SCHEME :K

Name :______________________________
Roll No.:_________ Year : 20 ___ 20 __
Exam Seat No. :______________________

LABORATORY MANUAL FOR

ALTERNATIVE ENERGY SOURCES AND ENERGY MANAGEMENT (316364)

MECHANICAL ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)

Maharashtra State
Board of Technical Education, Mumbai

VISION:

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION:

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

A Practical Manual for

Alternative Energy Sources and Energy Management (316364)

Semester – VI

“K- SCHEME”

Diploma in Mechanical Engineering

Maharashtra State Board of Technical Education, Mumbai

(Autonomous) (ISO 21001:2018) (ISO/IEC 27001:2013)

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

(Autonomous) (ISO 21001:2018) (ISO/IEC 27001:2013)

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MAHARASHTRA STATE
BOARD OF TECHNICAL EDUCATION

Certificate

This is to certify that Mr. / Ms ....Roll No……………………….of Sixth Semester of Diploma in ……………………………………………………….of **Institute Name:** ……………………………………………………………….. (**Institute Code** :………………..) has completed the term work satisfactorily in course **Alternative Energy Sources and Energy Management (316364)** for the academic year 20…… to 20…..... as prescribed in the curriculum.

Place: ………………. Enrollment No.: …………………

Date: …..................... Exam Seat No.: …………………...

Course Teacher **Head of the Department** **Principal**

Seal of the Institute

Preface

The primary focus of any engineering laboratory/ field work in the technical education system is to develop the much-needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programmes with National Education Policy 2020 (NEP-2020) and outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher; instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through 'chalk and duster' activity in the classroom situation. Accordingly, the 'I' scheme laboratory manual development team designed the practical to ***focus*** on the ***outcomes***, rather than the traditional age old practice of conducting practical to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

A comprehensive understanding of energy audit practices, determination of lux values, the CUSUM technique, and various non-conventional energy sources such as the measurement of parameters of solar modules, solar dryers, solar cookers, biofuels, hydrogen fuel cells, geothermal power plants, ocean thermal power plants, and wind power plants along with the principles of energy utilization in different mechanical equipment, is essential in all branches of engineering. Such knowledge equips engineers to design efficient systems, optimize energy consumption, and foster sustainable technological advancement across a wide range of industries.

The Practical manual development team wishes to thank MSBTE who took initiative in the development of curriculum and implementation and also acknowledge the contribution of individual course experts who have been involved in laboratory manual as well as curriculum development (K scheme) directly or indirectly. Although all care has been taken to check for mistakes in this laboratory manual, yet it is impossible to claim perfection especially as this is the first edition. Any such errors and suggestions for improvement can be brought to our notice and are highly welcome.

Lab Manual Development Team

Programme Outcomes (POs) to be achieved through Practical of this Course

Following POs are expected to be achieved through the practicals of the Heating Ventilation Air Conditioning course.

PO1. Basic and Discipline specific knowledge: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the mechanical engineering problems.

PO2. Problem analysis: Identify and analyze well-defined mechanical engineering problems using codified standard methods.

PO3. Design/ development of solutions: Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs in mechanical engineering.

PO4. Engineering Tools, Experimentation and Testing: Apply modern mechanical engineering tools and appropriate technique to conduct standard tests and measurements.

PO5. Engineering practices for society, sustainability and environment: Apply appropriate technology in context of society, sustainability, environment and ethical practices.

PO6. Project Management: Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well defined engineering activities in diverse and multidisciplinary fields.

PO7. Life-long learning: Ability to analyze individual needs and engage in updating in the context of technological changes in mechanical engineering.

List of Industry Relevant Skills

The practical exercises included in this laboratory manual are designed to help students develop industry-relevant skills and competencies in the areas of alternative energy sources and energy management in industries. Through the completion of these practicals, students will be able to:

1. Effectively use energy audit instruments in a given shop or section to perform industrial energy audits involving data collection, measurement, analysis, and report preparation for achieving sustainable energy management.
2. Measure illumination levels accurately in various workplace environments using a lux meter.
3. Record and analyse energy meter readings, apply the CUSUM (Cumulative Sum) technique, and interpret variations in electrical energy consumption.
4. Use various measuring instruments to evaluate the performance of solar modules at different tilt angles and orientations, and design rooftop solar power systems for domestic buildings or small office applications.
5. Understand the components and working principles of geothermal, ocean thermal, and wind power plants, and relate this knowledge to potential careers in renewable energy and power generation.

Practical- Course Outcome matrix

Course Outcomes (COs):

- CO1. Select Proper instruments for performing energy audit.
- CO2. Identify energy conservation opportunities in mechanical and electrical system.
- CO3. Design cost effective solar thermal and photovoltaic system as per requirement.
- CO4. Utilize wind and biomass as a renewable energy technology for energy generation.
- CO5. Select suitable source(s) of energy generation using principles of renewable energy.

S. No.	Laboratory Practical Titles	CO 1.	CO 2.	CO 3.	CO 4.	CO 5.
1	* Preliminary energy audit in workshop facility (Machine Shop)	√	-	-	-	-
2	Detailed energy audit for a computer laboratory.	√	-	-	-	-
3	* Determination of the value of lux for classroom, library, workshop, cafeteria/canteen, laboratory, corridor, etc. and suggest energy conservation for same.	-	√	-	-	-
4	Cumulative sum (CUSUM) technique to monitor the electrical energy consumption of different energy meters used in institute.	-	√	-	-	-
5	* Measurement of different parameters like voltage, ampere and temperature of the solar module of 100 Watts at different inclination angle.	-	-	√	-	-
6	Design rooftop solar system of 1 to 5 kW for a residential house and list the components and structure required for the same.	-	-	√	-	-
7	* Measure different parameters like temperature, relative humidity and time required in drying different materials (like grapes, raw mango, fruits, vegetables, herbs, grains, or spices) using solar dryer.	-	-	√	-	-
8	* Factors affecting on the efficiency solar cooker and measure their performance under various conditions.	-	-	√	-	-
9	* Measurement of wind speed at different heights and locations by using digital anemometer.	-	-	-	√	-
10	* Preparation of briquettes/pallets using waste saw dust/wooden dust/cow dung/cattle dung.	-	-	-	√	-
11	Comparative analysis of bio-fuels with conventional fuels in terms of energy content, viscosity, flash point, combustion efficiency, calorific value, fuel density, temperature and pH value.	-	-	-	√	-
12	* Demonstration of hydrogen fuel cell using video/animation.	-	-	-	-	√

13	Demonstration of geothermal power plant using video/animation.	-	-	-	-	√
14	Demonstration of thermal power plant using video/animation.	-	-	-	-	√
15	Demonstration of wind power plant using video/animation/visit.	-	-	-	√	-

Guidelines to Teachers

1. **Teacher needs to ensure that a dated log book** for the whole semester, apart from the laboratory manual is maintained by every student which s/he has to **submit for assessment to the teacher** in the next practical session.
2. There will be two sheets of blank pages after every practical for the student to report other matters (if any), which is not mentioned in the printed practical.
3. For difficult practical if required, teacher could provide the demonstration of the practical emphasizing of the skills which the student should achieve.
4. Teachers should give opportunity to students for hands-on after the demonstration.
5. Assess the skill achievement of the students and COs of each unit.
6. One or two questions ought to be added in each practical for different batches. For this teacher can maintain various practical related question banks for each course.
7. If some repetitive information like data sheet, use of software tools etc. has to be provided for effective attainment of practical outcomes, they can be incorporated in Appendix.
8. For effective implementation and attainment of practical outcomes, teacher ought to ensure that in the beginning itself of each practical, students must read through the complete write-up of that practical sheet.
9. During practical, ensure that each student gets chance and takes active part in taking observations/ readings and performing practical.
10. Teacher ought to assess the performance of students continuously according to the MSBTE guidelines.

Instructions for Students:

1. For incidental writing on the day of each practical session every student should maintain a ***dated log book*** for the whole semester, apart from this laboratory manual which s/he has to ***submit for assessment to the teacher*** in the next practical session.
2. For effective implementation and attainment of practical outcomes, in the beginning itself of each practical, student need to read through the complete write-up including the practical related questions and assessment scheme of that practical sheet.
3. Student ought to refer the data books, IS codes, Safety norms, Technical Manuals, etc.
4. Student should not hesitate to ask any difficulties they face during the conduct of practical.

Content Page

List of Practical and Progressive Assessment Sheet

S. No.	Laboratory Practical Titles	Page No.	Date of performance	Date of submission	FA PR marks (25)	Dated sign. of teacher	Remarks (if any)
11	Comparative analysis of bio-fuels with conventional fuels in terms of energy content, viscosity, flash point, combustion efficiency, calorific value, fuel density, temperature and pH value.	62					
12	* Demonstration of hydrogen fuel cell using video/animation.	67					
13	Demonstration of geothermal power plant using video/animation.	72					
14	Demonstration of thermal power plant using video/animation.	77					
15	Demonstration of wind power plant using video/animation/visit.	82					
Total							

Note: To be transferred to Proforma of CIAAN-2023.

A suggestive list of LLOs is given in the above table. More such LLOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practical marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.

Practical No. 01

Preliminary Energy Audit in Workshop Facility (Machine Shop).*

I. Practical Significance

Preliminary energy audit develops hands-on experience in measuring, analysing, and interpreting energy data, which strengthens their understanding of energy management systems and industrial best practices.

II. Industry/Employer Expected Outcome(s)

Industry and employers expect that after conducting such audits, students or professionals will be able to, Use of energy audit instruments for given shop/section for sustainable energy management.

III. Course Level Learning Outcome(s) (CO)

CO1- Select Proper instruments for performing energy audit.

IV. Laboratory Learning Outcome(s)

LLO 1.1: Use energy audit instruments to measure energy consumption in the workshop.

LLO 1.2: Identify energy consumption pattern.

V. Relative Affective Domain related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background with diagram (if required)

Preliminary Energy Audit:

It involves a site walk-through, a review of existing energy data like utility bills, and interviews with staff to pinpoint major inefficiencies and establish a baseline for energy consumption.

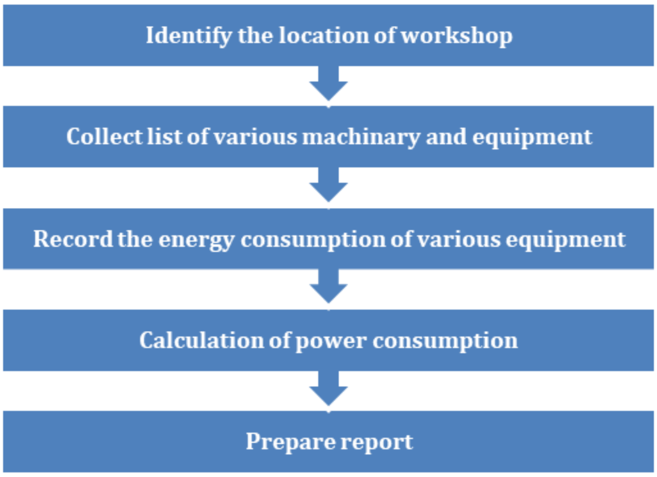

Fig. 1.1: Flow Chart of Preliminary Energy Audit

VII. Experimental setup

Fig. 1.2: Machine Shop

Name of Instruments and Photograph		
		
Digital clamp meter	**Energy Meter (kWh)**	**Thermometer**
		
Infrared Thermometer	**Lux Meter**	**Tachometer**

VIII. Required Resources /Apparatus/Equipment with specifications

S. No.	Name of Instruments	Specification	Quantity
1	Digital clamp meter	Measurement :True RMS Display size : Large with back light, Minimum 3.5 digit or better AC Ammeter: Upto 500A AC or Higher DC Ammeter: Upto 500A DC or Higher AC Voltage: Upto 500V AC or Higher DC Voltage: Upto 500V DC or Higher	01

S. No.	Name of Instruments	Specification	Quantity
		Resistance: Upto 1 Kilo Ohms Frequency counter:50Hz + 5 Hz	
2	Energy meter (kWh)	System: Single Phase, 2 Wire Rated Voltage: 240V Voltage Range: 70% to 120% of rated voltage Basic Current: 5A Maximum Current: 30A Rated Frequency: 50 Hz Accuracy Class: 1.0 Operating Temperature: -10°C to 55°C	01
3	Stop watch	up to 23h 59m 59s	01
4	Thermometer / infrared thermometer	$-10°C to 110°C$	01
5	Lux meter	Measuring Range: 0 to 50,000 lux Accuracy: ±3 % to ±4 % Resolution: 0.1 lux Sampling Time: 0.4 seconds Response Time: 1 second	01
6	Tachometer	Measurement method: Contact type Measurement range: 1 to 9,999 RPM Resolution: 0.1 RPM Display: Digital LCD with backlight	01

IX. Precautions to be Followed

1. Handle instruments with care.
2. Ensure all instruments are calibrated.

X. Procedure

1. Record general facility available in workshop: number of machines, working hours/day.
2. Record major electrical loads (list machines & rating from nameplates).
3. Measure various electrical parameters using measuring instruments.
4. Calculate energy consumed per day, per month and per year in kWh.
5. Record all readings in a table for calculations.

XI. Observations and calculations

Title **:** Preliminary Energy Audit at Machine Shop.

