Experimental Physics I
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Lecture – 42
Determination of electrical equivalent of heat

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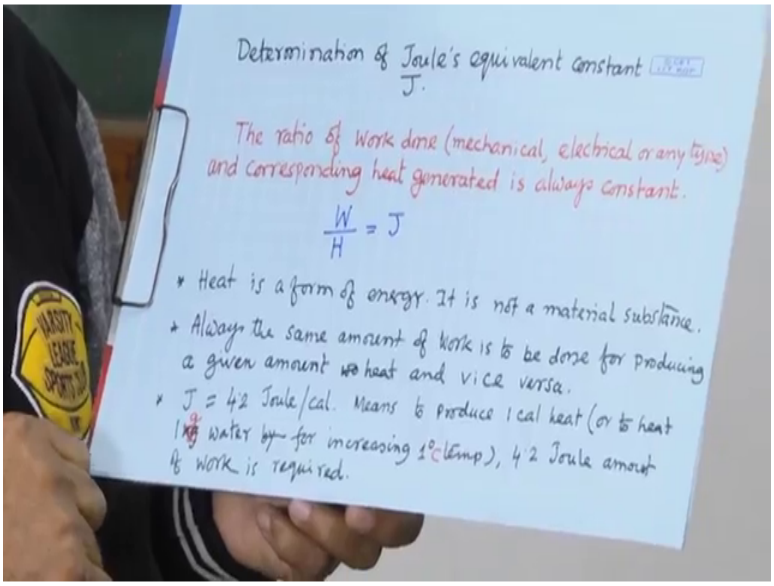

So, today we will demonstrate the experiment from measuring the Joules constant, Joule equivalent constant. You know this the Joules constant or Joules equivalent constant is basically a relation between the work and heat, ok. So, if we perform any work and if that work converted to the to the of energy, so the ratio of the work and the that heat; so this ratio is constant is equal to constant and that constant is we write J, and J is the is the Joules constant, ok. So, it is basically mechanical equivalent constant, J is the mechanical equivalent constant.

So, if work done this if its mechanical work and due to this work if heat is produced, equivalent heat is produced then this how much heat will be produced for this mechanical work. So, if you take this ratio this always constant, this always constant. So, that is why it is a constant and that constant is called Joules constant. So, here basically tells that heat is a form of energy it is not a material substance, ok.

Always the same amount of work is to be done for performing a given amount heat and vice versa, ok. J, J this value is specifically 4.2 Joule calorie, means to produce 1 calorie heat 4.2 Joule amount of work is required, ok. So, 1 calorie heat means, so it will heat 1 gram water for increasing 1 degree centigrade temperature. So, that is the 1 calorie. So, if we you can produce 1 calorie, 1 calorie if heat if for that we have to perform work mechanical work that is 4.2 Joule, ok.

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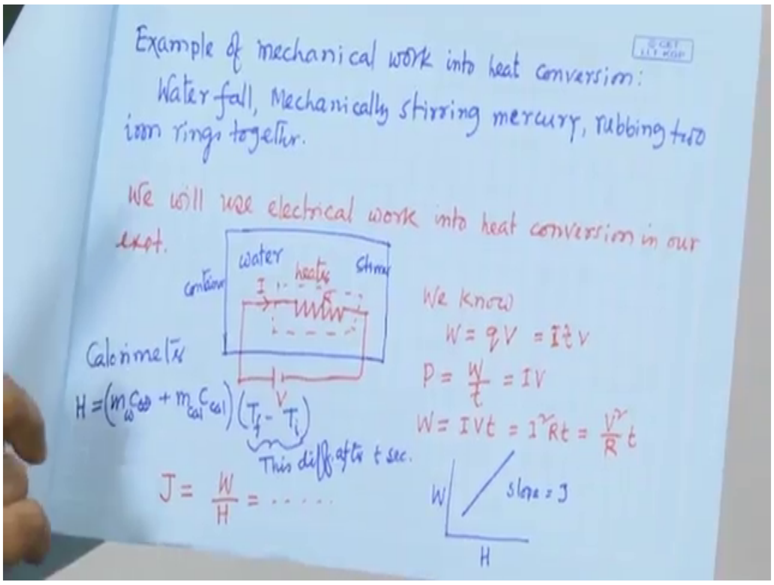

