Joule's Constant Measurement Setup
(By Electrical Method)
NV6054

Learning Material

Ver. 1.1

Designed & Manufactured by:

Nvis Technologies Pvt. Ltd.

141-B, Electronic Complex, Pardesipura, Indore- 452 010 India, **Tel.:** 91-731- 4211500, **Telefax:** 91-731-4202959, **Toll free:** 1800-103-5050, **E-mail:** info@nvistech.com
Website: www.nvistech.com

Joule's Constant Measurement Setup
(By Electrical Method)
NV6054

Table of Contents

Introduction

NV6054 Joule's Constant Measurement (By Electrical Method) works on the principle of low of conservation of energy. It uses Electrical energy to rise the temperature of a known mass of water inside a calorimeter. The electrical energy provided is equal to heat produced if very less or no energy is lost to the atmosphere. So by measuring the temperature rise corresponding to current passed for specific time and voltage. We can determine the joule's constant. It consists of measurement unit with LCD display with the help of which voltage, current and time are displayed simultaneously.

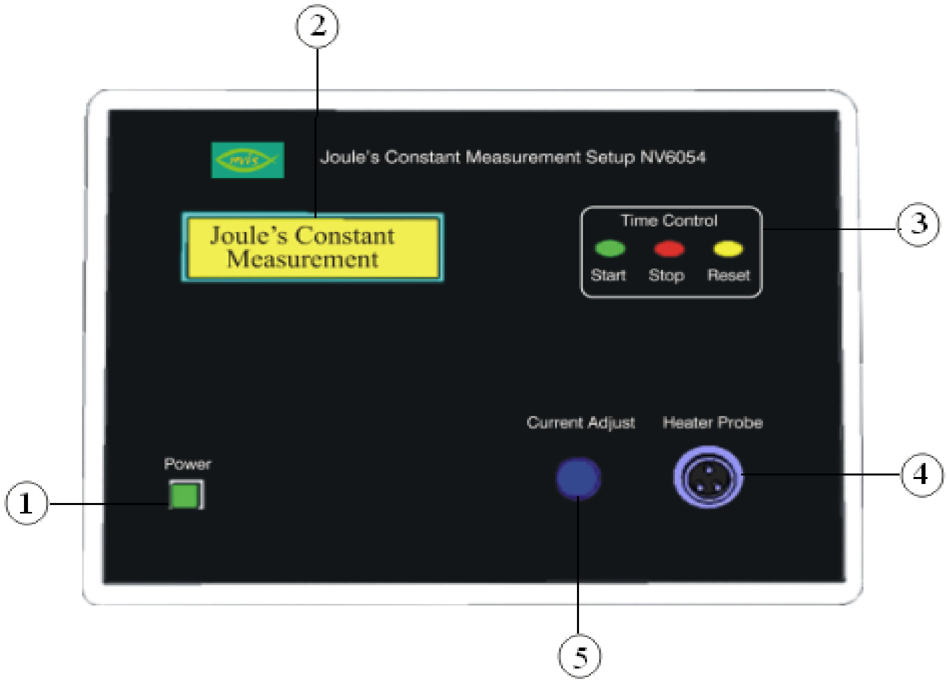
Features

- **Complete setup for measuring Joule's Constant**
- **Constant current source with LCD display**
- **Calorimeter to prevent heat loss**
- **LCD Display**
- **Learning Material**
- **2 Year Warranty**

Technical Specifications

Calorimeter		
Material	:	Copper Container
Volume	:	140 ml
Coil		
Material	:	Nichrome
Resistance	:	5 E
Thermometer		
Least Count	:	1^0C
Maximum Range	:	110^0C
Display	:	LCD
Power Supply		
Input	:	230 ± 10V / 50Hz
Output	:	0-11V / 0-1.5A
Accuracy	:	0.1% of reading 1 digit
Dimension (mm)	:	H 120 X W 220 X L

Front Panel of Measurement Unit



1. **Power Switch:** It is power On/Off switch
2. **LCD Display:** It displays Current, Voltage and Timer
3. **Time Control:** It has following functions for timer:
    - **Start :** To start the timer
    - **Stop :** To stop the timer
    - **Reset :** To reset the timer
4. **Heater Probe Socket:** It is input socket for providing supply to coil
5. **Current Adjust Pot:** With the help of this pot adjust the heater current

Theory

Energy

In physics, energy is a quantity that is often understood as the ability a physical system has to produce changes on another physical system.

The changes are produced when the energy is transferred from a system to another. A system can transfer energy by means of three ways, namely: physical or thermo dynamical work, heat transfer, or mass transfer.

Different forms of Energy

Kinetic Energy:

Consider a baseball flying through the air. The ball is said to have "kinetic energy" by virtue of the fact that it's in motion relative to the ground. You can see that it has energy because it can do "**work**" on an object on the ground if it collides with it (either by pushing on it and/or damaging it during the collision).

