PV Mythbuster: A Collection of Quizzes

Muhammad A. Alam
Purdue University

Answer the **multiple choice questions** below by **circling** the **one, best answer**.

(You are encouraged to use the **PVLimits** tool in nanoHUB to understand and answer the questions. Create a free account in nanoHUB, by visiting https://nanohub.org/register/ . Then run the tool from: https://nanohub.org/resources/pvlimits. Also, the appendix contains a table of simple, but very useful, equations).

Part A. The Source of the Solar Energy

1) If you could collect all the photons of the AM1.5G spectrum, the short circuit current would be
   a) 1000 mA/cm^2
   b) 700 mA/cm^2
   c) 70 mA/cm^2
   d) 7 mA/cm^2
   e) None of the above.

2) The temperature of the sun is 6000K. Had it cooled down by a factor of 2, the integrated energy arriving on the surface of the earth would be reduced by a factor of
   a) 2
   b) 4
   c) 8
   d) 16
   e) 32

3) AM1.5 means
   a) Amplitude modulation at 1.5 GHz.
   b) Sunlight at the sea level, when the sun is directly overhead.
   c) Sunlight at the sea level, when the sun is at ~50 degrees.
   d) Sunlight at the sea level, when the sun is at 1.5 radian tilted in the horizon.
   e) Air mass measured at 1.5 THz.

Part B. Single Junction Solar Cells

1) The maximum J_{sc} of a silicon cell is 46 mA/cm^2. Midgap defects are introduced in the bandgap to catch the subbandgap photons. The maximum current of the new cell is
   a) 700 mA/cm^2.
   b) 70 mA/cm^2
   c) 58 mA/cm^2
   d) less than 58 mA/cm^2.
   e) I am not working on intermediate bandgap cells, so I have no clue.

2) If the bandgap of a single junction solar cell is 1eV, the maximum V_{oc} would be
   a) 1.0 volt
   b) 0.7 volt
   c) 0.5 volt
   d) 0.3 volt
   e) Need more information.

3) A filter is placed in front of an AM1.5 source, but the short circuit remains unchanged. This could be due to the fact that
   a) The below bandgap light was cut-off.
   b) The above bandgap light was cut-off.
   c) The radiative emission was cut-off.
   d) The increased area of the scattered light compensated the loss in intensity.
   e) AM1.5 is insensitive to filtering.

4) The formula for maximum V_{oc} for a semiconductor with given E_g is
   a) E_g
   b) $E_g - 0.23$
   c) $0.95E_g - 0.23$
   d) $0.95E_g + 0.23$
   e) Cannot be determined.

5) The maximum fill-factor of a single material solar cell with bandgap between 0.5 to 2 eV is approximately
   a) 1.0
   b) 0.9
   c) 0.5
   d) 0.3
   e) 0.1

6) SQ limit assumes the following regarding the absorption of the above bandgap light
   a) 100% absorption.
   b) 80% absorption.
   c) Absorption up to the Yablonovitch limit.
   d) Depends on the band-tail states of the solar cells.
   e) Depends on the types of mirrors used in the cell.

7) The diffusion length of cell A is much larger than cell B. The contact area (which is often defined as the device area) is smaller than the area coverage of the active material. If they have equal area,
   a) Cell A will be affected more by parasitic light absorption compared to Cell B.
   b) Cell B will be affected more by parasitic light absorption compared to cell A.
   c) Cells A and B will both be equally affected: diffusion lengths has nothing to do with absorption.
   d) Depends on the relative strengths of radiative vs. non-radiative recombination.
   e) Cell area has nothing to do with parasitic absorption.

8) Pluto is very cold (T=50 K). How *efficient* would a Si solar cell deployed in Pluto would be compared to that in the Earth?
   a) It will be more efficient.
   b) Efficiency cannot change.
   c) It will be less efficient.
   d) The efficiency will be zero.
   e) I need a calculator.

9) A cell is tested at AM0 and AM1.5. How would the efficiencies compare?
   a) AM0-illuminated cells will be more efficient.
   b) AM1.5-illuminated cells will be more efficient.
   c) Efficiency would not depend on AM0 or AM1.5.

10) Assume that the full moon uniformly reflects the AM1.5 solar spectrum onto the earth with an intensity of 2.5 W/m^2. What is the maximum theoretical efficiency of a solar cell powered *exclusively* by this light?
   a) $\eta = 42\%$
   b) $\eta = 31\%$
   c) $\eta = 25\%$
   d) $\eta = 10\%$
   e) $\eta = 0\%$

Ans. The drop in efficiency with respect to SQ limit comes from two pieces: Most importantly, V_{oc} drops by $kT \times ln(I_{sun}/I_{moon})$ = 0.335 V. Also, FF drops slightly because of the decreased Voc (roughly from 0.89 to 0.845).