So, here in this lab we will we will perform experiment just we will use electrical electrical work done, electrical energy we will use not mechanical. But example of mechanical work is very common like waterfall if you have seen waterfall, ok, water is falling from mountain to the to the downed. So, it is basically this work done against the gravitation, right. So, that energy will be released and it will be converted to the heat. So, it is expected that water falling down that is temperature will be different from the water at the top of the mountain.

Also mechanically if you are studying the mercury, so we can see the change of temperature of the mercury. So that means, you are studying mercury, so you are doing mechanical work and that mechanical work is converted to the heat. So, because of the heat this temperature will change. And rubbing of two iron ring together, so if rub two rings together then we have seen that there will be or any for we are running if rubbing things between two items, so a heat generates, ok. So, that heat generates because of the mechanical work because you are doing when you are rubbing, so you are doing some mechanical work and that work is converted into heat and because of that heat this temperature changes, right.

So, as I told in our laboratory, we will do we will use basically electrical work and that will be converted into heat. So, what does it mean this electrical work? So, if charge force, if charge moves in a potential then work done is basically Q v, right Q V, Q V is a work done, right. So, that means, if current flows between the potential difference then the work done will be, then the work done will be I t V, V is potential difference voltage and I t is basically Q, I into t time not temperature, I t this the time, ok. So, of course, this if it is this watt and power is W by t, W by t, equal to I V anyway. So, we are interested about this work.

So, now, this W electrical work equal to I V t. So, that I can write V equal to I R, ok. So, if this current passes through resistance under a potential difference V. So, that resistance then I R will be the potential difference V. So, this will be I square Rt or also you can convert this I R equal to V, so this you can write also V square by R t, ok. So, work make electrical work, so that we can write I V t or I square Rt or V square by R t, V square by R t, t is the time.

Now, now for this work if you just convert this work into heat. So, then how we can convert it? So, now, this current we are passing through a heater you know heater, in heater what we do? Just there is a coil, it has resistance R, now we pass current through this coil and the potential difference in the coil two ends is say V. So, then it will, so we are we are we are, so that is basically that heater, now we have seen this we use this heater for heating substance say water, right. That means, current will current will flow through these resistance heaters, coil. So, it produce heat, right it produce equivalent heat.

Now, if I put this heater in water this is the basically calorimeter, if I put this heater in water and then water will we can see this water we can we can, we can see that this temperature of the water will increase, right that means, this work done that is converted to heat and because of this heat that heat absorbed by the water and that because of this heat we will see the change of temperature.

Now, basically to catch this heat, to catch this work done and its converting to the heat using the using the heater coil basically in form of coil. So, this coil if we put in a calorimeter in a calorimeter, so then calorimeter is basically definition calorimeter is it a it has a container and in that container there is a stirrer and there is a arrangement for measuring the temperature and there should not be any thermal conduction with environment, so thermal protection a arrangement is there, right. So, that is the calorimeter. So, we will use calorimeter. So, in calorimeter as I told there will be water in a container which stirrer. So,. So, you know this heat that is m s t or m c t; m is mass, c is specific heat and t is the temperature, right.

So, here I have written. So, mass is for water m w and this c w is the specific heat of water plus mass of calorimeter, calorimeter is basically as I told container and stirrer together is made of some gallium and copper. So, specific heat of that material is copper c calorimeter. So, then we have to note down the temperature difference initial temperature and final temperature. So, this increase of temperature or decrease of temperature whatever, so T f minus T i. So, this will be m s t, m c t.