Potential Energy:

Consider a book sitting on a table. The book is said to have "potential energy" because if it is nudged off, gravity will accelerate the book, giving the book kinetic energy. Because the Earth's gravity is necessary to create this kinetic energy, and because this gravity depends on the Earth being present, we say that the "Earth-book system" is what really possesses this potential energy, and that this energy is converted into kinetic energy as the book falls.

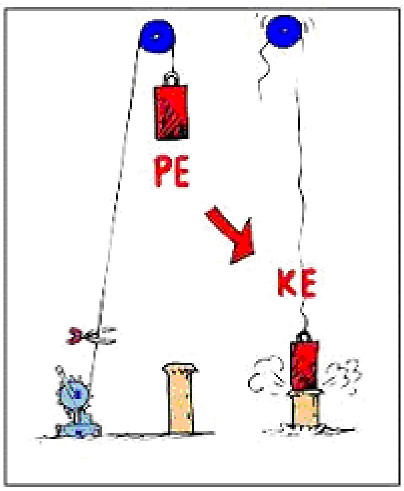


Figure 1

Thermal or heat energy:

Consider a hot cup of coffee. The coffee is said to possess "thermal energy", or "heat energy" which is really the collective, microscopic, kinetic and potential energy of the molecules in the coffee (the molecules have kinetic energy because they are moving and vibrating, and they have potential energy due their mutual attraction for one another - much the same way that the book and the Earth have potential energy because they attract each other). Temperature is really a measure of how much thermal energy something has. The higher the temperature, the faster the molecules are moving around and/or vibrating, i.e. the more kinetic and potential energy the molecules have.

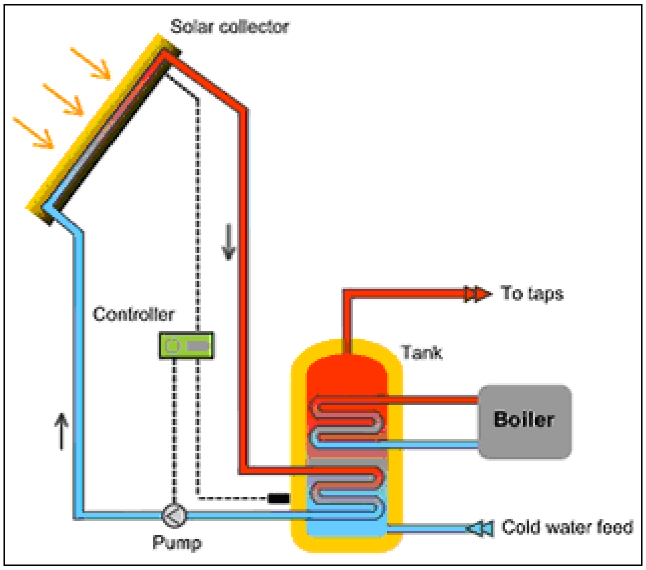


Figure 2

Chemical Energy:

Consider the ability of your body to do work. The glucose (blood sugar) in your body is said to have "chemical energy" because the glucose releases energy when chemically reacted (combusted) with oxygen. Your muscles use this energy to generate mechanical force and also heat. Chemical energy is really a form of microscopic potential energy, which exists because of the electric and magnetic forces of attraction exerted between the different parts of each molecule - the same attractive forces involved in thermal vibrations. These parts get rearranged in chemical reactions, releasing or adding to this potential energy.

Electrical Energy

All matter is made up of atoms, and atoms are made up of smaller particles, called protons (which have positive charge), neutrons (which have neutral charge), and electrons (which are negatively charged). Electrons orbit around the center, or nucleus, of atoms, just like the moon orbits the earth. The nucleus is made up of neutrons and protons.

Some material, particularly metals, has certain electrons that are only loosely attached to their atoms. They can easily be made to move from one atom to another if an electric field is applied to them. When those electrons move among the atoms of matter, a *current* of electricity is created.

This is what happens in a piece of wire when an electric field, or *voltage*, is applied. The electrons pass from atom to atom, pushed by the electric field and by each other (they repel each other because like charges repel), thus creating the electrical current. The measure of how well something conducts electricity is called its *conductivity*, and the reciprocal of conductivity is called the *resistance*. Copper is used for many wires because it has a lower resistance than many other metals and is easy to use and obtain. Most of the wires in your house are made of copper. Some older homes still use aluminum wiring.

The energy is really transferred by the chain of repulsive interactions between the electrons down the wire - not by the transfer of electrons. This is just like the way that water molecules can push on each other and transmit pressure (or force) through pipe carrying water. At points where a strong resistance is encountered, its harder for the electrons to flow - this creates a "back pressure" in a sense back to the source. This back pressure is what really transmits the energy from whatever is pushing the electrons through the wire. Of course, this applied "pressure" is the "voltage".