Date **: ---**

Auditor(s) **: ---**

Location **: ---**

Item	Rated Power			Measured Power			Power Factor $PF = \frac{Rated\ power}{Measured\ power}$	Used Hours per day*	Used Days per month**
	Rated Power (kW)	Qty. N	Total Measured Power $P = Rated\ power\ X\ N$ (kW)	Measured Voltage V (V)	Measured Current I (A)	Total Measured Power $P = \frac{V\ X\ I}{1000} X\ N$ (kW)			
Lathe									
Milling									
Drill Machine									
Grinder									
Illuminations like (LED, Tube light, CFL)									
Power Hacksaw									
Fan									
Exhaust fan									
		Total rated power=		**Total measured power=**					

* No. of hours machines/appliances use in a day (ex. 4 Hrs.).

** No. of days the machines/appliances use in a month (ex. 26days).

Calculation:

Sample calculation for individual machine:

- **Rated power (S):**

The total power flowing in an AC electrical circuit, measured in volt-amperes (VA) (Mention in components or machine specification table).

Rated Power (S) = ________________in watt

=____________/1000 kW

=____________ kW

- **Measured power (P):**

Active power is the portion of electrical energy in an AC circuit that performs useful work, such as producing light, heat, or mechanical energy. It is also known as true power or real power and is measured in watts (W).

Active (real) power (P) = Voltage (V) X Current (I) Watt

= ________/1000 kW

- **Power Factor (PF):**

Power Factor (PF) is the ratio of real power (the power used for useful work) to apparent power (the total power supplied to the circuit) in an AC electrical system.

$$PF = \frac{Rated\ power}{Measured\ power}$$

- **Energy consumed in rated power (E):**

Energy consumed is the amount of energy used or power utilized by a system or appliance.

Energy consumed (E) per day = Total rated power (P) (kW) X Time (hr.) kWh

= ______________kWh

Energy consumed (E) per month = Total rated power (P) (kW) X day per month kWh

=______________kWh

Energy consumed (E) per year = Total rated power (P) (kW) X no. of month in year kWh

=______________kWh

- **Energy consumed in measured power (E):**

Energy consumed is the amount of energy used or power utilized by a system or appliance.

Energy consumed (E) per day = Total measured power (P) (kW) X Time (Hour) kWh

= ______________kWh

Energy consumed (E) per month = Total measured power (P) (kW) X day per month kWh

=______________kWh

Energy consumed (E) per year = Total measured power (P) (kW) X no. of month in year kWh

=______________kWh

XII. Results:

Following parameters are calculated;

Parameter	Rated Power (kWh)	Measured Power (kWh)	Power Difference (kWh)
Total daily energy consumption			
Monthly energy consumption			
Annual energy consumption			

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Suggest instrument to measure illuminations of classroom.
2. Draw a chart showing the energy consumption of your residence for the last 10 months using electricity bill data.

[Space for Answer]

....

....

....

....

XVI. References / Suggestions for Further Reading

1. Bureau of energy efficiency: https://beeindia.gov.in/sites/default/files/1Ch3.pdf
2. Energy Audit: https://www.youtube.com/watch?v=XTQ6hzAFEn0

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 02

Detailed Energy Audit for a Computer Laboratory.

I. Practical Significance

A detailed energy audit provides a comprehensive analysis of how electrical energy is consumed within a computer laboratory.

II. Industry/Employer Expected Outcome(s)

Industry and employers expect that after conducting this practical, students will gain knowledge of how energy audits are performed in real industries, including data collection, measurement, analysis, and reporting.

III. Course Level Learning Outcome(s) (CO)

CO1- Select Proper instruments for performing energy audit.

IV. Laboratory Learning Outcome(s)

LLO 2.1 Prepare a list of computer peripherals including monitors, printers, scanners, etc., and other devices that consume electrical energy for the purpose of audit.

LLO 2.2 Measure humidity and temperature of HVAC system and also measure lightning by lux meter.

LLO 2.3 Identify energy conservation opportunities.

V. Relative Affective Domain related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background with diagram (if required)

Detailed Energy Audit: It involves a site walk-through, a review of existing energy data like utility bills, and interviews with staff to pinpoint major inefficiencies and establish a baseline for energy consumption.

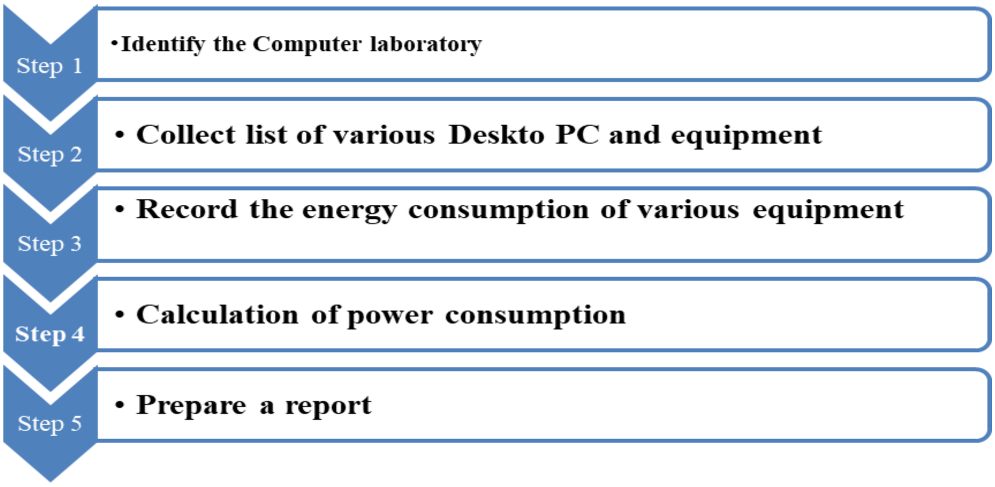

Fig. 2.1: Flow chart of Detailed Energy Audit

VII. Experimental setup

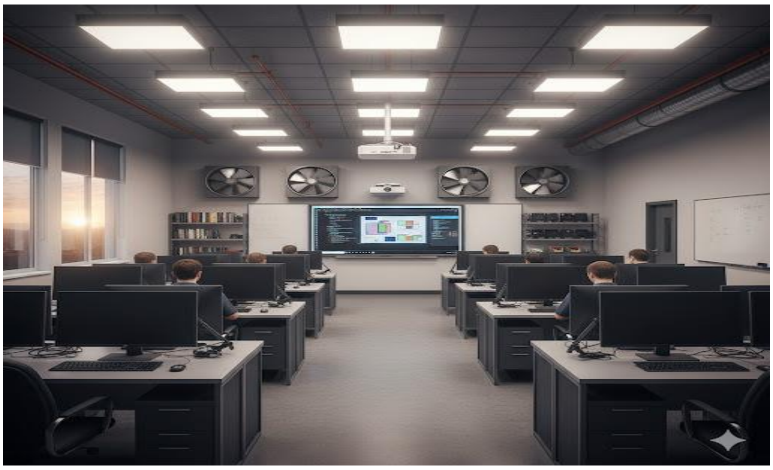

Fig. 2.2: Computer Laboratory

	
Digital Multimeter	**Digital Temperature and Hygrometer**

VIII. Required Resources /Apparatus/Equipment with specifications

S. No.	Name of Instruments	Specification	Quantity
1	Digital Multimeter	DC voltage Range : 100mV-1000V (Min.) DC voltage accuracy: Min.0.050 % of reading AC voltage range : 100mV- 750V AC voltage : (10 HZ TO 20 KHZ) Accuracy : Min. 0.1 % of reading Display type : Digital	01
3	Temperature and Hair hygrometer	Humidity Range : 20% to 100% RH. Temperature Range : 10°C to 50°C. Resolution : 1% for RH and 2°C for temp. Accuracy : ±3% RH	01

IX. Precautions to be Followed

1. Handle instruments with care.
2. Ensure all instruments are calibrated.

X. Procedure

1. Record connected load (computers, lights, fans, ACs, etc.) with their power ratings.
2. Record working hours and number of operational days per month.
3. Prepare a list of all electrical equipment in the laboratory.
4. Measure actual load using electrical equipments.

XI. Observations and Calculations

Title **:** Detailed Energy Audit at Computer Laboratory

Date **:** ---

Auditor(s) **:** ---

Location **:** ---

Equipment	**Rated Power (kW)**	**Quantity N**	**Measured Voltage V (V)**	**Measured Current I (A)**	**Total Measured Power** $P = \frac{V\ X\ I}{1000} X\ N$ **(kW)**	**Operating Hrs/day**	**Energy/day (kWh)**
Desktop Computer							
LCD Projector							
Printer							
Laptop							
Air Conditioner							
Tube Light (LED)							
Ceiling Fan							
Total =		**Total =**					

Calculation:

Sample calculation for individual machine:

- **Rated power (S):**

The total power flowing in an AC electrical circuit, measured in volt-amperes (VA). (Mention in components or machine specification table).

Rated power (S) = ________________in watt

=____________/1000 kW

=____________ kW

- **Measured power (P):**

Active power is the portion of electrical energy in an AC circuit that performs useful work, such as producing light, heat, or mechanical energy. It is also known as true power or real power and is measured in watts (W).

Active (real) power (P) = Voltage (V) X Current (I) Watt

= ________/1000 kW

- **Energy consumed in rated power (E):**

Energy consumed is the amount of energy used or power utilized by a system or appliance.

Energy consumed (E) per day = Total rated power (P) (kW) X Time (hr.) kWh

= ______________kWh

Energy consumed (E) per month = Total rated power (P) (kW) X day per month kWh

=______________kWh

Energy consumed (E) per year = Total rated power (P) (kW) X no. of month in year kWh

=______________kWh

- **Energy consumed in measured power (E):**

Energy consumed is the amount of energy used or power utilized by a system or appliance.

Energy consumed (E) per day = Total measured power (P) (kW) X Time (Hour) kWh

= ______________kWh

Energy consumed (E) per month = Total measured power (P) (kW) X day per month kWh

=______________kWh

Energy consumed (E) per year = Total measured power (P) (kW) X no. of month in year kWh

=______________kWh

XII. Results

Following parameters are calculated;

Parameter	Rated power (kWh)	Measured power (kWh)	Power Difference (kWh)	Corrective action
Total Daily Energy Consumption				
Monthly Energy Consumption				

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Identify the power consumption of smart board.
2. Enlist the steps to perform the energy audit of computer laboratory.
3. Enlist the equipment used to measure the different parameters (voltage, Current, Temp. etc).

[Space for Answer]

XVI. References / Suggestions for Further Reading

1. **Bureau of energy efficiency:** https://beeindia.gov.in/sites/default/files/1Ch3.pdf
2. **Energy Audit:** https://www.youtube.com/watch?v=XTQ6hzAFEn0

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 03

Determination of the Value of Lux for Classroom, Library, Workshop, Cafeteria/Canteen, Laboratory, Corridor, etc. and suggest Energy Conservation for same.

I. Practical Significance

It helps students understand the importance of proper illumination in different working environments such as classrooms, laboratories, and workshops. It also creates awareness about energy efficiency in lighting systems.

II. Industry/Employer Expected Outcome(s)

Ability to measure illumination levels accurately using a lux meter in various workplace environments.

III. Course Level Learning Outcome(s) (CO)

CO2- Identify energy conservation opportunities in mechanical and electrical system.

IV. Laboratory Learning Outcome(s)

LLO 3.1 Measure intensity of lighting by lux meter.
LLO 3.2 Identify energy conservation opportunities.

V. Relative Affective Domain related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background with diagram (if required)

Lux meter: The light sensor of the illuminometer has a photodiode that changes light into an electrical signal, an optical filter that makes it respond like the human eye, and a diffusing cover that helps measure light coming from different angles correctly. These parts together make the instrument accurate for measuring illumination.

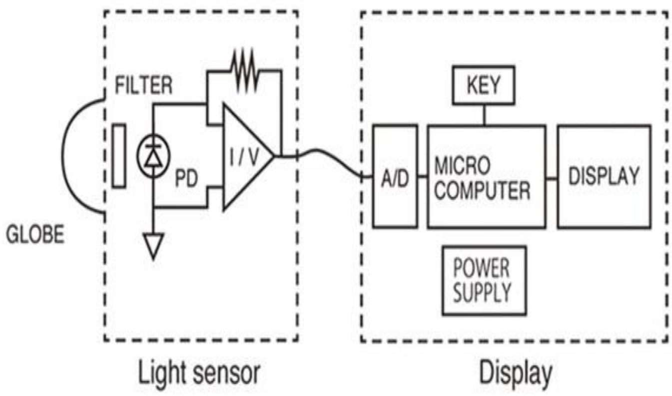

Fig. 3.1: Block diagram of Lux meter

VII. Experimental setup

Fig. 3.2: Lux Meter

VIII. Required Resources /Apparatus/Equipment with specifications

S. No.	Name of Instruments	Specification	Quantity
1	Lux meter	Measuring Range: 0 to 50,000 lux Accuracy: ±3 % to ±4 % Resolution: 0.1 lux Sampling Time: 0.4 seconds Response Time: 1 second	01

IX. Precautions to be Followed

1. Handle instruments with care.
2. Ensure all instruments are calibrated.

X. Procedure

1. Select the areas where light intensity will be measured; such as classroom, library, workshop, laboratory, cafeteria/canteen, and corridor.
2. Identify 3 measurement points in each area for better accuracy.
3. Place the lux meter sensor on the working surface (about 0.75 m above the floor).
4. Ensure no shadow falls on the sensor and the lighting conditions are normal (all lights switched on).
5. Record the lux readings at each point and note them in the observation table.
6. Repeat measurements for all selected areas.