So, that is the that is the heat H. And this temperature difference will be is because is after time T second. So, what you are doing? So, we will pass current I under the potential difference is V for time t. Before starting this time, what was the temperature of the calorimeter or water in the calorimeter? So, that is T i and after time t that is temperature in T f final temperature, and I have to take mass of calorimeter and mass of water, then I will get H and I will get W, ok.

So, experiment will perform that we will vary will vary. so we will vary the yeah, we will vary the work done and corresponding we note down the corresponding heat, ok. So, how we can vary, so this work done? So, if I take this form. So, that depends on your arrangement, either you are measuring the only voltage or only current. So, depending on the arrangement in our arrangement, so we will measure I V and t, ok. So, we will take this form I V t. So, either we will vary I or V or both or time t, ok.

So, this for 4 5 6 value of this of this I V t or one of them, so that means, we will get 4 5 6 work done and corresponding heat just noting down the temperature difference, for a time t. So, we will get the corresponding heat, ok. So, we will plot W work done versus the heat H, ok.

And now, from this slope. Now, that you have seen this W by H is, W by H is W by H is J, right. So, you have plotting here W versus H. Now, the slope, we will find out the slope of this curve of the straight line basically the slope will give directly the J value. So, as I told J value is 4.2 calorie Joule per calorie. So, here we are expecting this experimental value close to that. So, that is what we will find out.

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So, let us see our experimental setup. So, this is the experimental setup very simple setup. So, what we have to do first let us see this where we will pass current. So, here you can see this is the calorimeter, this is the calorimeter this container, right is made of copper this container because, and we have stirrer here you can see we have stirrer, we have stirrer, this one is stirrer, because we will just start the water. So, this is the stirrer, ok. And this is the thermometer. So, for measuring the temperatures, for measuring the temperature and you can see this is the, this one coil its coil is like heater coil, right.

So, we will pass current through this through this coil, ok. So, we will measure, we will measure the we will measure the, what is this is the multimeter this is the multimeter. So, we will measure the voltage this is. So, we will use as a voltmeter this one in voltmeter mode. So, we will measure the voltage across this across this coil, across this coil and we will pass current this is the constant current source this is the constant current source. So, we will pass current through this through this coil, right. So, we will pass current through this coil I can vary current here and corresponding voltage drop across this resistance R, so that we will note down from here. So, current we will note down from here and voltage we will note down from here, right.

Now, this. So, here we will take water, here we will take water. So, before taking water I have to take weight of this of this of this calorimeter, this we tell together calorimeter, but this beaker this beaker and this stirrer, ok. So, we have to take weight of this one. I think I have to keep properly anyway I will hold it. So, for, so this is the balance digital balance and it has 0.1 is accuracy is 0.1 gram, you have note down because for calculating the error you need.

So, this least count of this of this digital balance is 0.1 gram, ok. So, I have to just take weight of this one. So, this is 44.7, right this 44.7 that you have to note down. So, weight mass of the calorimeter mass of the calorimeter is 44.7 gram, right. Now, what I will do, I will just take water I will take water, so I have to I think yes, I will take water, yes, I have to take water in such a way these are this coil should be inside the water, ok. So, now, I have to take weight of this one, I have to take weight of this one. So, this weight is 141.7 gram, right. So, empty this one was, so now, I can find out the mass of the water. So, this reading minus 47 point something so that minus that 1. So, that will be the mass of water.

So, now, I know the mass of water as well as the mass of the calorimeter beaker and the stirrer together, ok. A specific heat, specific heat of water is 1, 1 calorie per gram per degree centigrade and this is the made of copper, copper is generally 0 point 0.1 you can approximately you can take 1 calorie per gram per degree centigrade, ok. Actual reading I think this is 0.093 calorie per gram per degree centigrade. So, that is for copper. So,. So, I know the mass of water as well as mass of the copper calorimeter, ok.