As the electrons move through a "resistor" in the circuit, they interact with the atoms in the resistor very strongly, causing the resistor to heat up - hence delivering energy in the form of heat. Or, if the electrons are moving instead through the wound coils of a motor, they instead create a magnetic field, which interacts with other magnets in the motor, and hence turns the motor. In this case the "back pressure" on the electrons, which is necessary for there to be a transfer of energy from the applied voltage to the motor's shaft, is created by the magnetic fields of the other magnets (back) acting on the electrons - a perfect push-pull arrangement!

Electrochemical Energy:

Consider the energy stored in a battery. Like the example above involving blood sugar, the battery also stores energy in a chemical way. But electricity is also involved, so we say that the battery stores energy "electro-chemically". Another electron chemical device is a "fuel-cell".

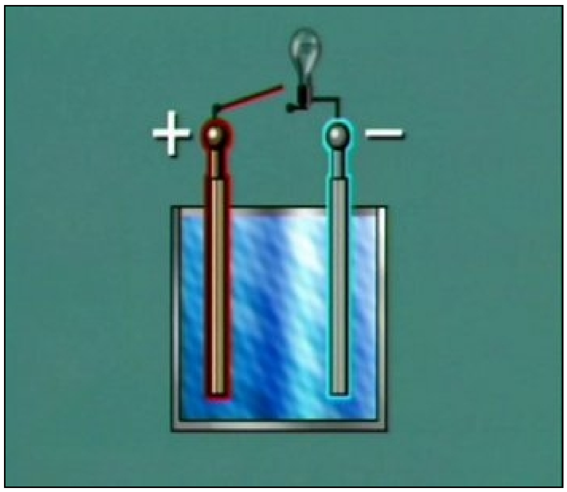


Figure 3

Sound Energy:

Sound waves are compression waves associated with the potential and kinetic energy of air molecules. When an object moves quickly, for example the head of drum, it compresses the air nearby, giving that air potential energy. That air then expands, transforming the potential energy into kinetic energy (moving air). The moving air then pushes on and compresses other air, and so on down the chain. A nice way to think of sound waves is as "shimmering air".

Nuclear Energy:

The Sun, nuclear reactors, and the interior of the Earth, all have "nuclear reactions" as the source of their energy, that is, reactions that involve changes in the structure of the nuclei of atoms. In the Sun, hydrogen nuclei fuse (combine) together to called make helium nuclei, in a process fusion, which releases energy. In a nuclear reactor, or in the interior of the Earth, Uranium nuclei (and certain other heavy elements in the Earth's interior) split apart, in a process called fission. If this didn't happen, the Earth's interior would have long gone cold! The energy released by fission and fusion is not just a product of the potential energy released by rearranging the nuclei. In fact, in both cases, fusion or fission, some of the *matter* making up the nuclei is actually converted into *energy*. As *matter itself is a form of energy!* This concept involves one of the most famous formulas in physics, the formula

$$E=mc^2$$

This formula was discovered by Einstein as part of his "Theory of Special Relativity". In simple words, this formula means:

The energy intrinsically stored in a piece of matter at rest equals its mass times the speed of light squared.

When we plug numbers in this equation, we find that there is actually an incredibly huge amount of energy stored in even little pieces of matter (the speed of light squared is a very large number!). For example, it would cost more than a million dollars to buy the energy stored intrinsically stored in a single penny at our current (relatively cheap!) electricity rates. To get some feeling for how much energy is really there, consider that nuclear weapons only release a small fraction of the "intrinsic" energy of their components.

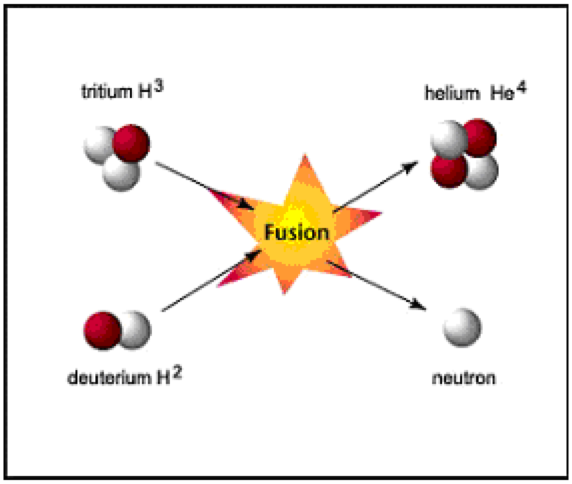


Figure 4

Heat

Heat is defined as thermal energy in transit. Scottish physicist James Clerk Maxwell, in his 1871 classic Theory of Heat, was one of the first to enunciate a modern definition of heat. Maxwell outlined four stipulations for the definition of heat:

- It is something which may be transferred from one body to another, according to the second law of thermodynamics.
- It is a measurable quantity, and thus treated mathematically.
- It cannot be treated as a substance, because it may be transformed into something that is not a substance, e.g., mechanical work.
- It is one of the forms of energy

Heat flows between systems that are not in thermal equilibrium with each other. It flows spontaneously from the areas of high temperature to areas of lower temperature. When two bodies of different temperature come into thermal contact, they exchange thermal energy, i.e. heat, until their temperatures are equal, that is until they reach thermal equilibrium.