Recommended Illumination Levels:

Area / Location	*Recommended Lux (lx)
Classroom	300 – 500
Library (Reading Area)	300 – 500
Workshop	500 – 1000
Laboratory	500 – 750
Cafeteria/Canteen	150 – 300
Corridor	100 – 200

Reference: *The Illuminating Engineering Society (IES) and other standards bodies provide these as guidelines to ensure comfort, safety, and productivity.*

XI. Observations and calculations

Observation Table:

S. No	Area	Lux Reading 1	Lux Reading 2	Lux Reading 3	Average Lux
1	Classroom				
2	Library (Reading Area)				
3	Workshop				
4	Laboratory				
5	Cafeteria/Canteen				
6	Corridor				

Calculation:

- **Calculate the average lux value for each area using:**

$$\text{Average Lux} = \frac{\text{Sum of all Lux Readings}}{\text{Number of Points Measured}}$$

XII. Results:

Following parameters are calculated;

S. No	Area	Recommended Lux (lx)	Average Lux (lx)	Remark
1	Classroom	300 – 500		
2	Library (Reading Area)	300 – 500		
3	Workshop	500 – 1000		
4	Laboratory	500 – 750		
5	Cafeteria/Canteen	150 – 300		
6.	Corridor	100 – 200		

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Identify visually areas in your home have insufficient or excessive lighting.
2. State the effect of poor illumination on shop floor.
3. List the application of lux meter with suitable example.

[Space for Answer]

XVI. References / Suggestions for Further Reading

1. https://www.hioki.com/sites/default/files/2021-03/client_upload_13_1507561846807.pdf
2. https://www.globalspec.com/learnmore/optics_optical_components/optoelectronics/lux_meters_light_meters
3. https://atp-instrumentation.co.uk/blog/how-to-measure-light-using-your-light-meter-correctly/
4. https://www.youtube.com/watch?v=ggh9-3LQFTA

XVII. Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (15 Marks)	**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
	Product Related (10 Marks)	**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 04

Cumulative sum (CUSUM) Technique to Monitor the Electrical Energy Consumption of Different Energy Meters used in Institute.

I. Practical Significance

The Cumulative Sum (CUSUM) technique is a sensitive statistical tool used to monitor changes in energy consumption over time. It helps in identifying small, consistent deviations from normal usage patterns, making it easier to detect inefficiencies, equipment faults, or unexpected increases in energy use.

II. Industry/Employer Expected Outcome(s)

Able to collect and tabulate energy meter readings and compute cumulative sums (CUSUM) to analyse variations in electrical energy consumption.

III. Course Level Learning Outcome(s) (CO)

CO2- Identify energy conservation opportunities in mechanical and electrical system.

IV. Laboratory Learning Outcome(s)

LLO 4.1 Select the specific energy meters in different parts of the institute.
LLO 4.2 Calculate the average energy consumption based on the collected baseline data.
LLO 4.3 Plot CUSUM chart using data obtained in LLO 4.2.

V. Relative Affective Domain related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background with diagram (if required)

CUSUM Technique: CUSUM works by adding up the small differences between the actual energy consumption and the expected (baseline) consumption for each time period.

$$S_i = S_{i-1} + (x_i - T)$$

Where: Si = Cumulative sum at time i; xi = Actual energy consumption; T = Target or baseline consumption; $S_0 = 0$

VII. Experimental setup

Fig. 4.1: Energy Meter

VIII. Required Resources /Apparatus/Equipment with specifications

S. No.	Name of Instruments	Specification	Quantity
1	Energy meter	Meter type : Single-phase (2-wire), Three-phase (3- or 4-wire), Smart Meter System voltage: 230V or 240V (single-phase), 400V or 415V (three-phase) Frequency : 50 Hz ± 5% Current rating : 10–60A (typical for residential use) Power consumption: Typically, < 2W and < 10VA per voltage circuit Display : LCD Temperature range : -10°C to 55°C Humidity : up to 95% RH	01

IX. Precautions to be Followed

1. Handle instruments with care.
2. Ensure all instruments are calibrated.

X. Procedure

1. Identify and select specific energy meters located in different parts of the institute such as the workshop, computer lab, hostel, and office area.
2. Record daily or weekly energy consumption readings (in kWh) from each selected meter over a fixed period (e.g., 7–10 days).
3. Calculate the average energy consumption for each meter from previous data. This average is taken as the baseline or standard consumption.
4. For each day, find the difference between the actual consumption and the baseline.
5. Add each day's deviation to the previous total.
6. Draw a graph of CUSUM (Y-axis) versus Day/Time (X-axis) using graph paper.

XI. Observations and calculations

Observation Table 4.1: Meter Reading at Different Location

S. No.	Location	Meter Readings in kWh					Average Meter Readings (Baseline Consumption)
		Day 1	Day 2	Day 3	Day 4	Day 5	
1	Main Building Energy Meter	12540	12680	12830	12950	13100	**12820**
2	Mechanical Engineering Workshop Meter						
3	Electrical Laboratory Meter						
4	Computer Laboratory Meter						
5	Administrative Office Meter						

Calculation:

$$\textbf{Baseline consumption} = \frac{12540+12680+12830+12950+13100}{5}$$

= 12820 kWh

a. Calculation Deviation:

Deviation = Actual Reading − Baseline

Day 1: DEV_{Day1} $= 12540 - 12820$

= -280

Day 2: DEV_{Day2} $= 12680 - 12820$

= -140

Day 3: DEV_{Day3} $= 12830 - 12820$

= 10

Day 4: DEV_{Day4} $= 12950 - 12820$

= 130

Day 5: DEV_{Day5} $= 13100 - 12820$

= 280

Observation Table 4.2: Deviation calculation

Sr. No.	Location	Deviation				
		DEV_{Day1}	DEV_{Day2}	DEV_{Day3}	DEV_{Day4}	DEV_{Day5}
1	Main Building Energy Meter	-280	-140	10	130	280
2	Mechanical Engineering Workshop Meter					
3	Electrical Laboratory Meter					
4	Computer Laboratory Meter					
5	Administrative Office Meter					

b. Compute Cumulative Sum (CUSUM):

$$S_i = S_i - 1 + \text{Deviation}$$

Day 1: $CUSUM_{Day1}$ $= -280 + 0$

= -280

Day 2: $CUSUM_{Day2}$ $= -280 + (-140)$

= -420

Day 3: $CUSUM_{Day3}$ $= -420 + 10$

= -410

Day 4: $CUSUM_{Day4}$ $= -410 + 130$

= -280

Day 5: $CUSUM_{Day5}$ $= -280 + (-280)$

= 0

Compute Cumulative Sum (CUSUM) calculation:

S. No.	Location	Compute Cumulative Sum (CUSUM)				
		CUSUM Day1	**CUSUM Day2**	**CUSUM Day3**	**CUSUM Day4**	**CUSUM Day5**
1	Main Building Energy Meter	-280	-420	-410	-280	0
2	Mechanical Engineering Workshop Meter					
3	Electrical Laboratory Meter					
4	Computer Laboratory Meter					
5	Administrative Office Meter					

XII. Results:

XIII. Interpretation of Results

1. **Main Building Energy Meter: (For reference)**
   i. The CUSUM starts negative, indicating lower-than-baseline consumption during the first few days.
   ii. It gradually returns to zero by Day 5, meaning energy use has stabilized back to the baseline level**.**
   iii. This analysis helps detect periods of under- or over-consumption and assess energy management effectiveness.
2. **Mechanical Engineering Workshop Meter: (Student has to write)**

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. List of Energy Meter Locations in the Institute.
2. List and explain the different types of energy meters used for measuring electrical energy consumption.

[Space for Answer]

XVI. References / Suggestions for Further Reading

1. https://www.hioki.com/sites/default/files/2021-03/client_upload_13_1507561846807.pdf
2. https://www.globalspec.com/learnmore/optics_optical_components/optoelectronics/lux_meters_light_meters
3. https://atp-instrumentation.co.uk/blog/how-to-measure-light-using-your-light-meter-correctly/
4. https://www.youtube.com/watch?v=4QEsOqgIo6M

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 05

Measurement of Different Parameters like Voltage, Current, and Temperature of a 100 W Solar Module at Different Inclination Angles*

I. Practical Significance

This practical helps students to understand the inclination angle of a solar module which affects its performance. It demonstrates the direct relationship between solar irradiance, module orientation, and output power essential for designing efficient solar PV systems for industrial, domestic, and agricultural use.

II. Industry / Employer Expected Outcome(s)

Use of Various instruments to measure performance of solar module for different inclinations.

III. Course Level Learning Outcome(s)

CO 3: Design cost effective solar thermal and photovoltaic system as per requirement.

IV. Laboratory Learning Outcome(s)

LLO 5.1: Measure current, voltage, and power output of the solar cells/panel.
LLO 5.2: Measure power output of the solar panel at different inclination angles.
LLO 5.3: Prepare the record sheet for data obtained in LLO 5.2.

V. Relevant Affective Domain Related Outcome(s)

Safe handling of solar modules and measuring instruments.

VI. Relevant Theoretical Background

Working Principle of Solar PV Module: A solar photovoltaic (PV) module converts sunlight directly into electricity using semiconductor materials (usually silicon). When sunlight strikes the solar cells, electrons are excited and generate a direct current (DC). The angle between the solar module surface and the ground is called the tilt angle. The output power of the module depends on how directly the sunlight falls on it. The optimal tilt angle changes with geographic location and season.

VII. Actual Circuit Diagram Used in Laboratory

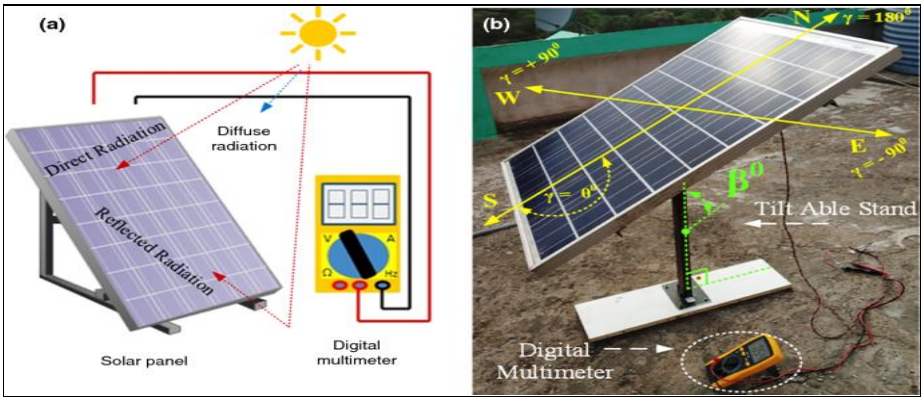

Fig.5.1: Connection Setup

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar panel/cell	12Volt polycrystalline or monocrystalline solar panel	01
2	Voltmeter	0-300V	01
3	Ammeter	0-5A	01
4	Variable resistor (load)	Nichrome wire, 300 Ω (ohm), 10A, 400V	01
5	Multimeter	2000 count digital display,1000 VDC/750 V AC ranges, 10 A AC/DC ranges	01
6	Non-Contact Thermometer	Infrared (IR), non-contact; Temperature Range: 0°C to 100°C; Accuracy: ±1°C or ±1.5% of reading; Resolution: 0.1°C or 0.1°F	01
	Light source (Sunlight)	-	-

IX. Precautions to be Followed

1. Ensure all electrical connections are tight and correct.
2. Observe readings accurately to avoid rapid irradiance fluctuation.
3. Keep instruments away from direct sunlight to avoid heating errors.

X. Procedure

1. Set the solar module inclination angle to 0° (horizontal) using the adjustable frame.
2. Measure the voltage (V), current (I), and surface temperature (T) of the module.
3. Record the voltage (V), current (I), and surface temperature (T) of the module in the observation table.
4. Repeat steps for inclination angles of 6°, 12°, 18°, 24°and 30°.
5. Calculate power output $P = V \times I$ for each angle.

XI. Observations and Calculations

S. No.	Inclination Angle (°)	Voltage (V)	Current (A)	Power (W)	Module Temp (°C)
1	6^0				
2	12^0				
3	18^0				
4	24^0				
5	30^0				

XII. Results

S. No.	Inclination Angle (°)	Power (W)	Module Temp (°C)	Remark
1	6^0			
2	12^0			
3	18^0			
4	24^0			
5	30^0			

XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the effect of tilt angle on solar module efficiency.
2. State the relationship between power and temperature of solar module
3. State the typical optimum tilt angle for any four cities in Maharashtra.

[Space for Answer]

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XVI. References/Suggestions for further reading

1. Solar Photovoltaic Fundamentals, Technologies and Applications: Chetan Singh Solanki, PHI Learning.
2. MNRE (Government of India) : https://mnre.gov.in
3. Measurement of solar parameters: https://youtu.be/i_oV91xoCyI
4. Practical guidance of solar module guide: https://youtu.be/bZiXehKfin0

XVII. Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (15 Marks)	**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
	Product Related (10 Marks)	**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 06

Design Rooftop Solar System of 1 to 5 kW for a Residential House and List the Components and Structure required for the same

I. Practical Significance

This practical will help to design of complete residential PV system design workflow from load assessment (bills) to system sizing, panel/inverter selection, mounting structure design and cable sizing.

II. Industry / Employer Expected Outcome(s)

Design rooftop solar system for domestic/small offices.