Now, I have to insert it, I have to insert it, ok. So, let me I think I have to put it first I have to put it first. Yes, I have to just put it, yes. So, we have to be we have to be careful, we have to be careful I think this from top I should insert it, that is the problem. In laboratory always we have to work carefully because this type of things will happen all the time. So, let me cord is not very tight, anyway now looks fine, looks fine. So, so I put stirrer inside, so there from outside I can just start the water. So, now, I will put. So, this coil should not touch coil, should not touch the this body of the calorimeter. So, I think yes, I will put it, ok. So, looks fine, looks fine.

So, just I will check it whether its where is this whether any short, in resistance I will go yeah resistance 0, fine. So, its kilo not 0 resistance should be 0 there should be some resistance it is a Ohm, ok, ok. It is showing resistance 2.2, 2.2 Ohm so that means, our coil is not touching the body, ok. Then what I will do? So, these I will put you see this is the thermally, thermal insulator I will put inside of it, ok. So, I have to take reading from the yes, yes, I have put it, ok. So, I will be able to stir it, I will be able to stir it and this is connection is fine this showing 2.1 Ohm my resistance of this coil, ok.

Now, I have to note down the temperature. Temperature I can see is 20 degree centigrade, ok. So, initial temperature is 20 degree centigrade. I know the mass of water, mass of this calorimeter which stirrer, ok. Now, I will pass current through it, and current the reading I will get from here and voltage across this across this coil I will note done from here. So, I will go back to the go back to the voltage mode, ok.

So, its I kept it 2 volt let us see. So, 2 or 20, 20 volt range I will keep it, ok. So, so this then we have we will note down this voltage, and I have to I will put some current and immediately I have to start my watch, because current will pass through this coil I, this voltage V and this time for how long we are allowing current through this coil. So, that I have to note down. So, that would be I V t, ok.

So, in this experiment generally what we will do, I have to I have to vary I V t means w, ok. So, we will keep this current fixed and we will vary this time we will vary the time, ok. So, each time will change the water, each time will change the water. Again, we will start this from this initial temperature or close to this temperature what. Now, we have seen 20 degree centigrade, or we can take other temperature different temperature also, but I will just show one experiment and you have to continue you have to continue this experiment you have to repeat this experiment for different time, ok. At least for 5, 5 times, 5 different time keeping this current constant and voltages will be more or less constant, ok.

So, then basically I am varying the t that means, I V t is varying, W is varying. So, for 5 5 W I will get this corresponding H and then I will plot it. So, I will just show you how to take one data, one set of data and the rests you have to repeat and plot the graph and directly the slope of the graph will give me the give me the value of J.

So, let me keep watch ready. I think this watch have some problem, ok. So, sometimes its working, fine. It is a 0. This watch you can see this reading in 0. I will start and stop, ok.

So, let me apply current first. So, switch is in here, on switch I have. So, here current also 0, voltage also 0, temperature is 20 degree centigrade.

So, now I have to I have to change the current I think here I have to change the current. So, let me keep it at say 1, 1 ampere or 2 ampere nearly, ok. Then, otherwise I have to longer time, so I will kept at 2 ampere, right. 2 ampere, I have to note down current 2 ampere I will start this my, so it will take time to start this watch has some problem, ok. I have to take another watch, ok.

So, I will start this watch time, so which is 0, then I have start it, ok. So, I should start immediately, ok. So, I have started my watch. So, I have to note down this current 2.00 volt, 2.00 volt, right sorry ampere 2.00 ampere and voltage is 3.35 volt, these 3.35 volt and I have to stir you know continuously. Otherwise, this heating will not be uniform and temperature will not be uniform of this. So, I have to stir continuously and I have to watch the change of temperature it was 20. Now, it is it seems 21, 22, ok. So, at least I will I will take 10 degree difference. Let us see how much time it is taking, ok.