The first law of thermodynamics states that the energy of an isolated system is conserved. Therefore, to change the energy of a system, energy must be transferred to or from the system. Heat and work are the only two mechanisms by which energy can be transferred. Work performed on a body is, by definition, an energy transfer to the body that is due to a change to external parameters of the body, such as the volume, magnetization, center of mass in a gravitational field. Heat is the energy transferred to the body in any other way. In the case of bodies close to thermal equilibrium where notions such as the temperature can be defined, heat transfer can be related to temperature difference between bodies. It is an irreversible process that leads to the bodies coming closer to mutual thermal equilibrium. Human notions such as hot and cold are relative terms and are generally used to compare one object's temperature to another or its surroundings.

Definitions

Several modern definitions of heat are as follows:

- The energy transferred from a high-temperature object to a lower-temperature object is called heat.
- Any spontaneous flow of energy from one object to another caused by a difference in temperature between the objects is called heat.
- In a thermodynamic sense, heat is never regarded as being stored within a body. Like work, it exists only as energy in transit from one body to another or between a system and its surroundings. When energy in the form of heat is added to a system, it is stored as kinetic and potential energy of the atoms and molecules making up the system

Notation and units

The unit for the amount of energy transferred by heat in the International System of Units (SI) is the joule (J), though the British Thermal Unit (BTU) and the calorie are still used in the United States. The unit for the rate of heat transfer is the watt (W = J/s).

The total amount of energy transferred as heat is conventionally abbreviated as Q. The conventional sign convention is that when a body releases heat into its surroundings, $Q < 0$ (negative); when a body absorbs heat from its surroundings, $Q > 0$ (positive). Heat transfer rate, or heat flow per unit time, is denoted by:

$$\dot{Q} = \frac{dQ}{dt}$$

It is often measured in watts. Heat flux is defined as rate of heat transfer per unit cross-sectional area, and is denoted q, resulting in units of watts per square metre.

Specific heat

Specific heat is defined as the amount of energy that has to be transferred to or from one unit of mass or mole of a substance to change its temperature by one degree. Specific heat is a property, which means that it depends on the substance under consideration and its state as specified by its properties. Fuels, when burned, are converted to molecules with a lower internal energy. The change in energy is heat. Upon changing from one phase to another, a pure substance releases or absorbs heat without its temperature changing. The amount of heat transfer during a phase change is known as latent heat and depends primarily on the substance and its state.

The specific heats of monatomic gases (e.g., helium) are nearly constant with temperature. Diatomic gases such as hydrogen display some temperature dependence and triatomic gases (e.g., carbon dioxide) still more.

Calorimeter

Principal of calorimeter

A simple calorimeter is a vessel generally made of copper with a stirrer of the same material. The vessel is kept in a wooden box to isolate it thermally from the surrounding. A thermometer is used to measure the temperature of the contents of the calorimeter.

Objects at different temperature are made to come in contact with each other in the calorimeter. As a result, heat is exchanged between the objects as well as with the calorimeter. Neglecting any heat exchange with the surrounding, the principle of calorimeter states that the total heat given by the hot object equals the total heat received by the cold objects.

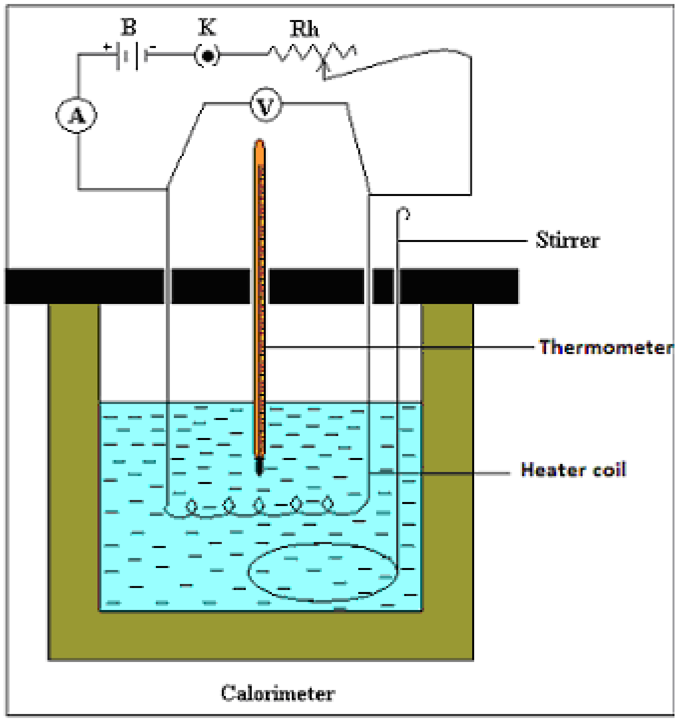


Figure 5

Calorimeter constant:

Calorimetry is the measurement of the amount of heat gained or lost during some particular physical or chemical change. Heats of fusion or vaporization, heats of solution and heats of reaction are examples of the kinds of determination that can be made in calorimetry. The term itself derives the Latin word for heat, caloric, as is the name of the instrument used to make these determinations, the calorimeter.