III. Course Level Learning Outcome(s)

CO3- Students will be able to, design cost effective solar thermal and photovoltaic system as per requirement.

IV. Laboratory Learning Outcome(s)

LLO 6.1 Review the last 12 months data obtained from electricity bills for average monthly energy consumption in kilowatt-hours (kWh)
LLO 6.2 Determine the Size of the Solar System.
LLO 6.3 Calculate the Number of Panels
LLO 6.4 Select an inverter that matches the capacity of the solar panels and is suitable for residential use.
LLO 6.5 Design the mounting structure for the panels on the roof by using CAD
LLO 6.6 Calculate the size and length of DC and AC cable

V. Relevant Affective Domain Related Outcome(s)

- Safe installation and correct documentation.
- Safe handling of solar modules and measuring instruments.

VI. Relevant Theoretical Background

Solar P-V Calculations:

1. From Bills to Daily Energy (LLO 6.1)

Monthly energy (kWh) from bills.

Average daily consumption,

$$E_{daily} = \frac{E_{monthly}}{30} \qquad \textbf{(kWh/day)}$$

2. PV Array Size (LLO 6.2)

Choose Peak Sun Hours (PSH). For most of India PSH ≈ **4.0–5.5**; use **5.0** as example.

System derating/overall efficiency (account for inverter losses, dust, temperature, wiring): typically, **0.70–0.80** (use 0.75 example).

Required PV capacity (kW):

$$P_{pv}(\text{kW}) = \frac{E_{daily}(\text{kWh/day})}{\text{PSH (h/day)} \times \text{system\_efficiency}}$$

3. Panels & Number of Panels (LLO 6.3)

Number of panels:

$$N = \lceil \frac{P_{pv}(\text{W})}{P_{panel}(\text{W})} \rceil$$

Where;

$$P_{pv}(\text{W}) = P_{pv}(\text{kW}) \times 1000)$$

4. Inverter Selection (LLO 6.4)

Inverter nominal AC output ≈ system size (choose inverter slightly higher or equal). For single-phase residential: 1 kW → 5 kW inverters. Consider MPPT range, voltage window, anti-islanding, efficiency, grid standards, and whether hybrid with battery is required.

5. Cable Current and Sizing (LLO 6.6)

DC string current (approx.): $I_{string} \approx I_{mp}$(panel Imp) × safety factor (1.25).

AC inverter output current:

$$I_{AC} = \frac{P_{system}(\text{W})}{V_{AC} \times \text{pf} \times \eta}$$

Take $V_{AC} = 230\text{V}$ (single phase), pf ≈ 1, inverter eff. η ≈ 0.96.

Voltage drop check:

$$V_{drop} = I \times L \times R_{cable}$$

Choose cable to keep voltage drop ≤ 1–3% (recommended ≤1.5% for DC runs; ≤3% on AC distribution.

VII. Actual Circuit Diagram Used in Laboratory (with Equipment Specifications)

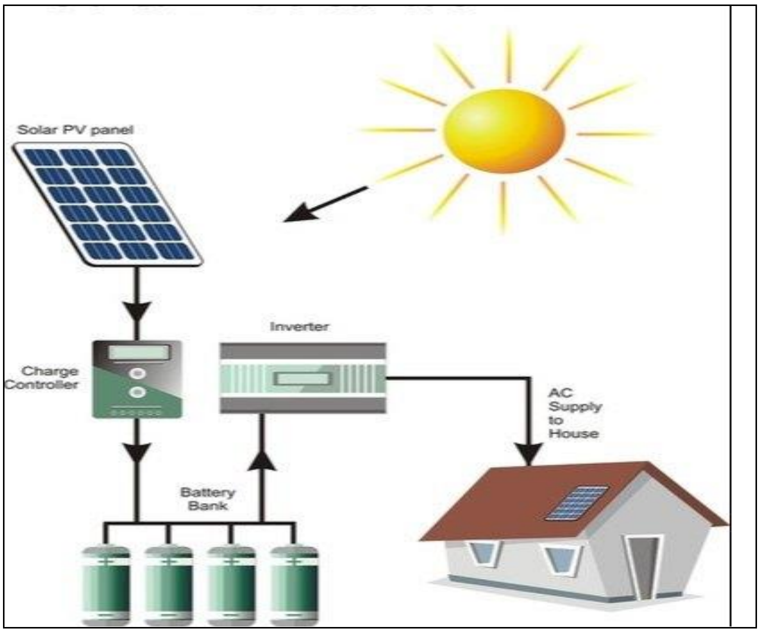

Fig. 6.1: Solar Power System for Residential Application (ON Grid)

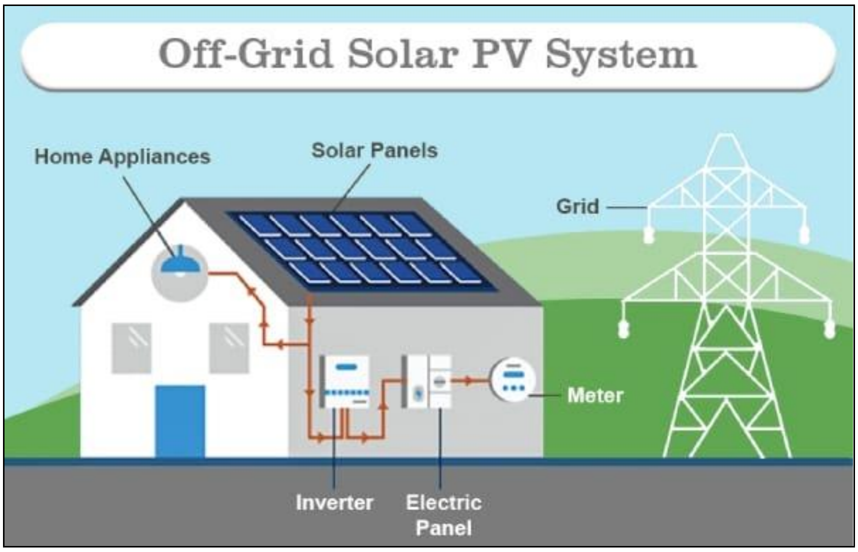

Fig. 6.2: Solar Power System for Residential Application (OFF grid)

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Electric Bill (Residential)	Last 12 Months (for energy consumption analysis)	01
2	PV Panels	12 V Polycrystalline or Monocrystalline Solar Panel	As per system capacity
3	Inverter	Single-phase Grid-tie: 1 kW, 2 kW, 3 kW, 4 kW, 5 kW nominal models; MPPT input range matching array; Efficiency ≥ 96%; Anti-islanding protection; Hybrid versions available for battery integration	01
4	DC Isolator	Rated voltage: 1000 V DC (≥ array Voc); Rated current: 32 A (≥ array Isc); 2-pole type, IP65 enclosure	01
5	AC Isolator / MCB	Rated voltage: 230 V AC (single phase); Rated current: 20–25 A (as per inverter output current); 2-pole type, 10 kA breaking capacity, IP65 enclosure	01
6	DC Cables	PV-graded DC cables (PV1-F / UV resistant), Copper conductors	As required
7	AC Cables	Copper conductor, rated for inverter output	As required
8	Earthing & SPD	Lightning/surge protection and earthing kit	1 set
9	Mounting Structure	Aluminium rails, clamps, anchor bolts, flashing for roof penetration	1 set
10	DC Combiner Box	For > 1 string, with fuses and protection features	01
11	Energy Meter / Bi-directional Meter	For net metering as per utility requirements	01

IX. Precautions to be Followed

1. Use PV-rated cables for array runs; avoid direct sunlight on exposed conductor terminations.
2. Ensure proper circuits connections.
3. Use PPE (insulated gloves, goggles) whenever required.

X. Procedure

Step 1: Data Collection (LLO 6.1)

1. Collect the electricity bills of the house for the last 12 months.
2. Record monthly energy consumption in kWh.
3. Calculate the average monthly consumption and average daily consumption:

$$\mathbf{E_{daily}} = \frac{\mathbf{E_{monthly}}}{\mathbf{30}}$$

Step 2: Determine Solar System Size (LLO 6.2)

1. Decide the percentage of energy to be supplied by the solar system (e.g., 100% daytime, 50% overall).
2. Note the average Peak Sun Hours (PSH) for the location (e.g., 5 h/day).
3. Apply system derating factor (≈0.75) to account for losses (wiring, inverter, temperature).
4. Calculate the required PV capacity (kW) using:

$$\boldsymbol{P_{pv}} = \frac{\boldsymbol{E_{daily}}}{\mathbf{PSH \times derating\ factor}}$$

Step 3: Calculate Number of Panels (LLO 6.3)

1. Select the panel rating (e.g., 330 W or 450 W).
2. Calculate the number of panels:

$$\mathrm{N_{panels}} = \mathrm{ceil}\left(\frac{\mathrm{P_{pv}} \times 1000}{\mathrm{P_{panel}}}\right)$$

“ceil” means round up to the nearest whole number.

Verify the roof area available is sufficient for all panels.

Step 4: Select Inverter (LLO 6.4)

1. Choose single-phase inverter (grid-tie) with AC output equal to or slightly higher than total array DC capacity.
2. Check inverter MPPT voltage range, max DC input, efficiency, and safety features.

Step 5: Design Mounting Structure (LLO 6.5)

1. Measure roof dimensions and slope.
2. Use CAD software to design mounting layout:
   - ✓ Panel spacing & tilt angle (≈latitude).
   - ✓ Rail and clamp arrangement.
   - ✓ Anchor bolt positions and access pathways.
3. Check for sunlight shading and maintain clearances.

Step 6: Calculate Cable Sizes (LLO 6.6)

DC Side:

1. Calculate string current from panel datasheet: $I_{string} = I_{mp} \times 1.25$(safety factor).
2. Select DC cable size using current rating tables.
3. Check voltage drop: $V_{drop} = I \times L \times R_{cable}$, ensure ≤1–1.5%.

AC Side:

1. Calculate AC current from inverter rating: $I_{AC} = \frac{P_{AC}}{V_{AC}}$
2. Choose conductor (Cu or Al) and insulation temp-rating, then apply derating factors (ambient, grouping, altitude).
3. for copper PVC single-core conductors, approximately use 2.5 mm² for up to 20 A, 4 mm² for 20–32 A, 6 mm² for 32–50 A, 10 mm² for 50–70 A, and 16 mm² for 70–100 A, adjusting as needed for aluminium conductors or different insulation types

Step 7: Documentation

1. Record all calculations in the observation table.
2. Include: PV system size, panel count, inverter, mounting layout, DC/AC cable sizing.
3. Estimate total system cost.
4. Attach CAD drawings of panel layout and roof structure.

XI. Observations and Calculations

S. No.	Parameter	Formula / Method Used	Observed/ Calculated Value	Remarks
1	Average monthly energy consumption (kWh/month)	From last 12 months electricity bills		Step 1
2	Average daily energy consumption (kWh/day)	(Monthly Energy) ÷ 30		Step 2
3	Required solar system capacity (kW)	(Daily Energy) ÷ 4.5 (avg. sun hours/day)		Step 3
4	Solar panel capacity (Watt)	As per datasheet (e.g. 250 Wp or 400 Wp)		Step 4
5	Number of panels required (e.g.	(System Capacity × 1000) ÷ Panel Capacity		Step 5
6	Total roof area required (m²)	No. of Panels × Area of one panel		Step 6
7	Selected inverter capacity	Equal to or slightly higher than total panel capacity		Step 7
8	DC cable size (mm²)	Based on current and distance (using standard chart)		Step 8
9	AC cable size (mm²)	Based on load and distance (using standard chart)		Step 9
10	Mounting structure design	CAD model (angle, spacing, layout)	Attached / Not Attached	Step 10
11	Estimated total system cost (₹)	Based on panel + inverter + structure + installation		Step 11

XII. Results

S. No.	Parameter	Result / Outcome
1	Average monthly energy consumption	________ kWh/month
2	Average daily energy consumption	________ kWh/day
3	Designed solar system capacity	________ kW
4	Solar panel capacity selected	________ Wp
5	Total number of panels required	________ Nos
6	Total rooftop area required	________ m²
7	Selected inverter capacity	________ kVA / kW
8	DC cable size	________ mm²
9	AC cable size	________ mm²
10	Type of mounting structure	________ (Fixed / Adjustable Tilt)
11	Estimated total system cost	₹ ________ (approx.)

XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Write specification of solar PV cell for residential application.
2. Enlist any five Solar PV cell manufacturers in India.
3. Calculate the number of 400 W panels required for a 4 kW rooftop PV system
4. List the five essential electrical components required for a grid-tied 3 KW rooftop solar system.

[Space for Answer]

XVI. References/Suggestions for further reading

1. MNRE (Ministry of New & Renewable Energy) — rooftop PV guidelines
2. *Solar Photovoltaics: Fundamentals, Technologies and Applications* — C. S. Solanki.

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(**60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		(**40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 07

Measure Different Parameters like temperature, relative humidity and time required in drying different materials (like grapes, raw mango, fruits, vegetables, herbs, grains, or spices) using solar dryer.*

I. Practical Significance

This Practical helps students understand the working and performance characteristics of a solar dryer. It shows how solar energy can be effectively used for drying agricultural and food materials, reducing dependency on conventional fuels, and ensuring hygienic and economical drying.

II. Industry / Employer Expected Outcome(s)

To study solar dryers by measuring temperature, humidity, and drying time, evaluating drying performance for various materials, and understanding their design, working, and practical applications in food and agricultural industries.

