Lappeenranta-Lahti University of Technology LUT

School of Energy Systems

BL20A1400 Renewable Energy Technology

EXAMINATION: 03rd November 2026, C. Breyer/A. Gulagi

TIME: 16:30 – 18:30

- You are allowed to use one, double-sided sheet of A4-sized paper as a study aid during the exam. This study aid must be hand-written. No printouts or photocopies will be allowed. No other supplementary materials or dictionaries are allowed.
- You do not need to submit your study aid.
- Read and follow the instructions for each question carefully.
- Use the answer paper provided to show detailed calculations. Showing your formulas and calculations in detail will ensure that part marks can be awarded if minor calculation errors occur.
- Your name and student number must appear on all answer booklets.
- Calculators with empty memory/offline may be used.
- All questions should be answered in English in a clear and legible handwriting.

EXAM TOTAL: 40 points

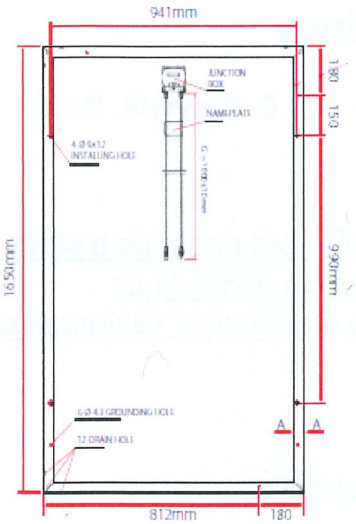
Answer **ALL** of the following questions. Showing your calculations in detail will ensure that part marks can be awarded if minor calculation errors occur.

1. Use the manufacturer's specifications provided for the TSM-PC05 solar modules. **(Total 10 points)**
   - **a.** Calculate the efficiency of the **TSM-245 PC/PA05 at NOCT**. **(2 points)**
   - **b.** Calculate the MPP, short circuit current, open circuit voltage and efficiency of the TSM-245 panel at a cell temperature of 15 °C **higher** than NOCT, assuming all other conditions are the same. **(8 points)**

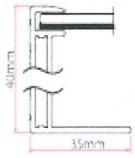
LUT Group Confidential - Other information (3Y)

TSM-PC05 / TSM-PA05 THE UNIVERSAL SOLUTION

DIMENSIONS OF PV MODULE TSM-PC/PA05

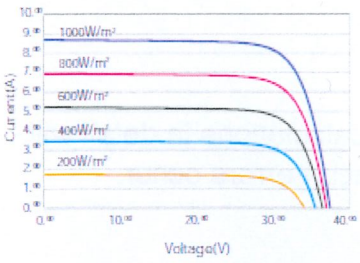


Back View



A-A

I-V CURVES OF PV MODULE TSM-245 PC/PA05



Average efficiency reduction of 4.5% at 200W/m² according to EN 60904-1.

CERTIFICATION

ELECTRICAL DATA @ STC	TSM-235 PC/PA05	TSM-240 PC/PA05	TSM-245 PC/PA05	TSM-250 PC/PA05
Peak Power Watts-P_{MAX} (Wp)	235	240	245	250
Power Output Tolerance-P_{MAX} (%)	0/+3	0/+3	0/+3	0/+3
Maximum Power Voltage-V_{MP} (V)	29.3	29.7	30.2	30.3
Maximum Power Current-I_{MPP} (A)	8.03	8.10	8.13	8.27
Open Circuit Voltage-V_{OC} (V)	37.2	37.3	37.5	37.6
Short Circuit Current-I_{SC} (A)	8.55	8.62	8.68	8.85
Module Efficiency η_m (%)	14.4	14.7	15.0	15.3

Values at Standard Test Conditions STC (Air Mass AM1.5, Irradiance 1000W/m², Cell Temperature 25°C).
Power measurement tolerance: ±3%

ELECTRICAL DATA @ NOCT	TSM-235 PC/PA05	TSM-240 PC/PA05	TSM-245 PC/PA05	TSM-250 PC/PA05
Maximum Power-P_{MAX} (Wp)	171	174	178	181
Maximum Power Voltage-V_{MP} (V)	26.4	26.6	26.8	27.0
Maximum Power Current-I_{MPP} (A)	6.48	6.55	6.64	6.70
Open Circuit Voltage (V)-V_{OC} (V)	34.0	34.1	34.2	34.3
Short Circuit Current (A)-I_{SC} (A)	6.97	7.04	7.10	7.25

NOCT: Irradiance at 800W/m², Ambient Temperature 20°C, Wind Speed 1m/s.
Power measurement tolerance: ±3%

MECHANICAL DATA	
Solar cells	Multicrystalline 156 × 156mm (6 inches)
Cell orientation	60 cells (6 × 10)
Module dimensions	1650 × 992 × 40mm (64.95 × 39.05 × 1.57 inches)
Weight	19.5kg (43.0 lb)
Glass	High transparency solar glass 3.2mm (0.13 inches)
Frame	Anodized aluminium alloy
J-Box	IP 65 rated
Cables	Photovoltaic Technology cable 4.0mm² (0.006 inches²), 1000mm (39.4 inches)
Connector	MC4

TEMPERATURE RATINGS	
Nominal Operating Cell Temperature (NOCT)	45°C (±2°C)
Temperature Coefficient of P_{MAX}	- 0.43%/°C
Temperature Coefficient of V_{OC}	- 0.32%/°C
Temperature Coefficient of I_{SC}	0.047%/°C

