PHOTOVOLTAICS

You have 60 minutes to solve this test. You may answer in English or Portuguese. Assume reasonable data for any relevant parameters that are not presented.

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1. Please indicate if these statements are true or false. [6]

   [A right answer yields 1 point while a wrong answer loses 1 point so avoid the lottery!

   The total value for this question is 6. The minimum value for the question is 0 (zero) points.]

   a) The inclination of PV modules in a solar-powered irrigation pump that only operates in the summertime should be higher than the local latitude.

   b) Although costly, building-integrated PV systems can be cost-competitive if they replace other expensive materials on façades.

   c) The power of the inverter should always be lower than the nominal power of the PV array.

   d) A PV system will never generate the electricity used for its manufacturing.

   e) In Solar Home Systems (SHS) in tropical areas, the battery should be stored in a closed case to protect it from humidity.

   f) For a PV system to be profitable, it must be cleaned every 3 months, regardless of its location.

2. Consider a solar car with $3m^2$ of solar panels set on the horizontal plane.

   a) Estimate its daily solar range for a day in winter and one day in summer considering the average insolation in Lisbon (assume 0.10 kWh/km and 25% PV efficiency). [3]

   b) If the battery is Li-ion (150 Wh/kg) determine the weight of the battery for 3 days autonomy. [2]

   c) How do these results impact the feasibility of solar mobility? Discuss its main benefits and challenges. [2]

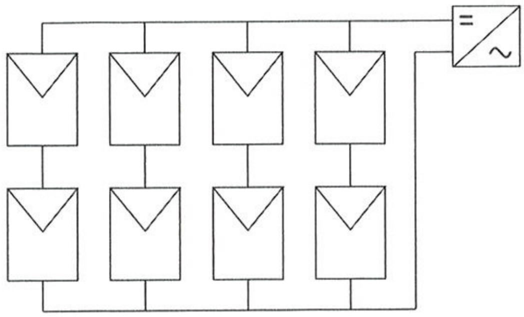
Table 1. Solar irradiation for Lisbon, ($Wh/m^2/day$)

for the horizontal and optimally inclined plane.

Month	Horizontal plane	Optimally inclined plane
Jan	2180	3510
Feb	3210	4670
Mar	4680	5750
Apr	5640	6040
May	6680	6450
Jun	7450	6790
Jul	7620	7100
Aug	6880	7110
Sep	5400	6460
Oct	3800	5230
Nov	2510	4000
Dec	1950	3350
Year	**4840**	**5540**

3. Consider the PV system shown in the figure, composed of 8 modules with the specifications defined in the table. The system is in a region with 4.8 kWh/m²/day and the ambient temperature range is [-5 °C, 28 °C].

Panel efficiency	15.4%
V_{mpp}	30.0 V
I_{mpp}	8.55 A
V_{oc}	38.0 V
I_{sc}	9.0 A
Voltage T coef.	-0.33 %/°C
NOCT	45 °C



Determine:

a) the STC nominal power and the area of each module. [1]

b) the fill factor. [1]

c) the average yearly energy generation of this system. [1]

d) the maximum current generated by the PV array. [1]

e) the inverter input voltage range. [3]

K = 1.38 x 10^{-23} kg/s²/K   q = 1.6 x 10^{-19} C $I = I_L - I_0\left[\exp\left(\frac{qV}{nkT}\right) - 1\right]$

PV TEST 2023/2024

(1)

a) F (should be lower, in the summer the sun is higher in the sky)

b) T

c) F (it <u>may</u> be lower and use the money saved in the inverter to buy more modules but it's not required)

d) F (energy pay back is 1-2 years and lifetime > 20 years)

e) F (battery should always be ventilated)

f) F (rain can clean modules so really depends on location)

(2.) 3 m^2 PV on a car

a) daily solar range winter / summer?

summer: 7620 Wh/m^2/day
(july) × 3 m^2 (area)

23 kWh/day
× 0.25 (efficiency)

5.7 kWh/day
÷ 0.10 kWh/km

57 km/day

winter: 1950 Wh/m^2/day
(dec) (...)

14 km/day

obs: this is probably an over estimation because there are other losses such as shading, temperature, DC-DC conversion, etc.

2. b) 150 Wh/kg

Let's assume that the vehicle drives 30 km/day. In summer the solar resource is abundant so we need to look only at winter:

Driving range: 30 km
Solar range: −14 km

16 km/day
× 3 days

48 km

0.10 kWh/km × 48 km = 4.8 kWh

weight: 0.15 kWh/kg

$$\frac{4.8}{0.15} = 32\,\text{kg}$$

→ less than an adult ü

e) weight not relevant.
[and then talk about initial cost, reliability, looks & colour, but also range anxiety, operational cost, charging frequency, etc]

3.

a) $P_{STC} = V_{mp} \times I_{mp} = 30 \times 8.55 = \underline{256.5\ W}$

$$\text{Area} \times 1000\ \frac{W}{m^2} \times 0.154 = 256.5\ W$$

$$\text{Area} = \underline{1.67\ m^2}$$

b) $FF = \dfrac{V_{mp} \times I_{mp}}{V_{OS} \times I_{SC}} = \dfrac{256.5}{38 \times 9} = \underline{0.75}$

c) $4.8\ kWh/m^2/day \times 1.67\ m^2 \times 0.154 \times 365\ \dfrac{days}{year}$

$= \underline{3604}\ kWh/year$

d) 4 strings $\times\ I_{sc} = 36\ A$

(for sizing of the inverter we should consider an extra factor $\times 1.25$)

e) cf next page

3 c) $V_{max} = ?$ ← lowest T, V_{oc}

(assume $T_c = T_{amb} = -5°C$)

$\Delta T = 25 - (-5) = 30°C$

$\Delta V(\%) = 0.33 \times 30 = 10\%$

$V_{max} = 2 \times V_{oc} \times 1.1 = \underline{83.6\ V}$

↑ 2 modules in series

$V_{min} = ?$ ← highest T, V_{mp}, $G = 800\ W/m^2$

$T_c = T_a + \frac{NOCT - 20}{800} 800 = 53°C$

$\Delta T = 25 - 53 = -28°C$

$\Delta V = -0.33 \times 28 = -10\%$

$V_{min} = 2 \times V_m \times (1 - 0.10) = \underline{54.5\ V}$

the voltage range for the inverter is [54, 84] V.