III. Course Level Learning Outcome(s)

CO-3 Design cost effective solar thermal and photovoltaic systems as per requirement.

IV. Laboratory Learning Outcome(s)

LLO7.1: Select different materials for drying.
LLO 7.2: Prepare a record sheet for external and internal temperature, relative humidity after every 15 min.
LLO 7.3: Analyse the data collected during the drying process.

V. Relevant Affective Domain Related Outcome(s)

- Develops awareness toward energy-efficient drying methods.
- Demonstrates responsibility in handling materials sustainably using the solar dryer.

VI. Relevant Theoretical Background

Working Principle of a Solar Dryer: A solar dryer uses solar energy to heat air, which in turn removes moisture from the material placed inside the drying chamber. The process depends on solar radiation intensity, airflow, and ambient humidity.
The drying rate is governed by:

$$Drying\ Rate = \frac{(M_1 - M_2)}{t}$$

Where,
$M_1 M_1$= Initial moisture content (kg) $M_2 M_2$= Final moisture content (kg) tt= Drying time (hr)

Equation for Efficiency:

$$Dryer\ Efficiency = \frac{m \times L}{I \times A \times t} \times 100$$

Where,

m= mass of water evaporated (kg),

L= latent heat of vaporization (kJ/kg),

I= solar insulation (kW/m²),

A= area of collector (m²),

t= time (hr)

VII. Actual Circuit Diagram Used in Laboratory (with Equipment Specifications)

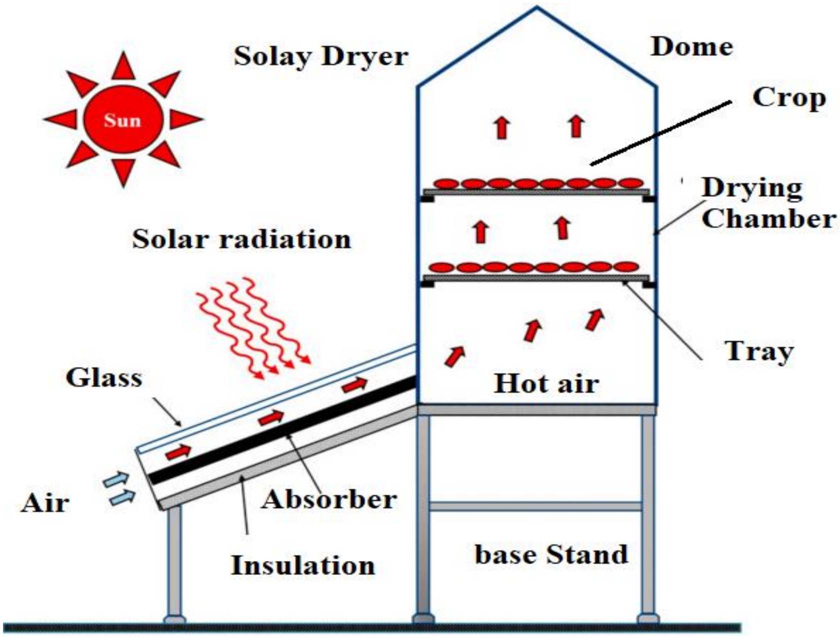

Fig. 7.1: Principle of Solar Dryer

Fig. 7.2: Actual Solar Dryer

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar dryer (natural convection or forced circulation type)	Chamber size ~1 m × 0.6 m × 0.5 m	01
2	Thermometers / Digital temperature sensors	Range 0–100°C	03
3	Hygrometer / Digital humidity meter	Range 0–100% RH	01
4	Weighing balance	0–5 kg, accuracy ±1 g	01
5	Stopwatch / Timer	Digital, 0–60 min	01
6	Selected drying materials	Grapes, mango, chillies, herbs, grains	As required
7	Data recording sheet	–	–

IX. Precautions to be Followed

1. Do not overload the dryer trays; maintain uniform spacing.
2. Avoid opening the chamber frequently to prevent heat loss.
3. Handle thermometers and sensors carefully.
4. Ensure no moisture leakage or shading on the collector surface.
5. Take readings at regular intervals for accurate analysis.

X. Procedure

1. Select different crops for drying (e.g., grapes, raw mango slices, chillies). Record initial weight and moisture content of each material sample.
2. Place samples uniformly on the drying trays inside the solar dryer.
3. Measure and record: a) Inside chamber temperature (°C)
   b) Outside ambient temperature (°C)
   c) Relative humidity (%)
   d) Time (every 15 minutes)
4. Continue drying until the material weight becomes nearly constant.
5. Record final weight and calculate the moisture removed.

XI. Observations and Calculations

Name of crop selected for drying: ______________________

Time (min)	Chamber Temp (°C)	Ambient Temp (°C)	Relative Humidity (%)	Crop Initial Weight (g)	Final Weight Dry condition (g)	Moisture Removed (g)
0						
15						
30						
45						
60						
90						
120						

XII. Results

1. The drying time for (Crop name) was found to be _____ minutes/hours.
2. The average chamber temperature was _____°C and relative humidity was _____%.
3. The solar dryer achieved efficient moisture reduction of approximately _____%.

XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State advantages of solar dryers.
2. List major components of a solar dryer.
3. Explain the principle of operation of a solar dryer.
4. Describe the role of solar radiation in the drying process.
5. Write specification of solar dryer available in the market.

[Space for Answer]

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XVI. References/Suggestions for further reading

1. Ministry of New and Renewable Energy (MNRE) schemes for agriculture sector in Maharashtra-https://mnre.gov.in/en/policies-and-regulations/schemes-and-guidelines/schemes/
2. Solar Dryer Manufacturing Business-https://youtu.be/_7M1XAtSF6E
3. Solar energy applications in cooking, desalination-https://youtu.be/gx_bt63lTxw
4. Solar radiation-
https://youtu.be/Og4LEc7SpdQ?list=PLwdnzlV3ogoXUifhvYB65lLJCZ74o_fAk
5. Solar Collectors Basics-
https://youtu.be/jjlXDUxyPEs?list=PLbMVogVj5nJTAW6mqiozHsjDGfkKJvNxo

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 08

Factors Affecting on the Efficiency of Solar Cooker and Measure their performance under various conditions.*

I. Practical Significance

This Practical helps students understand the working principle, efficiency, and performance factors of a solar cooker. It demonstrates how solar energy can be harnessed for cooking purposes, highlighting the effects of ambient temperature, solar irradiance, and type of food material on thermal performance.

II. Industry / Employer Expected Outcome(s)

Ability to select suitable materials, measure performance parameters, and analyse efficiency of solar cooking systems for practical renewable energy applications.

III. Course Level Learning Outcome(s)

CO3- Design cost effective solar thermal and photovoltaic system as per requirement.

IV. Laboratory Learning Outcome(s)

LLO 8.1: Select different food materials or liquids to cook, such as water, rice, vegetables, or a simple food item.
LLO 8.2: Measure ambient temperature and initial temperature of the cooking material using a thermometer.
LLO 8.3: Measure temperature of the cooking material at regular intervals.
LLO 8.4: Calculate the efficiency of the solar cooker using recorded temperature and time data.

V. Relevant Affective Domain Related Outcome(s)

Develops awareness of clean energy and careful handling of the solar cooker and instruments.

VI. Relevant Theoretical Background

Working Principle of Solar Cooker: A solar cooker concentrates solar radiation on a cooking vessel to heat and cook food. Heat transfer occurs primarily via conduction, convection, and radiation.

Factors Affecting Performance:

a. **Solar irradiance:** Direct sunlight intensity affects the rate of heating
b. **Ambient temperature:** Higher surrounding temperature reduces heat loss.
c. **Cooking material:** Different food items have varying specific heat capacities.
d. **Cooker design:** Shape, insulation, and reflectors determine energy capture efficiency.

Efficiency Calculation:

$$\eta = \frac{m \cdot c \cdot (T_f - T_i)}{E_s \cdot A \cdot t} \times 100$$

Where:

$\eta\eta$= Efficiency (%)

mm= Mass of cooking material (kg)

cc= Specific heat capacity (J/kg°C)

$T_f, T_i T_f, T_i$= Final and initial temperatures (°C)

$E_s E_s$= Solar irradiance (W/m²)

AA= Aperture area of the cooker (m²)

tt= Time of exposure (s)

VII. Actual Circuit Diagram Used in Laboratory (with Equipment Specifications)

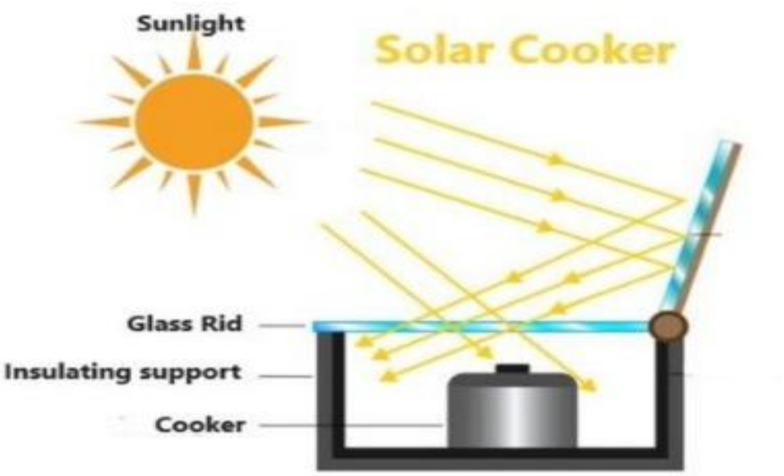

Fig. 8.1: Solar Cooker

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar Cooker	Box or parabolic type	01
2	Cooking Vessel	Black-painted, 1–2 liters	01
3	Thermometer	0–100°C, digital preferred	01
4	Stopwatch / Timer	Digital or analog	01
5	Food Materials	Water, rice, vegetables	As needed
6	Digital Solar power Meter	0–1000 W/m²	01

IX. Precautions to be Followed

1. Avoid direct contact with hot surfaces of the cooker.
2. Ensure accurate reading of thermometer and timer.
3. Position the solar cooker correctly facing the sun.
4. Record temperatures at consistent intervals.
5. Avoid reflective glare toward eyes while adjusting reflectors.

X. Procedure

1. Place the solar cooker in direct sunlight, facing south (for northern hemisphere).
2. Measure and record ambient temperature ($T_{ambient}T_{ambient}$) and initial temperature (T_iT_i) of cooking material.
3. Place the food material or liquid in the cooking vessel inside the cooker.
4. At fixed intervals (e.g., every 10 minutes), measure and record the temperature of the material.
5. Continue until target temperature or cooking completion is reached.
6. Calculate the solar cooker efficiency using the formula provided in the theoretical background.
7. Repeat for different food materials or liquids to compare efficiency.

XI. Observations and Calculations

S. No.	Food Material	Mass (kg)	T_Initial (°C)	T_Final (°C)	Time (s)	*Solar Irradiance (W/m²)	Efficiency (%)
1	Water	**1**					
2	Rice	**0.5**					
3	Vegetables	**0.5**					

Use standard data of solar irradiance.

XII. Results

Maximum temperature reached for material.

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Efficiency calculated for each type of food material.

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XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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V. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the influence of cooking material type on heat absorption and efficiency.
2. Compare the performance of a box-type and parabolic-type solar cooker.
3. State the role of insulation and reflectors in energy retention within the solar cooker.

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XVI. References/Suggestions for further reading

1. MNRE – Solar Cooker Program (Government of India): https://mnre.gov.in/solar/schemes/#solar-cookers
2. Vikaspedia (Govt. of India Knowledge Portal) – Working & Types of Solar Cookers https://vikaspedia.in/energy/renewable-energy/solar-energy/solar-cookers
3. National Institute of Solar Energy (NISE) – Training Manuals and Test Standards- https://nise.res.in/training-programmes
4. Classification of energy resources- https://youtu.be/aHjGcKP_7qE?list=PLwdnzlV3ogoXUifhvYB65lLJCZ74o_fAk
5. How Solar Panel Work-https://youtu.be/ENswOzEQR0Y
6. Organic Nano Particles Based Solar Cells- https://youtu.be/sCaNBQfSWSI?list=PLLy_2iUCG87Dxsmc322YcSuNl_KCEbqPl

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 09

Measurement of Wind speed at different heights and locations by using Digital Anemometer.*

I. Practical Significance

This practical familiarizes students with the process of measuring wind speed using a digital anemometer. It demonstrates how wind velocity varies with height and location due to surface roughness, obstacles, and atmospheric conditions- an essential concept in the design and placement of wind turbines for efficient energy conversion.

II. Industry / Employer Expected Outcome(s)

Ability to operate an anemometer, record and interpret wind data, and select suitable heights and locations for wind energy applications.

III. Course Level Learning Outcome(s)

CO4- Utilize wind and biomass as a renewable energy technology for energy generation.

IV. Laboratory Learning Outcome(s)

LLO 9.1 Select a location for the measurement of wind speed at various heights.
LLO 9.2 Measure wind speed using given meters at different heights and locations.
LLO 9.3 Plot the graph of wind speed vs. height for different locations.

V. Relevant Affective Domain Related Outcome(s)

- Demonstrate systematic observation and recording of meteorological data.
- To learn the importance of accurate field measurement in wind resource assessment.

VI. Relevant Theoretical Background

Principle of Wind Speed Measurement: Wind speed can be measured using mechanical or digital anemometers. A digital anemometer measures the velocity of airflow and displays it in units such as m/s or km/h.