11) What would be the ideal bandgap if one were to use the spectrum from a red dwarf (assume a blackbody at T=3000 K) with an intensity of 1 kW/m^2?
   a) $E_g = 1.4$ eV
   b) $E_g = 1.1$ eV
   c) $E_g = 1.0$ eV
   d) $E_g = 0.7$ eV
   e) $E_g = 0.3$ eV

12) An experimental group reports $J_{sc} = 35\ mA/cm^2$ for an organic cells with 1.8 eV bandgap, illuminated by AM1.5G solar spectrum. Is this current?
   a) Too high.
   b) Too low.
   c) About right.
   d) J_{sc} does not depend on bandgap
   e) None of the above.

Part C. Multi-junction, Bifacial and/or Concentrator Solar Cells

1) The increase in efficiency of a concentrator solar cell arises from the suppression of
   a) Carnot loss.
   b) Loss due to radiative recombination.
   c) Loss due to angle entropy.
   d) Below bandgap loss.
   e) Above bandgap loss.

2) The sum of short circuit currents for both materials in a tandem cell:
   a) Cannot exceed that of the larger bandgap material in a single cell configuration
   b) Must exceed that of the larger bandgap material in a single cell configuration.
   c) Cannot exceed that of the smaller bandgap material in a single cell configuration.
   d) Must exceed that of the smaller bandgap material in a single cell configuration.
   e) The currents are unrelated.

3) A tandem cell and a module with two cell in series have the following elements in common
   a) Both increase the output voltage at the expense of output current.
   b) Both are affected by series resistance.
   c) The cell currents must be matched in both cases.
   d) Self-heating will affect the performance of both types of cells
   e) All of the above.

4) Compare two different solar cells A and B. Cell A is 28% efficient under 1-sun. Cell B is also 28% efficient, but under 10 sun. The output of the cells are

   a) At 1-sun, cell A is less efficient than cell B.
   b) At 1-sun, cell A is more efficient than cell B.
   c) Cell A produces 280 watts, but cell B produces 2800 watts.
   d) Both cells produce 280 watts.
   e) Both b and c.

5) What is the J_{sc} for a optimized three junction tandem cells under AM1.5 illumination (choose the closed approximate value)

   a) 10 mA/cm^2
   b) 20 mA/cm^2
   c) 30 mA/cm^2
   d) 40 mA/cm^2
   e) 50 mA/cm^2

Part D. Physics of Solar Modules

1) If the efficiency of a cell with fully reflecting mirror at the back is 20%, with 10% of light reflected from its front surface, then how much power is dissipated by the cell?
   a) 1000 W/m^2.
   b) 800 W/m^2.
   c) 700 W/m^2.
   d) 500 W/m^2.
   e) 200 W/m^2.

2) Assume that heat dissipation within a cell is $P = 500$ W/m^2, ambient temperature is 300K, and the convective heat transfer coefficient $h = 10.45 - v + 10\sqrt{v}$ [W/m^2 K], where v is relative speed on wind (m/s) and the equation is valid between 2-20 m/s. What is the temperature of the cell with $v = 0$?
   a) 700 K.
   b) 500 K.
   c) 400 K.
   d) 350 K.
   e) 325 K.

3) For the preceding problem, assume $v = 10.45\ m/s$. What is the temperature rise?
   a) 100 degrees K.
   b) 50 degrees K.
   c) 15 degrees K.
   d) 10 degrees K.
   e) 5 degrees K.

4) Thin film solar cells are connected in series to the following reason/reasons:
   a) To reduce the output voltage
   b) To reduce series resistance loss.
   c) To eliminate self-heating.
   d) To improves aesthetic appeal.
   e) To increase the output current.

5) Which of the cells below will need a busbar to collect the current
   a) Silicon
   b) CdTe
   c) CIGS
   d) OPV
   e) Perovskite.

6) Two panels have identical series resistance, power-output, short-circuit current, and self-heating. One panel is made of Si thick-film cells and the other is a CdTe thin-film cells. Which cell would have higher joule heating loss due to series resistance?

   a) CdTe solar cells.
   b) Silicon solar cells.
   c) It depends on processing conditions.

d) It depends on the light intensity.
e) All of the above.