Theory and Practice of Solar Cells: A Cell to System Perspective
Final Exam
Purdue University

There are 30 multiple choice questions in this problem set. Use the following link (https://forms.gle/h8eksPCAu4BQByabA) to choose the best answer from the options provided. A printout of the lecture notes will help you answer the questions. You can use google and/or any other resources, but you should work on your own and not consult anyone else. **The deadline for the exam is May 2nd, 10 am**.

Introductory Lecture

1. What percentage of the world's total energy is supplied by renewable energy?
    (a) 1-10%   (b) 10-20%   (c) 20-40%   (d) 40-60%   (e) More than 50%

2. 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.

3. The planet temperature depends on the albedo (α) of the planet as follows
    (a) $\sqrt{(\alpha)}$
    (b) α
    (c) $1 - \alpha$
    (d) $\sqrt{(1 - \alpha)}$
    (e) $(1 - \alpha)^{0.25}$

4. Between the wavelengths of 300-2250 nm, the peak O2 absorption occurs at
    (a) 350nm (b) 500 nm (c) 750 nm   (d) 1350 nm   (e) 2000 nm.

5. What simulator should you be using to simulate the properties of organic solar cell?
    (a) PVAnalyzer (b) PVPanelSim   (c) Purdue-LCOE (d) OPVLab (c)PVLimits

Thin Film Solar Cells

6. Which of the following properties are true for a thin-film solar cell
    (a) It is made of direct bandgap material
    (b) Its thickness is less than 1-2 um
    (c) It does not contain any busbar
    (d) It suffers from significant shunt conduction
    (e) All of the above

7. The voltage dependence of photo-current arises from
    (a) Voltage dependence of the diode conduction
    (b) Voltage dependence of the shunt conduction
    (c) Voltage dependence of the series resistance
    (d) Voltage dependence of photo-carrier collection

8. Which of the following is NOT a thin-film solar cell
    (a) a-Si
    (b) CdTe
    (c) CIGS
    (d) Perovskite
    (e) mc-Si

Grids in thin and thick-film solar cells

9. 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.

10. Which of the cells below will need a busbar to collect the current

    (a) Silicon
    (b) CdTe
    (c) CIGS
    (d) OPV
    (e)   Perovskite.

Reliability of Solar Cells

11.   PID occurs only in a

a) High voltage system
b) Silicon solar cell
c) High efficiency solar cell
d) Thin-film solar cell
e) Small stand-alone system

12. A bypass diode is used to address the following reliability issue

a) Potential induced degradation
b) Shadow degradation
c) Corrosion
d) Yellowing
e) Light induced degradation

13. A module with spiral-shaped subcells has the following properties

a) It reduces the series resistance loss, but increases the shadow degradation
b) It increases the series resistance loss, but reduces the shadow degradation
c) It increases both the series resistance loss as well as shadow degradation
d) It decreases both the series resistance loss as well as shadow degradation
e) None of the above

14. Light-induced corrosion is correlated to

(a) Shadow degradation
(b) Yellowing of the solar cell
(c) Potential induced degradation
(d) Hot spot formation
(e) None of the above

15. Which of the following degradation modes cannot be accelerated by increasing the temperature

(a) Thermal cycling
(b) Damp heat test
(c) Humidity-Freeze experiment
(d) UV damage
(e) Light induced degradation

PV System and Farm Design

16. A string inverter

    (a) Is connected to a subset of panels in a solar farm
    (b) Is connected to every panel
    (c) Is connected to all the panels in a solar farm
    (d) Can convert AC electricity to DC electricity
    (e) None of the above

17. What is the optimum tilt angle for maximum energy yield of a module in Chicago, IL

    (a) 20
    (b) 30
    (c) 40
    (d) 50
    (e) 60

18. A cross-string method is used to calculate the contribution of

    (a) Direct light
    (b) Diffuse light
    (c) Albedo light
    (d) Direct and diffuse light
    (e) Diffuse and albedo light

19. Albedo light collection (per module) is

    (a) Higher in individual module compared to a solar farm
    (b) Lower in individual module compared to a solar farm
    (c) They are about the same
    (d) Depends on the ground reflectivity
    (e) Cannot be determined without detailed calculation

20. The SBR of a solar farm in Chicago, IL is

    (a) < 1
    (b) Between 1 and 2
    (c) Between 2 and 3
    (d) Between 3 and 4
    (e) Between 4 and 5

21. How does pumped-hydro storage compare to electro-chemical battery storage

    (a) Pumped hydro has higher storage capacity than typical electro-chemical batteries
    (b) Pumped hydro is less expensive (per kW and per kWh) compared to batteries
    (c) Pumped hydro is more reliable than batteries

(d) Pumped hydro has longer discharge time compared to batteries

(e) All of the above

22. Compared to a Li-ion battery, a Lead Acid battery is

(a) More reliable
(b) Have lighter weight
(c) Less expensive
(d) More reliable
(e) All of the above

23. For most efficient energy storage

(a) The charging voltage of the battery stack must equal to the output voltage of the solar module
(b) The number of batteries must equal to the number of cells in a solar module
(c) The number of batteries must be larger than the number of cells in the solar modules
(d) The output voltage of the solar module must be larger than the output voltage of the battery.
(e) None of the above

Levelized cost of electricity

24. Use LCOE calculator posted at https://www.nrel.gov/pv/lcoe-calculator) to explain the importance of the Bank discount rate. If the Bank discount rate is changed from 5% to 3.5% (with everything else remaining the same), how much is the LCOE reduced by

(a) Less than 10%
(b) 10-20%
(c) 20-30%
(d) 30-50%
(e) 50-70%

25. Given that c=28 years for mc-Si, by which year do we expect the efficiency to reach 22%?

(a) 2020
(b) 2030
(c) 2040
(d) 2050
(e) More than 2050

26. What is the LR for thin-film CIGS cells?

(a) 8.1
(b) 12.3
(c) 19.1
(d) 24.2
(e) 30.5

Thermodynamics of Solar Cells

27. If you could collect all the photons of the AM1.5G spectrum, the short circuit current would be
    a) 1000 mA/cm²
    b) 700 mA/cm²
    c) 70 mA/cm²
    d) 7 mA/cm²
    e) None of the above.

28. 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.

29. An experimental group reports $J_{sc} = 35 \ mA/cm^2$ for an organic cell 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.

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

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