Wind Speed Variation with Height: Wind velocity increases with height due to reduced friction near the ground surface. This variation is often represented by the *power law* relation:

$$V = V_{ref}(\frac{h}{h_{ref}})^{\alpha}$$

Where:

VV= wind velocity at height hh

$V_{ref}V_{ref}$= reference wind velocity at height $h_{ref}h_{ref}$

$\alpha\alpha$= surface roughness exponent (0.1–0.4 depending on terrain)

VII. Actual Circuit Diagram Used in Laboratory (with Equipment Specifications)

Fig. 9.1: Anemometer

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Anemometers	Digital or Cup Type	01
2	Measuring Tape.	At least 5 meters	01
3	Tripod or Stable Base	For mounting anemometer	01
4	Compass	Magnetic/Analog or Digital	01
5	Stopwatch	Digital or Analog	01

IX. Precautions to be Followed

1. Handle the anemometers and measurement equipment with care to avoid damage.
2. Ensure the mast is erected securely and stabilized with guy wires to prevent it from falling. Maintain a safe distance during setup and measurement.
3. Be aware of overhead power lines and maintain a safe distance from them.
4. Conduct the experiment in suitable weather conditions. Avoid strong winds, lightning, or heavy rain.
5. Wear appropriate safety gear (hard hats, safety shoes, high-visibility vests, gloves) at all times during the experiment.
6. Work in groups and ensure proper supervision by the instruction.

X. Procedure

1. Select three open locations for measurement (e.g., near a building, open field, terrace).
2. Fix the anemometer on the mast at the first height (1 meter).
3. Record the wind speed for duration of 1 minute and note the average value.
4. Repeat the measurement at heights of 1 m, 2 m,3 m, 4m and 5 m.
5. Repeat all measurements for each selected location.
6. Analyse how wind velocity changes with both height and location.

XI. Observations and Calculations

*Location	*Height (m)	Wind Speed (m/s)	Average Wind Speed (m/s)	Remarks
Open Field	1			
	2			
First Floor Building	3			
	4			
***Terrace/Balcony**	5			

Under the guidance of supervisor

XII. Results

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XII. Interpretation of Results

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XIII. Conclusion and Recommendation

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XIV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Plot the graph of wind velocity and measurement height.
2. Compare the wind speed characteristics of open-field and near-building locations.

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XV. References/Suggestions for further reading

1. MNRE: Wind Energy Basics (Government of India): https://mnre.gov.in/wind/
2. Online Wind Speed & Resource Mapping: https://globalwindatlas.info/
3. Basics of Wind Energy Technology: https://energyeducation.ca/encyclopedia/Wind_energy
4. Wind Speed and Height Variation: https://www.renewableenergyworld.com/wind-power/
5. Introduction to Wind Energy: https://youtu.be/A6HvViANpkM?list=PLyqSpQzTE6M-ZgdjYukayF6QevPv7WE-r
6. Wind Speed and Power Analysis: https://youtu.be/X0WR9N67qJA?list=PLyqSpQzTE6M-ZgdjYukayF6QevPv7WE-r
7. Wind Speed and Power Analysis (Part 2): https://youtu.be/PDGEZxrwEAM?list=PLyqSpQzTE6M-ZgdjYukayF6QevPv7WE-r

XVI. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 10

Preparation of Briquettes/Pallets using Waste saw dust/wooden dust/cow dung/ cattle dung.*

I. Practical Significance

This practical introduces students to renewable and sustainable sources of energy. It demonstrates how biomass waste materials like sawdust, wooden dust, or cow dung can be converted into solid fuel in the form of briquettes or pellets, promoting waste-to-energy conversion and reducing environmental pollution.

II. Industry / Employer Expected Outcome(s)

Ability to select suitable biomass materials, manually prepares briquettes/pellets, and evaluates their drying and usability for practical applications.

III. Course Level Learning Outcome(s)

CO4- Utilize wind and biomass as a renewable energy technology for energy generation.

IV. Laboratory Learning Outcome(s)

LLO 10.1: Collect sawdust/wooden dust/cow dung.
LLO 10.2: Prepare briquettes and pellets manually.
LLO 10.3: Lay the briquettes or pellets on a drying rack or tray.

V. Relevant Affective Domain Related Outcome(s)

Develops awareness and responsibility in handling biomass while appreciating its role in sustainable renewable energy applications.

VI. Relevant Theoretical Background

Biomass Energy:
Biomass refers to organic materials such as agricultural residues, wood waste, or animal dung used as fuel. When converted into briquettes or pellets, these materials provide a renewable energy source suitable for cooking, heating, and industrial applications.

Briquetting Principle:
The process involves compressing biomass waste into dense, solid blocks (briquettes) that can be easily handled and burned. Binding agents such as clay, starch, or cow dung may be used to improve strength.

Basic Equation (for Efficiency Calculation):

$$Efficiency = \frac{Useful\ Heat\ Output}{Energy\ Input} \times 100$$

VII. Flowchart for Practical Performance / Process / Setup Diagram Used in Laboratory

Fig. 10.1: Briquettes and machine for making cow dung Briquettes

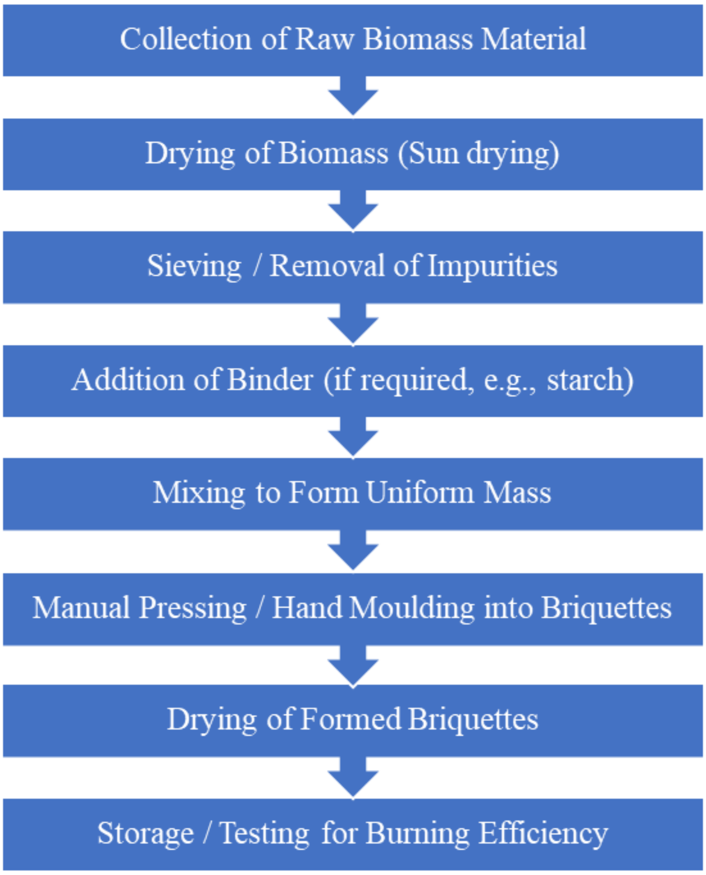

Fig. 10.2: Flow Chart for Process of Briquettes making

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Sawdust / Wooden dust / Cow dung	Clean, dry, sieved biomass material	As required
2	Binder (clay/starch/cow dung)	Natural binding material	As required
3	Mould	Manual or fabricated press mould	1
4	Drying tray/rack	Wire mesh or steel sheet	1
5	Measuring balance	Up to 5 kg	1
6	Mixing tools	Spade or wooden stick	1 set

IX. Precautions to be Followed

- Ensure all materials are dry and free from large impurities.
- Keep moulds clean and properly lubricated before use.
- Allow sufficient drying time before testing briquettes.

X. Procedure

1. Collect biomass material such as sawdust, wooden dust, or cow dung.
2. Mix the biomass with a small amount of binder and water to form a uniform paste.
3. Fill the paste into the mould to form briquettes or pellets.
4. Carefully remove the formed briquettes from the mould.
5. Place the briquettes/pellets on a drying rack or tray under sunlight.
6. Allow them to dry until the moisture content is sufficiently low for burning tests.

XI. Observations and Calculations

S. No.	Type of Biomass Used	Binder Type	Moisture Content (%)	Drying Time (hrs)	Briquette Quality (Good/Average/Poor)
1	Sawdust	Clay			
2	Cow dung	-			
3	Wooden dust	Starch			

XII. Results

- Briquettes prepared from _____________ with _____________ binder showed the best structural strength and burning quality.

XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Define biomass energy and its importance.
2. List different materials suitable for briquette making.
3. State advantages of briquettes over traditional wood fuel.
4. Mention parameters that affect briquette strength and burning rate.
5. State one environmental benefit of using biomass briquettes.

[Space for Answer]

XVI. References/Suggestions for further reading

1. MNRE: Biomass Power & Cogeneration Programme: https://biogas.mnre.gov.in/
2. FAO: Simple Technologies for Charcoal Briquettes Production: http://www.fao.org/3/X5328E/X5328E00.htm
3. Energy from Bio-based Feedstock: https://youtu.be/vU26CBu5CpI?list=PLwdnzlV3ogoU_xd_1SOtPpMPis4Li8yHe
4. Indian Institute of Science (IISc) – Biomass Briquetting Research: https://cgpl.iisc.ac.in/biomass-briquetting/
5. National Institute of Renewable Energy (Sardar Swaran Singh NIRE)Biomass Energy Resources: https://www.nibe.res.in/
6. Solid fuels: https://youtu.be/jhsFNAmTC5E?list=PLwdnzlV3ogoU_xd_1SOtPpMPis4Li8yHe
7. Energy scenario: https://youtu.be/19ruvTD65v8?list=PLwdnzlV3ogoU_xd_1SOtPpMPis4Li8yHe

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 11

Comparative analysis of bio-fuels with conventional fuels in terms of energy content, viscosity, flash point, combustion efficiency, calorific value, fuel density, temperature and pH value.

I. Practical Significance

This practical provides understanding of how bio-fuels differ from conventional fossil fuels in essential fuel properties such as calorific value, viscosity, flash point, density, combustion efficiency, and energy content. It helps students evaluate the suitability of various bio-fuels for industrial, domestic, and transportation applications and promotes knowledge of sustainable, eco-friendly energy alternatives to reduce dependence on non-renewable fuels.

II. Industry / Employer Expected Outcome(s)

Ability to test, compares, and interprets fuel properties for selecting suitable fuels in industrial and automotive applications.

III. Course Level Learning Outcome(s)

CO4- Utilize wind and biomass as a renewable energy technology for energy generation.

IV. Laboratory Learning Outcome(s)

LLO 11.1: Select a bio-fuels and conventional fuels for study purpose.
LLO 11.2: Prepare a comparison chart.

V. Relevant Affective Domain Related Outcome(s)

1. Develops responsible laboratory behaviour
2. Develop awareness of sustainable alternatives to fossil fuels.

VI. Relevant Theoretical Background:

Bio-fuels are renewable fuels derived from organic materials such as plant biomass, agricultural waste, animal waste, algae, or microbial fermentation products. Common forms include biodiesel, bio-ethanol, biogas, and solid briquettes. Bio-fuels are gaining importance due to increasing global energy demand, limited availability of fossil fuels, and rising environmental concerns. Conventional fuels, such as petrol, diesel, kerosene, LPG, and coal, are derived from fossil resources. They offer high energy output but contribute significantly to greenhouse gas emissions, air pollution, and long-term environmental degradation.

VII. Flow chart for practical:

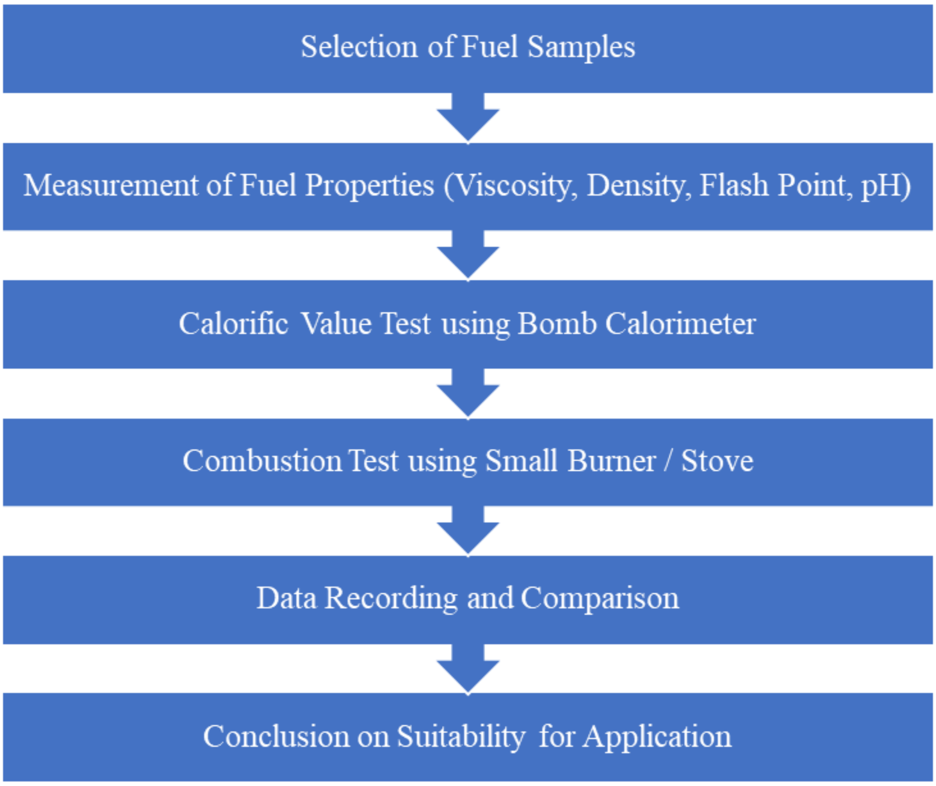

Fig. 11.1: Flow chart of Steps to check the properties of Bio fuel

VIII. Required Resources / Apparatus / Equipment

S. No.	Equipment / Material	Specification	Quantity
1	Bio-fuel sample (e.g., biodiesel/ethanol)	Laboratory grade	100 ml
2	Diesel/Petrol (Conventional fuel)	Standard grade	100 ml
3	Viscometer	Cup or rotational type	01
4	Density bottle	50 ml	01
5	Bomb calorimeter	Standard test type	01
6	Flash point apparatus	Pensky-Martens type	01
7	pH meter	Digital	01
8	Thermometer	0–200°C	01

IX. Precautions to be Followed

1. Handle fuels carefully; keep away from flames.
2. Use proper ventilation when burning samples.
3. Calibrate instruments before measurement.
4. Dispose fuel residues safely.