Calorimeter constant (denoted C cal) is a constant that quantifies the heat capacity of a calorimeter. It may be calculated by applying a known amount of heat to the calorimeter and measuring the calorimeter's corresponding change in temperature. In SI units, the calorimeter constant is then calculated by dividing the change in enthalpy (ΔH) in joules by the change in temperature (ΔT) in kelvins or degrees Celsius:

$$C_{cal} = \frac{\Delta H}{\Delta T}$$

The calorimeter constant is usually presented in units of joules per degree Celsius (J/°C) or joules per kelvin (J/K). Every calorimeter has a unique calorimeter constant.

Low of conservation of energy

The **law of conservation of energy** is an empirical law of physics. It states that the total amount of energy in an isolated system remains constant over time (is said to be *conserved* over time). A consequence of this law is that energy can neither be created nor destroyed: it can only be transformed from one state to another. The only thing that can happen to energy in a closed system is that it can change form: for instance chemical energy can become kinetic energy.

Albert Einstein's theory of relativity shows that energy and mass are the same thing, and that neither one appears without the other. Thus in closed systems, both mass and energy are conserved separately, just as was understood in pre-relativistic physics. The new feature of relativistic physics is that "matter" particles (such as those constituting atoms) could be converted to non-matter forms of energy, such as light; or kinetic and potential energy (example: heat). However, this conversion does *not* affect the total mass of systems, since the latter forms of non-matter energy still retain their mass through any such conversion[1]

Today, conservation of "energy" refers to the conservation of the total system energy over time. This energy includes the energy associated with the rest mass of particles and all other forms of energy in the system. In addition, the invariant mass of systems of particles (the mass of the system as seen in its center of mass inertial frame, such as the frame in which it would need to be weighed) is also conserved over time for any single observer, and (unlike the total energy) is the same value for all observers. Therefore, in an isolated system, although matter (particles with rest mass) and "pure energy" (heat and light) can be converted to one another, both the total amount of energy and the total amount of mass of such systems remain constant over time, as seen by any single observer. If energy in any form is allowed to escape such systems (see binding energy), the mass of the system will decrease in correspondence with the loss.

A consequence of the law of energy conservation is that perpetual motion machines can only work perpetually if they deliver no energy to their surroundings.

Principal of Joule's calorimeter

By the low of conservation of energy, mechanical energy (or work) can be completely converter into heat. If H heat is obtained from W joule work then

$$W = JH$$

Or,

$$H = \frac{W}{J} \quad \text{.......... (1)}$$

Where J is a constant, which is called the mechanical equivalent of heat (or joule constant)

Now if current I amp is passed for t sec under a potential difference of V volt through a conducting coil, the charge passed through the coil in t sec is

$$Q = I \times t \quad \text{coulomb.}$$

Work done in passing Q coulomb charge under a potential difference of V volt is

$$W = QV$$

$$Or$$

$$W = ItV$$

And if H cal heat is produced from this work, then eq^n. (1)

$$H = \frac{VIt}{J} \quad \text{..........(2)}$$

To find the amount of heat, the coil is kept immersed in water contained in a calorimeter and the increase in temperature of calorimeter and water is measured. If mass of calorimeter with stirrer is m gm, the specific heat of its material(copper) is s Cal/gm ^oC, The amount of water taken in calorimeter is m_1 gm, specific heat water is 1 cal/gm ^0C, Initial temperature of water is $\theta_1\ ^0C$ and final temperature of water is $\theta_2\ ^0C$, then

Heat produced H = heat taken by the calorimeter +heat taken by water

$$= ms(\theta_2 - \theta_1) + m_1(\theta_2 - \theta_1) \text{ Cal}$$

$$= (ms\text{-}m_1)(\theta_2 - \theta_1) \text{ Cal} \quad \text{..........(3)}$$

From eqn (2) and (3)

$$(ms-m_1)\ (\theta_2 - \theta_1) = \frac{VIt}{J}$$

Or,

$$J = \frac{VIt}{(ms - m_1)(\theta_2 - \theta_1)} \text{ Joule/cal}$$

Where,

V = Potential difference at the ends of coil (in volt)

I = Current in coil (in amp)

t = Time of passage of current in the coil (in sec)

m = Mass of calorimeter with stirrer (in gm)

s = Specific heat of calorimeter (in cal/gm ^{0}C)

m_1 = Mass of water taken n calorimeter (in gm)

θ_1 and θ_2 = Initial and final temperature of water (in ^{0}C)

Using the above formula the value of j is calculated

Experiment 1

Objective:

To determine mechanical equivalent of heat (J) joule's constant by electrical method.