MAXIMUM RATINGS	
Operational Temperature	-40~+85°C
Maximum System Voltage	1000V DC(IEC)/ 600V DC(UL)
Max Series Fuse Rating	15A

WARRANTY
10 year workmanship warranty
25 year linear performance warranty

(Please refer to product warranty for details)

PACKAGING CONFIGURATION
Modules per box: 24 pcs
Modules per 40' container: 672 pcs

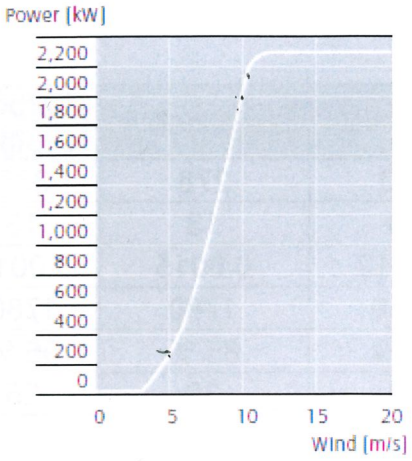
TSM_EN_Jan_2012

LUT Group Confidential - Other information (3Y)

2. Use the manufacturer's specifications provided for the 2.3 MW wind turbine. **(Total 14 points)**

Sales power curve

The calculated power curve data are valid for standard conditions of 15 degrees Celsius air temperature, 1,013 hPa air pressure and 1.225 kg/m³ air density, clean rotor blades, and horizontal, undisturbed air flow. The calculated curve data are preliminary.



a) Estimate the total annual energy production for the turbine with an availability of 90%. Average wind speed is 7 m/s. Provide the missing information from the Table below for Power, Probability and Energy. Use a Rayleigh distribution to determine the probability. **(13 points)**

Wind speed (m/s)	Power (kW)	Probability	Energy (MWh/year)
3	75	0.0833	49.23
4	150	0.0992	117.34
5			
6	450	0.1080	383.21
7	700	0.1023	564.64
8	1100	0.0919	797.34
9			
10	2000	0.0645	1017.63
11			
12	2300	0.0383	693.72
13	2300	0.0278	503.40
14	2300	0.0194	351.68
15	2300	0.0131	236.72
16			
17	2300	0.0053	96.18
18	2300	0.0032	58.11
19	2300	0.0019	33.90

LUT Group Confidential - Other information (3Y)

20	2300	0.0011	19.10
		Total (GWh)	

b) Calculate the number of annual full load hours for the turbine. **(1 point)**

3. Consider the following data for Israel in 2030, where the components of the electricity system are assumed to be ground-mounted solar PV, stationary batteries, and a PtG system (including gas storage). Assume WACC is 5%. **(Total 10 points)**

Parameter	Unit	Electrolysis	Methanation	Carbon capture	CCGT	Solar PV
Capex	€/kW	380	278	335	775	390
Opex_fixed	€/kW	13	13	13	19	11
Opex_variable	€/kWh	0.0012	0.0015	0.0013	0.002	0
FLH	hours	1780	1780	1780		1700
Efficiency	%	70 %	85 %	95 %	58 %	
Lifetime	years	30	30	25	30	35

Parameter	Unit	Battery	Gas storage
Capex	€/kWh	134	0.05
Opex_fixed	€/kWh	4	0.001
Opex_variable	€/kWh	0.0002	0
Efficiency (round trip)	%	85 %	100 %
Lifetime	years	20	50

Parameter	Unit	Value
Average daily consumption	kWh_e	15
Number of households		200000
Hours of year	h	8760
Daily consumption	GWh_e	3
Annual consumption	GWh_e	1095
Average hourly power demand	kW_e	125000
Battery capacity	kWh_e	8
Battery E/P	h	6
Battery cycles/a		365
Number of batteries		200000

a) Calculate the total amount of energy that would be charged to the batteries in GWh_e. **(2 points)**

b) Calculate the total amount of energy that would be discharged from the batteries in GWh_e. **(2 points)**

c) Calculate the amount of electricity output that would come from the CCGT in GWh_e. **(2 points)**

d) Calculate the amount of gas that would be needed to produce this much electricity in GWh_{gas}. **(1 point)**

e) Calculate the total amount of PV energy that would need to be generated over the year in GWh_e. **(2 points)**

f) Calculate the PV capacity needed to produce that energy in MW_p. **(1 point)**

4. PtX: Methanol production (6 points)

Methanol production in the PtX process is defined by the following:

Methanol synthesis

$$CO_2 + 3H_2 \leftrightarrow CH_3OH + H_2O \quad \Delta H_{298K,50\,bar} = -40.9\ \frac{kJ}{mol}$$

Assume that an electrolyser can be operated at 84% efficiency to create hydrogen gas, and that CO_2 can be produced in a scrubber at an energy demand of 500 kWh/ton. The lower heating values of hydrogen and methanol are 120.21 and 20.094 MJ/kg, respectively. Calculate the efficiency of the PtX (here: power-to-methanol) process as a whole if only 80% of the raw materials are converted by the methanol synthesis process. Hint: assume 1000 mol production and calculate mass and energy flows.

Molar mass		
CO	g/mol	28
CO_2	g/mol	44
H_2	g/mol	2
CH_3OH	g/mol	32
H_20	g/mol	18

LUT Group Confidential - Other information (3Y)