d.c. meter. Resistor,
4.7kΩ
Resistance, 0 to 10kΩ
Power supply, 10V 2mA d.c. or a.c.

Procedure:
Record the power, P_L, dissipated in the load when the load resistance, R_L, is varied from 1 to 10kΩ
The 4.7kΩ resistor acts as the internal resistance, R_s, of the source.

P_L should have a maximum value when $R_L = R_S$ (In this condition, the power dissipated in the load is equal to that dissipated in the source.)

Power in A.C. Circuits

Apparatus:
Joulemeter/wattmeter
10V d.c. meter instead of 1mA d.c. meter.
Audio signal generator capable of 5V r.m.s. output Meters
50mA a.c. and 5V a.c.
Resistor, 470Ω
Capacitor, 470nF
Inductor, 2400 turns ≈150mH

Procedure:
Set the signal generator frequency to 100Hz and adjust the output p.d. to give a current of about 10mA in the resistive load. Ensuring that the p.d. remains constant, vary the frequency, f, from 100Hz to 1kHz and record the current, I, and the power, P, dissipated in the load.
Maintaining the same p.d., repeat the procedure with the capacitor and the inductor, separately, in place of the resistor. In the case of the inductor, the frequency must be kept above about 250Hz to avoid current overload.

The joulemeter provides evidence that
(a) the resistance of a pure resistor is independent of frequency
(b) no power is dissipated in a pure capacitor (in practice, resistive leakage may become apparent at high frequencies, as the reactance of the capacitor decreases.

(c) the power dissipated in the resistive component of the inductor is governed by the inductive reactance, which increases with frequency.

Energy Stored by a Capacitor

Apparatus:
Joulemeter/wattmeter
10V d.c. meter instead of 1mA d.c. meter.
Electrolytic capacitor, 1000uF 25V Resistor,
10kΩ (or resistance box) Meter, 10V d.c.
Source of smooth d.c. 0 to 10V 1mA

Procedure:
Charge the capacitor, recording the charging p.d., V_0 and the energy, W_1, dissipated in the load resistance, R, by the charging current. Discharge the capacitor through the load and measure the energy, W_2, stored by the capacitor. Repeat the procedure for other values of p.d.

Note:
1. After each discharge, the capacitor terminals should be shorted to remove any residual charge due to hysteresis in the dielectric.
2. With the given component values, about 10% of the total energy in both the charge and discharge processes is dissipated in the input resistance (125kΩ) of the instrument and is not recorded.
3. Large electrolytic capacitors are prone to significant leakage. If this proves troublesome, it is usually possible to reform the dielectric by maintaining the capacitor at its full rated working voltage until the leakage current falls to an acceptable value.

The wattmeter can be used to investigate the dependence on load resistance of a) time constant
b) total energy dissipated
Note: the initial current must not exceed the maximum of the range selected.

Energy Stored by an Inductor

Apparatus:
Joulemeter/Wattmeter
Large Iron cored Inductor
10V d.c. meter instead of 1mA d.c. meter.
Source of smooth d.c. 0 - 9V 1mA

Procedure:
Remove the core from the inductor and connect the 17000 and 20000 turn coils in series so that their inductance is minimised.
Measure the energy, W_1 supplied to the load in 40s and record the current, I_0
Replace the coils on the core to give the same resistance, R, but maximum inductance, L. Ensure that the pole faces are clean and accurately fitted.

Without changing the supply p.d., Vo, measure the energy, W_2 supplied in 40s.
The maximum current should be the same as before.
Repeat the procedure for other values of current.

Note:
1) The inductor should be disconnected before the supply is switched off so that the circuit is isolated from the resulting back e.m.f.
2) The meter is connected in the load circuit to avoid measurement of the current through the input resistance 125kΩ of the joulemeter.
The d.c. resistance of the meter is small compared with that of the inductor (~7kΩ)

The wattmeter can be used to investigate the dependence on load resistance of a) time constant b) total energy dissipated

Periodic testing
Check the mains lead and plugs at either end, 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.
Please note:
This instrument must be tested (PAT) using the 10 amp Earth Bond test.

Applying the 25 amp test is likely to damage the unit, does NOT make the unit safer, and damage so caused is not covered by the warranty.
Check that the fuse in the mains plug (5A recommended) are of the correct rating.

Warranty, repairs and spare parts

The joule and wattmeter 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 fuse socket, the power supply should be referred to the Philip Harris recommended repair agent.

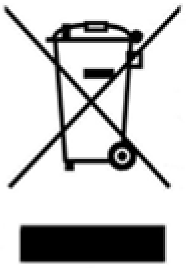
Instructions for authorized service technicians

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.

Disclaimer

If the equipment is used in a way not specified by Philip Harris, then the protection provided may be impaired.

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.

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