Equipments Needed:

1. Calorimeter with Stirrer
2. Thermometer
3. Mains Cord

Arrange the following equipments from your laboratory:

4. Physical Balance
5. Water (approx. 200 ml)

Procedure:

1. First of all weight the copper container of calorimeter along with stirrer on physical balance and note its mass **m**.
2. Place the copper container in side the calorimeter & fill the sufficient water in it, such that the heater coil gets fully immersed in water.
3. Take the stirrer and fix it on the coil & stirrer arrangement with the help of stirrer cap as shown in the below figure.

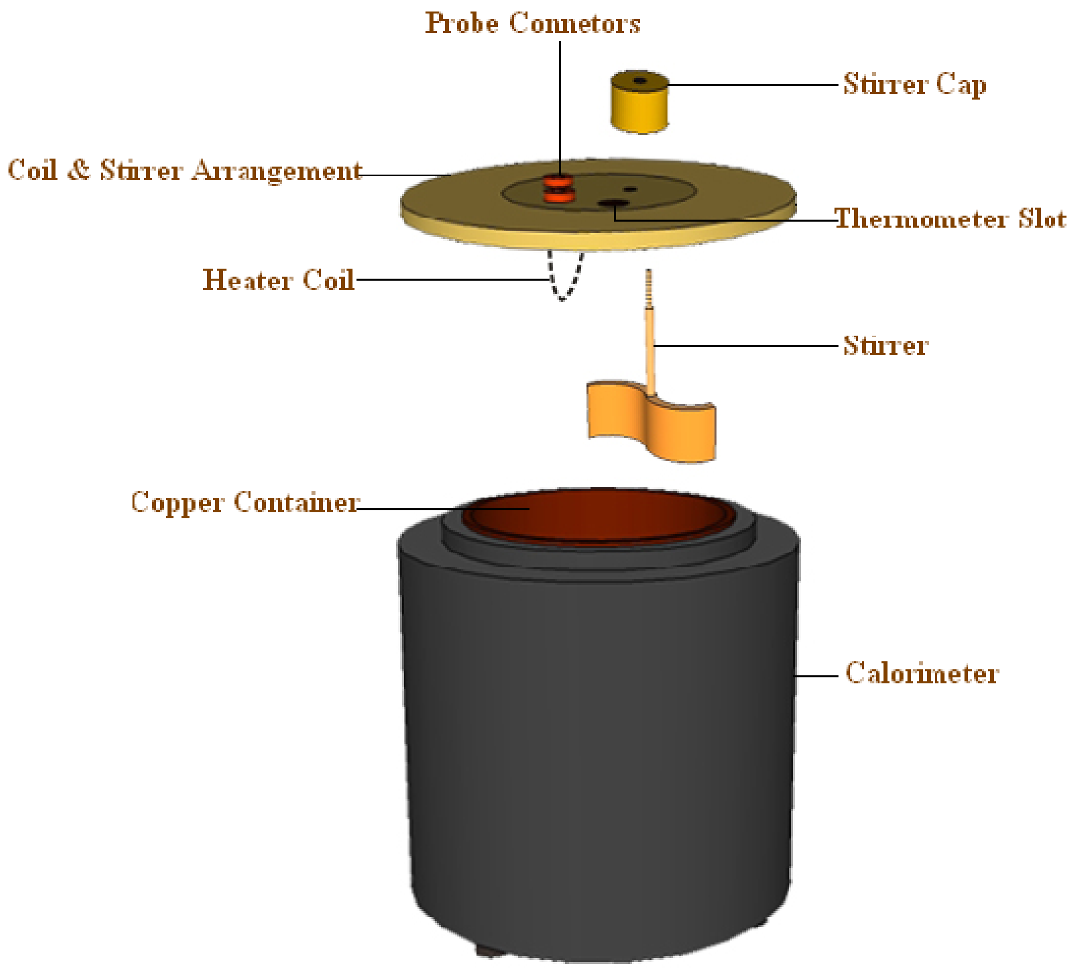


Figure 6

4. Now place the complete coil & stirrer arrangement on the calorimeter such that the coil gets immersed in it.
5. Now take the Joule's Constant Measurement Unit and connect it to mains supply with the help of mains cord.
6. Now connect the calorimeter and the Joule's Constant Measurement Unit with the help of heater probe as shown in figure below.
7. Also place the thermometer in its slot as shown in figure below.