X. Procedure

1. Collect fuel samples (bio-fuel and conventional fuel).
2. Measure viscosity of each fuel using a viscometer.
3. Measure density using a density bottle.
4. Determine flash point using flash point apparatus.
5. Measure calorific value using a bomb calorimeter.
6. Record fuel temperature and measure pH value.
7. Compare combustion properties by burning small quantities safely.
8. Tabulate the results for comparison.

XI. Observations and Calculations

Property	Bio-fuel Sample	Conventional Fuel	Remarks
Viscosity (Pa·s)			
Density (kg/m³)			
Flash Point (°C)			
Calorific Value (kJ/kg)			
Combustion Efficiency (%)			
Temperature Rise (°C)			
pH Value			

XII. Results

The comparative analysis showed that ___________________ has higher/lower calorific value and ___________________ displays better combustion and handling characteristics.

XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Define bio-fuel and give two examples.
2. State the viscosity important in fuel injection.
3. Compare calorific value of diesel and biodiesel.
4. State one environmental advantage of using bio-fuels.
5. List types of bio fuels and their generations.

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XVI. References/Suggestions for further reading

1. Bio-fuels in India: Overview and Applications: https://youtu.be/vtmHwwgEQyc
2. Bio-energy and Bio-fuels: https://youtu.be/_iiAcuOO-Ds
3. Bio-energy and Bio-fuels: https://youtu.be/uHS-956eyuU
4. Production of Bio-fuel using microbes: https://youtu.be/PQAdAt6kx2U
5. Biomass Conversion and Bio-refinery: https://youtu.be/H1hrkC--dto

XVIII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 12

Demonstration of Hydrogen Fuel Cell (Using Video/Animation).*

I. Practical Significance

This practical introduces students to clean and futuristic energy systems based on hydrogen fuel cells. It helps learners understand how chemical energy stored in hydrogen is directly converted into electrical energy without combustion, resulting in zero carbon emissions.

II. Industry / Employer Expected Outcome(s)

Ability to explain the working of hydrogen fuel cells and recognize the industrial applications of green hydrogen in transportation, power generation, and portable energy systems.

III. Course Level Learning Outcome(s)

CO5- Select suitable source(s) of energy generation using principles of renewable energy.

IV. Laboratory Learning Outcome(s)

LLO 12.1: Identify different components of fuel cell.

V. Relevant Affective Domain Related Outcome(s)

Develops environmental responsibility and awareness of zero-emission energy alternatives.

VI. Relevant Theoretical Background

Working Principle: A hydrogen fuel cell generates electricity through an electrochemical reaction where hydrogen gas at the anode splits into protons and electrons. The protons move through the electrolyte while electrons flow through an external circuit, producing electric current.

Overall Reaction: At the cathode, oxygen from air combines with protons and electrons to form water.

Net Reaction:

$2H_2 + O_2 \rightarrow 2H_2O + Electricity + Heat$

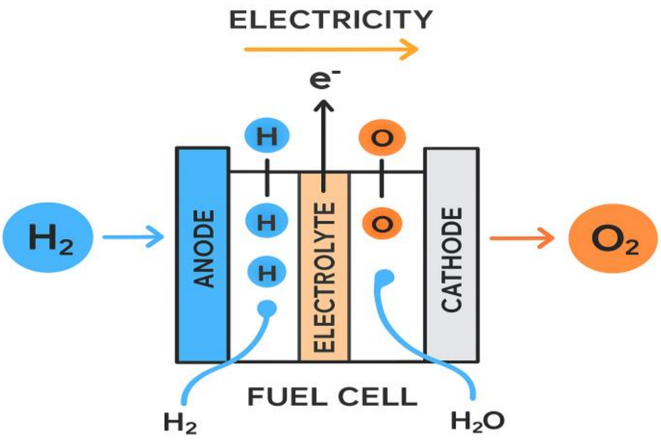

Fig. 12.1: Hydrogen fuel cell reaction

1. **Key Characteristics and Applications:**

Hydrogen fuel cells operate without combustion, produce zero harmful emissions (only water), and are used in electric vehicles, backup power systems, portable energy devices, and clean industrial energy solutions.

VII. Concept Demonstration (Video / Animation Links)

Source	Topic	Link
MNRE – National Hydrogen Mission	Green Hydrogen Development in India	https://mnre.gov.in/hydrogen/
NISE (Govt of India)	Hydrogen Fuel Cell Basics	https://nise.res.in/#
National Renewable Energy Lab (NREL)	Interactive Hydrogen Fuel Cell Overview	https://www.nrel.gov/hydrogen/fuel-cells.html
IIT Bombay NPTEL	Hydrogen Storage & Fuel Cell Technology	https://nptel.ac.in/courses/112/101/112101096/
IIT Madras – Hydrogen Economy Lecture	Hydrogen as Future Fuel	https://nptel.ac.in/courses/122106030
How hydrogen fuel cell works- Animation link	How hydrogen fuel cell works	https://youtu.be/GfJN3EMe0Jk

VIII. Required Resources / Apparatus / Equipment

Since this is a Demonstration Practical, a display system is needed:

Item	Quantity
Computer / Smart Classroom	01
Internet / Local Video File	01
Whiteboard & Marker	01

IX. Precautions to be Followed

1. Pay close attention to each step shown in the video/animation without skipping.
2. Note the components and reactions carefully as they may not be visible again.
3. Do not perform any live experiment with hydrogen without instructor supervision.
4. Refer to authenticated educational or government-approved sources for technical clarity.
5. Record observations during the demonstration in real-time for accurate reporting.

X. Procedure

1. Introduce hydrogen fuel and renewable energy context.
2. Play the selected video/animation explaining PEM fuel cell.
3. Pause at key moments to explain: Hydrogen splitting at anode, Electron flow in circuit & Water formation at cathode/
4. Discuss practical applications: Hydrogen cars.
5. Conduct student reflection discussion.

XI. Observations and Calculations

Parameter Observed	Remarks
Cell type (PEM / Alkaline / SOFC)	
Fuel used	
Output form	
Note on Emission	
Possible Applications	

XII. Results

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XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the overall chemical reaction taking place in a hydrogen fuel cell.
2. Explain the role of the electrolyte in a fuel cell.
3. List two industrial applications of hydrogen fuel cell technology.
4. Mention the major advantage of using green hydrogen as an energy source.

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XVI. References/Suggestions for further reading

1. MNRE: Hydrogen & Fuel Cell Programme (Government of India) https://mnre.gov.in/hydrogen/
2. Introduction to hydrogen storage: https://youtu.be/jVGxQMaGdPI?list=PLOzRYVm0a65dtZiqOUeyWCiCWL4vWaDwj
3. NREL (National Renewable Energy Laboratory) – Fuel Cell Learning Resources- https://www.nrel.gov/hydrogen/fuel-cells.html
4. Cryogenic and Metal Hydride based Hydrogen Compressors- https://youtu.be/u9zI60DDr98?list=PLOzRYVm0a65dtZiqOUeyWCiCWL4vWaDwj
5. Classification of Hydrogen related Hazards- https://youtu.be/KXOlETWlTJM?list=PLOzRYVm0a65dtZiqOUeyWCiCWL4vWaDwj
6. Utilisation in Different Sectors, Global Status and Future Directions- https://youtu.be/GqT09rJFW3c?list=PLOzRYVm0a65dtZiqOUeyWCiCWL4vWaDwj

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 13

Demonstration of Geothermal Power Plant using Video/Animation.

I. Practical Significance

The demonstration of a geothermal power plant using video and animation helps students visually understand the renewable geothermal energy that is converted into electrical energy. Through this practical, students gain a clear conceptual understanding of the working principle, layout, and key components of geothermal power plants.

II. Industry / Employer Expected Outcome(s)

Understand the main components and working of a geothermal power plant, which are useful for careers in renewable energy and power generation.

III. Course Level Learning Outcome(s)

CO5- Select suitable source(s) of energy generation using principles of renewable energy.

IV. Laboratory Learning Outcome(s)

LLO 13.1: Identify different components of geothermal power plant.
LLO 13.2: Prepare a report on geothermal power plant.

V. Relevant Affective Domain Related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background

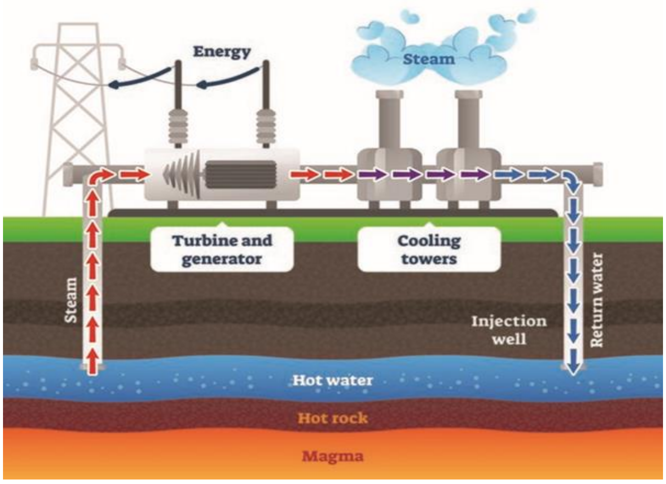

Fig. 13.1: Basic of Geothermal Power Plant

The heat from magma warms the underground water to a high temperature (above 182°C). This hot water is brought to the surface through wells. The steam separated from the hot water is used to rotate the turbine, and the turbine runs a generator to produce electricity. After use, the steam is cooled and the water is sent back underground.

VII. Actual Power Plant Diagram Used (with Equipment Function/Description)

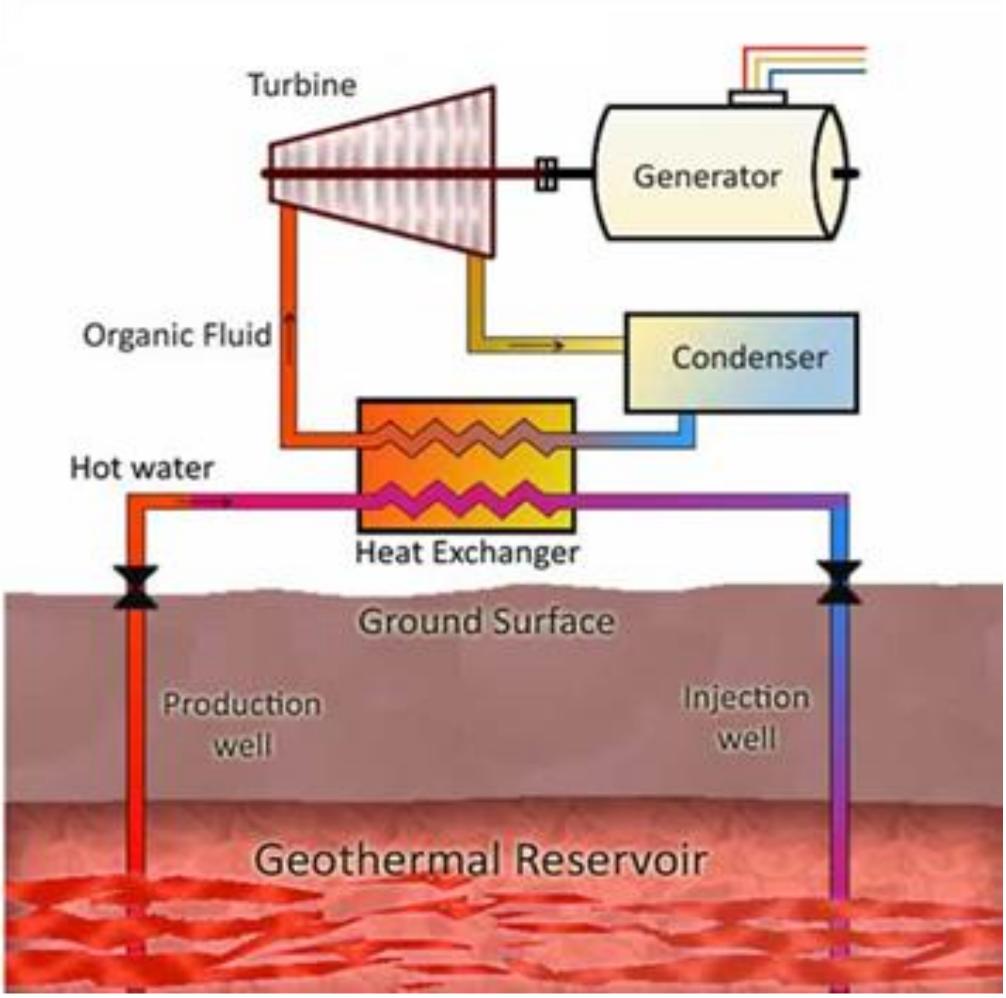

Fig. 13.2: Geothermal Power Plant

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Instruments	Specification	Quantity
1	LCD / Smart Digital board	Standard	01
2	Model or chart of Geothermal power plant	3D components or colorful chart with labeling of components	01

Video link:

Source	Topic	Link
Geothermal Power Plant (3D HD video)	Visualization of the plant operation	https://www.youtube.com/watch?v=du2GGQlQMPE

IX. Precautions to be Followed

1. Handle all electronic equipment such as projectors and computers carefully.
2. Ensure the video or animation is properly set up before starting the demonstration.
3. Maintain discipline and avoid touching equipment without permission.
4. Note down observations carefully while watching the video or animation.