So, 4 degree, 5 degree you can take also. So, depending on time how much time it is taking. So, because resistance is small to around 2.2 Ohm. So, this I have to; so just you have to keep watch of this one, you have to keep watch of this one, ok. So, this, ok, so reading I think you can see now, this 20 is 22, around 22 time is one this 2 second, 2 minute time is over yes; 2 minutes, 7, 8 second, 9 second, 10 second. So, but this watch will do it will it will tell me final time. So, I have to it is 23 it seems, it is 23, ok.

So, it is taking time for time to, ok. So, its around 20, 24, its around 24. So, just you take you if you want to take time difference more say 25, generally 3 4 5 degree if difference if you take that, so that is also good enough. So, now, 3 minute 28 second and fractional one also. So, I will stop and then final reading I will take from this watch. So, I have note down current is 2 ampere, voltage is 3.35 volt its volt and initial reading was 20, now it is 24; now it is 24 I will stop it, ok. So, now, this time this 3 minutes means 3 into 60, 180; 180 second plus 54 second, 180 plus 54 that means, 234.53, ok, 0.53.

So, this least count of this watch is 0.01 second that you have to note down and here is the least count is it is a two order. So, its I think 10 milliampere. So, 10 milliampere this least count of this one and least count of this one also 10 milli volt, ok. So, this you know I, you know t, you know V, you know t. So, I V t equal to W, right, equal to W. So, W you know, and here from H you will know from here as I showed you as I showed you. Now, let me just stop it. Let me just stop it.

So, I have reading now. So, you know the you know, so now, you know the W, you know the W, right I V and t we have noted down, we have noted down, right. So, W for this W what is H, that you will get here, you will get from here. So, m water mass of water you know and mass of calorimeter that you know you have noted down, right you have noted down.

So, as I told this specific heat of this you will take 0.1 calorie per gram per degree centigrade, for water it is 1 calorie per gram per degree centigrade, mass we have noted down, mass of water, mass of calorimeter, initial and final temperature we have noted down, 24 final temperature, initial temperature is 20, 20. So, now, from here you will get H, ok. So, on this, so you have to plot curve. So, one point you got.

Now, for second point, for second point just as I told this either you can change the water or or you can start from here, ok. Now, you stopped. Now, I will again note down the temperature and I will start, just switch on it. I will just I will note down this temperature it is still 20. Now, it is 25, it is 25 I will note down this one, ok. Now, I will just start it, ok. Now, my I will start and I will start my stopwatch, ok. I will start my stopwatch, ok. So, I should start immediately. So, if I start. So, then I will, so starting temperature was initial 25 then I let me wait for temperature around 30, for this I will note down time and I keep this current and voltage same, only I will vary the time.

So, earlier this time was how much? This 3 3 second 3 minutes 50 50 50 54 54 second, ok. So, now, I will increase the time, I time now 3 second it was now, I will make it 4 second sorry 4 minute, ok, then next reading for 5 minutes, then next reading for 6 minutes, keeping this. So, I will not down initial temperature and final temperature. Then I can I can get 5 5 sets of data and for I will plot it and from this slope I will find out the J value, ok. So, this is very simple experiment. This is very simple experiment, but one has to do very carefully and starting the watch at right time and noting down the, noting down the temperature and you have to stir it continuously. So, depending on this your skill accuracy will depend, ok.

So, generally in our lab we get this value is close to the 4.1, ok. So, because this is slightly less than this 4.2 because is may not be perfectly this radiation protected, ok. So, some heat is lost, ok. So, it is not very ideal, so that is why you will lose some heat, ok. So, that is why we will get these values slightly less than actual value 4.2.

But this is a very good demonstration of the of this experiment how electrical work is convert into heat, and also whether its mechanical energy or electrical energy. This conversion of, conversion also this ratio of this of this work done and the corresponding heat this all the time it is constant, and that is the Joule constant J and this that is what we demonstrate here.

So, I will stop here.

Thank you.