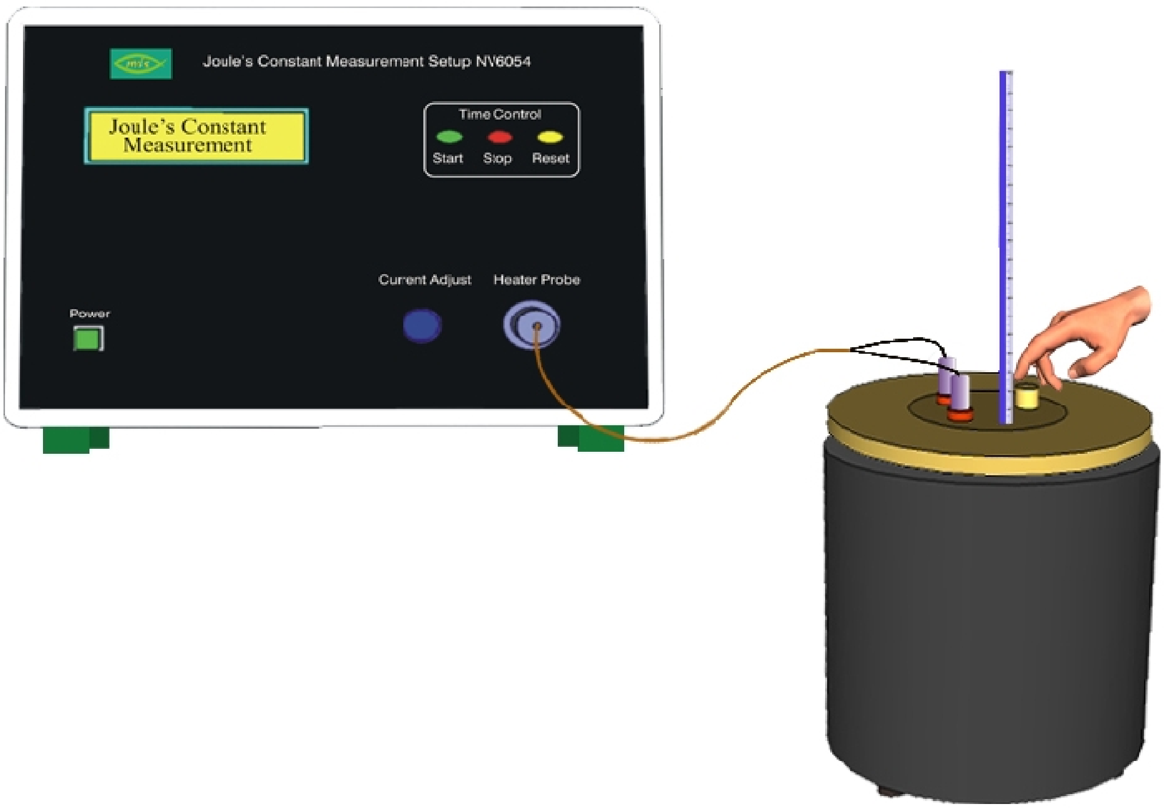


Figure 6

8. Now set the value of current with the help of **Current Adjust** knob (say 1A). Now stir the water manually using stirrer cap.

Note: Perform the experiment in 1A to 1.4A range.

9. Note the initial value of temperature along with voltage and current in the below observation table at time t =0.
10. After note down the initially reading, at once press the **Start** switch till the timer starts.
11. Note the value of voltage, current and time for every 1^0C rise in temperature, till the temperature of water rises with, near about 5^0 C. Take care water is stirred continuously.
12. Stop supplying current through the heater coil with the help of **Current Adjust** knob as well as press stop switch till the timer stop & note the time **t** taken to rises the temperature of water by 5^0C.

13. Now let the water cool for the same time **(t)** that is being taken for rising the temperature of water by 5^0 C and note the final temperature after cooling say $\boldsymbol{\theta}''$.

14. Now again weight the copper container of calorimeter with water & stirrer find its weight **M**.

15. Now take the mean of voltage and current.

Observation Table:

Sr. No.	Voltage (in Volt)	Current (in Ampere)	Time (in Second)	Temperature (^{0}C)
1.				= θ_1 (Initial Temperature)
2.				= θ_1+1
3.				= θ_1 +2
4.				= θ_1+3
5.				= θ_1+4
6.			= t (Final Time)	= θ_1+5 (Final Temperature θ')

Mass of calorimeter and stirrer **m** = ………..…gm

Mass of calorimeter, stirrer and water **M** =…….gm

Note the final time **t** for which the current is passed =……...Sec

Temperature of water after cooling it for time t sec $\boldsymbol{\theta}''$=……^{0}C

Calculation:

Mass of water in the calorimeter $\mathbf{m_1}$= **M-m** =……….gm

Final temperature of water after applying correction $\theta_2 = \theta' + \dfrac{\theta' - \theta''}{2}$ =……^{0}C

Mean Voltage = ……...V

Mean Current =………A

Formula Used:

$$J = \frac{VIt}{(ms + m_1)(\theta_2 - \theta_1)} = \text{..........Joule/Cal}$$

Where,

V= Mean Voltage (in Volt), **I** = Mean Current (in Amp), **t** = Final Time (Sec),

m= Mass of calorimeter (in gm), **s** = Specific heat of material of calorimeter 0.093 Cal/gm ^{0}C

$\mathbf{m_1}$= Mass of water in calorimeter (in gm), $\boldsymbol{\theta_1}$ and $\boldsymbol{\theta_2}$= Initial and final temperature (in ^{0}C)

16. Put all the values in the above formula and determine the value of Joule's Constant

17. Standard value of joules constant = 4.18 Joules /Cal

$$\text{Persentage Error}\,\% = \frac{\text{standard value} - \text{experimental value}}{\text{standard value}} \times 100\%$$

Warranty

1) We guarantee the instrument against all manufacturing defects during 24 months from the date of sale by us or through our dealers.