X. Procedure

1. The instructor explains the aim and objectives of the practical.
2. Arrange the necessary equipment such as a computer, projector, and video or animation of the geothermal power plant.
3. Play the video or animation showing the working of a geothermal power plant.
4. Observe carefully how hot water and steam are used to run the turbine and generate electricity.
5. Identify the main parts of the plant such as production well, turbine, generator, condenser, and cooling tower.
6. Note down the important points like plant type, components, and working principle in the observation table.
7. Discuss the function of each part as shown in the animation or video.
8. Prepare a neat labelled diagram of the geothermal power plant.
9. Write a short report based on your observations and discussion.
10. Submit the completed report and observation sheet to the instructor for evaluation.

XI. Observations and Calculations

S. No.	Components of Geothermal Plants	Function/Description
1	**Production Well**	Brings hot water or steam from deep inside the Earth to the surface.
2	**Separator**	
3	**Turbine**	
4	**Generator**	
5	**Condenser**	
6	**Cooling Tower**	
7	**Reinjection well**	

XII. Results

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XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. List the three main types of geothermal power plants.
2. List the alternative sources of energy to geothermal power.
3. Explain the demerits of geothermal power plants
4. List the geothermal energy conservation power plant in global.

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XVI. References / Suggestions for Further Reading

1. https://www.youtube.com/watch?v=mCRDf7QxjDk

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 14

Demonstration of Ocean thermal power plant using video/animation.

I. Practical Significance

The demonstration of an ocean thermal power plant using video and animation helps students visually understand the renewable ocean thermal energy that is converted into electrical energy. Through this practical, students gain a clear conceptual understanding of the working principle, layout, and key components of ocean thermal power plants.

II. Industry / Employer Expected Outcome(s)

Understand the main components and working of an ocean thermal power plant, which are useful for careers in renewable energy and power generation.

III. Course Level Learning Outcome(s)

CO5- Select suitable source(s) of energy generation using principles of renewable energy.

IV. Laboratory Learning Outcome(s)

LLO 14.1: Identify different components of ocean thermal power plant.
LLO 14.2: Prepare a report on ocean thermal power plant.

V. Relevant Affective Domain Related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background

An Ocean Thermal Energy Conversion (OTEC) power plant generates electricity using the temperature difference between warm surface seawater (approximately 25°C) and cold deep seawater (approximately 5°C). This process works on the principle of a Rankine cycle, using a low-boiling working fluid like ammonia.

VII. Actual Power Plant Diagram Used (with Equipment Function/Description)

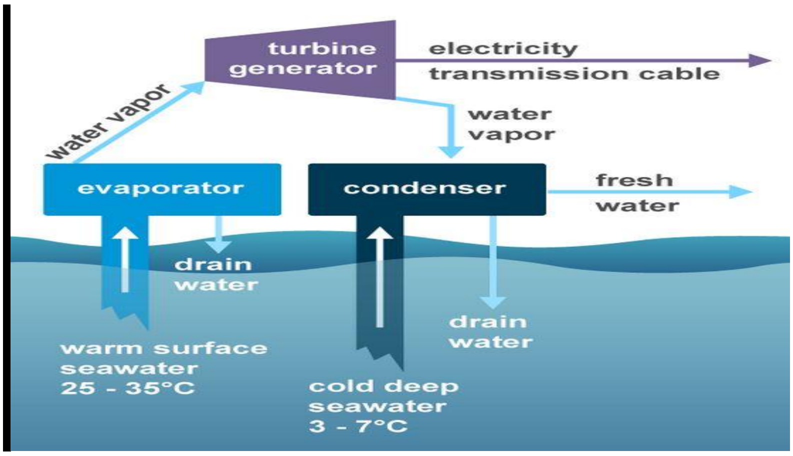

Fig. 14.1: Ocean Thermal Energy Conversion Power Plant

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Instruments	Specification	Quantity
1	LCD / Smart Digital board	Standard	01
2	Model or chart of Ocean thermal power plant	3D components or colorful chart with labeling of components	01

Video link:

Source	Topic	Link
Ocean Thermal Energy Conversion	Animated and explained with 3d program	https://www.youtube.com/watch?v=IASV8IH-ytE
OTEC a green energy source	Working of ocean thermal energy conversion OTEC a green energy source	https://www.youtube.com/shorts/u_qH94AWUPg
Ocean thermal energy conservation otec | otec power plant animation | otec in renewable & smart grid	Working principle of ocean thermal energy conversion	https://www.youtube.com/watch?v=ala3ruvZMho
Ocean Thermal Energy Conversion (OTEC)	OTEC Energy, OTEC Working Pros & Cons	https://www.youtube.com/watch?v=ggY81DjqOds

IX. Precautions to be Followed

1. Handle all electronic equipment such as projectors and computers carefully.
2. Ensure the video or animation is properly set up before starting the demonstration.
3. Maintain discipline and avoid touching equipment without permission.
4. Note down observations carefully while watching the video or animation.

X. Procedure

1. The instructor explains the aim and objectives of the practical.
2. Arrange the necessary equipment such as a computer, projector, and video or animation of the geothermal power plant.
3. Play the video or animation showing the working of a geothermal power plant.
4. Observe carefully how hot water and steam are used to run the turbine and generate electricity.
5. Identify the main parts of the plant such as production well, turbine, generator, condenser, and cooling tower.
6. Note down the important points like plant type, components, and working principle in the observation table.
7. Discuss the function of each part as shown in the animation or video.
8. Prepare a neat labelled diagram of the geothermal power plant.
9. Write a short report based on your observations and discussion.
10. Submit the completed report and observation sheet to the instructor for evaluation.

XI. Observations and Calculations

Following are the components of ocean thermal power plant with its function/ description;

S. No.	Components of Ocean Thermal Power Plant	Function/Description
1	Evaporator	Uses warm surface seawater (approx. 25°C) to heat a working fluid (such as ammonia) with a low boiling point. This causes the fluid to evaporate and form high-pressure vapor.
2	Turbine	
3	Generator	
4	Condenser	
5	Pump	
6	Pipes (Warm and Cold-Water Pipes)	
7	Working Fluid (e.g., Ammonia or Propane)	

XII. Results

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XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the temperature difference required between surface water and deep water for effective operation of an OTEC plant.
2. Mention one limitation of OTEC technology.
3. State the typical efficiency of an OTEC power plant
4. Compare open-cycle and closed-cycle OTEC systems
5. List the ocean thermal energy conservation power plant in global.

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XVI. References / Suggestions for Further Reading

1. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/Ocean_Thermal_Energy_V4_web.pdf
2. https://www.power-technology.com/projects/makais-ocean-thermal-energy-conversion-otec-power-plant-hawaii/
3. en.wikipedia.org/wiki/Ocean_thermal_energy_conversion
4. www.energyglobal.com/wind/23082023/global-otec-and-enogia-partner-to-develop-otec-plants
5. www.power-technology.com/projects/hainan-ocean-thermal-energy-conversion-otec-power-plant
6. OTEC: https://www.youtube.com/watch?v=LJV4d4XtHuo

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60**%)
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40**%)
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 15
Demonstration of wind power plant using video/animation/visit.

I. Practical Significance

The demonstration of a wind power plant using video and animation helps students visually understand how renewable wind energy is converted into electrical energy. Through this practical, students gain a clear conceptual understanding of the working principle, layout, and key components of a wind power plant, enhancing their knowledge of sustainable energy generation.

II. Industry / Employer Expected Outcome(s)

To understand the main components and working principle of a wind power plant that will be useful for developing careers in renewable energy and power generation.

III. Course Level Learning Outcome(s)

CO4- Utilize wind as a renewable energy technology for generation.

IV. Laboratory Learning Outcome(s)

LLO 15.1: Identify different components of wind power plant.
LLO 15.2: Prepare a report on wind power plant.

V. Relevant Affective Domain Related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background

The wind power plant works on the principle of conversion of kinetic energy of wind into mechanical energy, and then into electrical energy. When wind blows, it moves the turbine blades, causing the rotor to spin. This rotational (mechanical) energy is transferred to the generator through a shaft and gearbox, where it is converted into electrical energy by electromagnetic induction.

VII. Actual Power Plant Diagram Used (with Equipment Function/Description)

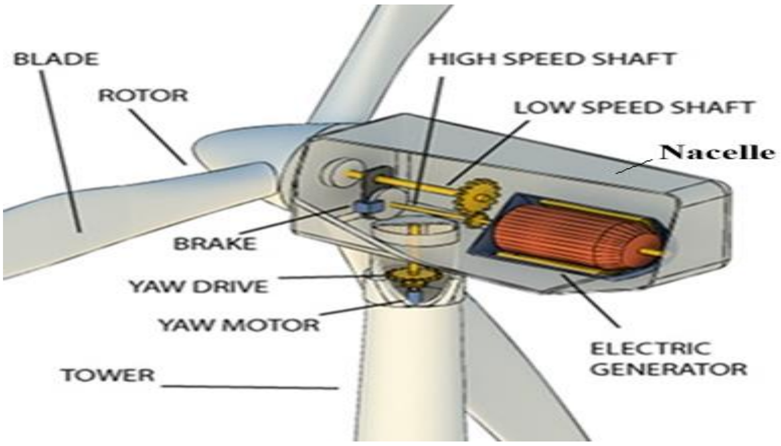

Fig. 15.1: Wind Power Plant

VIII. Required Resources / Apparatus / Equipment

S. No.	Name of Instruments	Specification	Quantity
1	LCD / Smart Digital board	Standard	01
2	Working Model or chart of Wind power plant	Model with components or colorful chart with labeling of components	01

Video link:

Source	Topic	Link
Wind Turbines/Wind Power	Working with 3D animation	https://www.youtube.com/watch?v=CyHOl-hetbU
Wind Turbine	Wind Turbine Animation	https://www.youtube.com/watch?v=ytkw3fS8iFw
Wind turbine	Working of wind turbines	https://www.youtube.com/watch?v=qSWm_nprfqE

IX. Precautions to be Followed

1. Handle all electronic equipment such as projectors and computers carefully.
2. Ensure the video or animation is properly set up before starting the demonstration.
3. Maintain discipline and avoid touching equipment without permission.
4. Note down observations carefully while watching the video or animation.

X. Procedure

1. The instructor explains the aim and objectives of the practical.
2. Arrange the necessary equipment such as a computer, projector, and video or animation of the geothermal power plant.
3. Play the video or animation showing the working of a geothermal power plant.
4. Observe carefully how hot water and steam are used to run the turbine and generate electricity.
5. Identify the main parts of the plant such as production well, turbine, generator, condenser, and cooling tower.
6. Note down the important points like plant type, components, and working principle in the observation table.
7. Discuss the function of each part as shown in the animation or video.
8. Prepare a neat labelled diagram of the geothermal power plant.
9. Write a short report based on your observations and discussion.
10. Submit the completed report and observation sheet to the instructor for evaluation.

XI. Observations and Calculations

Following are the components of ocean thermal power plant with its function/description;

S. No.	Components of ocean thermal power plant	Function/Description
1	Blades	
2	Rotor	
3	Nacelle	The housing on top of the tower that contains key components like the gearbox, generator, and control system.
4	Gearbox	
5	Generator	
6	Tower	
7	Yaw Mechanism	Rotates the nacelle so that the turbine faces the wind direction for maximum efficiency.
8	Brake System	
9	Controller	

XII. Results

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XIII. Interpretation of Results

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XIV. Conclusion and Recommendation

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Name the instrument used to measure wind speed and direction.
2. State the criterion for horizontal vertical axis wind mill.
3. Compare horizontal and vertical axis wind mill.
4. Write the report on wind power plant station.
5. List the wind power plant in India.

[Space for Answer]

XVI. References / Suggestions for Further Reading

1. https://www.youtube.com/watch?v=EYYHfMCw-FI
2. https://www.youtube.com/watch?v=DILJJwsFl3w
3. https://www.youtube.com/watch?v=XGnxMBaaTxE
4. https://www.youtube.com/watch?v=Z5c50-_hcD0

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**(60%)**
1	Handling of the measuring Instruments	40%
2	Calculation of final readings	20%
Product Related (10 Marks)		**(40%)**
3	Interpretation of result	30%
4	Practical related questions	10%
	Total	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	