2) The guarantee covers manufacturing defects in respect of indigenous components and material limited to the warranty extended to us by the original manufacturer, and defect will be rectified as far as lies within our control.

3) The guarantee does not cover perishable item like transistor etc. other imported components.

4) The guarantee will become **INVALID.**

- **a)** If the instrument is not operated as per instruction given in the learning material.
- **b)** If the agreed payment terms and other conditions of sale are not followed.
- **c)** If the customer resells the instrument to another party.
- **d)** Provided no attempt have been made to service and modify the instrument.

5) The non-working of the instrument is to be communicated to us immediately giving full details of the complaints and defects noticed specifically mentioning the type & sr. no. of the instrument, date of purchase etc.

6) The repair work will be carried out, provided the instrument is dispatched securely packed & insured with the railways. To and fro charges will be to the account of the customer.

List of Service Center

Baroda
Flat No. A/1, Mudra Complex, Behind Sudha Hotel, Ellora Park, Baroda-390023 (Gujarat)
Tel: +91-0265-3089505
Fax : +91- 0265-3089506
email : baroda@scientech.bz

Guwahati
Avijit Roy Building, A.K. Dev Road, Fatashil Ambari, Near jalaram Mandir, Guwahati-25 Assam
Mobile: 09435144068
email: guwahati@scientech.bz

Indore
94, Electronic Complex, Pardesipura, Indore-452 010
Tel: 91-731-2570301/02, 4211100,
Fax: 91-731-2555643
E-mail: info@scientech.bz

New Delhi
First Floor, C-19, F.I.E., Patparganj Industrial Area, Delhi-110092 (INDIA)
Ph: 011- 22157370, 22157371,
Fax: +91-011-22157369
email: ndel@scientech.bz

Bangalore
202/19, 4th Main Street, Ganganagar, Bangalore - 560032
Ph.: +91-080-41285011
T.Fax: +91-080-41285022
email: bangalore@scientech.bz

Kolkata
AC-101, Prafullla Kanan, Near Kestopur Bus Stop, Krishnapur, Kolkata- 700059 (West Bengal)
Tel: +91 33-65266800
Mob: 9433029888
email: kolkata@scientech.bz

Mumbai
E Type, Bldg No. 5/1/3, Sector 1,Vashi, Navi Mumbai-400703
Ph: +91-022-27826616, 65266616
email: mumbai@scientech.bz

Jaipur
Flat No. G-2, S-101, Bhagat Vatika North, Civil Lines, Jaipur - 302006 (Raj.)
Mobile: 097998-10236
email: jaipur@scientech.bz

Lucknow
First Floor, 279/54/20/A, Chuhar Singh Colony, Pan Dariba, Lucknow (U.P.)
Mobile: 09918670737
email: lucknow@scientech.bz

Hyderabad
Plot No. 24, Flat no. 203, Laxmi Residency, Chandragiri Housing Society, Trimulgherry Secunderabad- 500015.
Ph:040-27740147,9247712763
email: hyd@scientech.bz

Cochin/Kochi
C/o Pragalbha Valsan, Poriyam-adathil house, ABMS Lane, Asoka Road, Near Mathrubhumi, Kaloor, Kochi-682 017
Ph: 0484-2409441
email: kochi@scientech.bz

Chandigarh
201, 2nd floor KMB Hospitality Services, SCO 19, Near Kabir Petrol Pump, Ambala-Zirakpur Highway Zirakpur, Mohali - 140603
Ph.: 0172-6530329
email: chandigarh@scientech.bz

Pune
105/106, 1st floor, Ajinkyatara, Ganesh Mala, Sinhgad Road, Pune - 411030
Ph.: +91-020-24254244/55
Fax: +91-020-24254244
email: pune@scientech.bz

Chennai
Flat C, 1st Floor, Old No. 49 New No. 64, Bajanai Koil Street, Sriram Nagar Extention, Pallipattu, Chennai-600113
Tel: 044-43514212, 43514213
email: chennai@scientech.bz

Orissa
Plot No-67 (1st Floor) Aerodrom Area,Vimpur mouza Near Vimpur Primary School Bhubaneswar- 751020
Mobile: 09238307873
email: orissa@scientech.bz

List of Accessories

1. Heater Probe ……………………………………………………………..………………………1 No.
2. Thermometer (110^{o}C)……………………………………………………………………………1 No.
3. Calorimeter with Stirrer..……………………………………...…………………………….1 No.
4. Mains Cord………………………………………………………………………………….1 No.