UC San Diego MAE 119 W2017 Review Notes
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Key topics and issues:

1. Fundamentals: What is work? What is energy? How does energy relate to work? What is power? What is the first law of thermodynamics? What is a system, and a system boundary? What is the environment? How does these elements relate to the first law of thermodynamics? What is the second law of thermodynamics? How do these influence the maximum theoretical efficiency of energy conversion in heat engines?

2. How does access to energy influence human quality of life? What relative fractions of the human population have "adequate" access to energy resources? What fraction does not? What fraction is in the process of improving their access to these resources? How do these factors impact expected future energy demand?

3. What are the primary forms or sources of energy in use today? Into what secondary forms are these sources converted? What are the end uses of these secondary energy forms? What fraction of human energy demand is met today by fossil fuels? From renewable sources (including wind, solar, hydroelectric, and conventional geothermal)? From nuclear sources?

4. What are the essential elements of the simple 0-d (i.e. mathematical point) thermal balance model we developed for the Earth? What is the rough wavelength range of the incoming solar radiation and outgoing infra-red radiation? Why is this difference important? If the density of infra-red absorbing molecules is increased, what happens to the transmission of this heat radiation through the atmosphere? What does this do to the equilibrium temperature of the atmosphere and surface in this model?

5. What are the essential elements of the Earth's carbon balance? Where does carbon get stored in the system? How do we characterize the exchange rate of C between these different regions? How does this carbon balance model get modified by the addition of a new source of C injection into the atmosphere? How does the C content in the atmosphere then adjust? What does this do to the Earth's heat balance?

6. Given anticipated future human energy demand and limits on C emission rates due to climate change concerns, what is the rough order of magnitude of C-free power sources needed? What are the possible energy sources to consider in trying to meet this demand? Which of those possible sources do *not* scale to meet this demand (i.e. their maximum physically plausible power production is no more than a few percent of anticipated C free power required). Which ones *do* scale?

7. Derive the power per unit area available in the wind? What is the maximum theoretical conversion efficiency of a wind turbine and what is the physics basis for it? What factors impact the minimum required distance between wind turbines? What is this minimum spacing? What is a wind-speed probability distribution function? How would you use such a function to compute average wind speed? Average power produced from a turbine placed in that wind field? Why does the average power calculation tend to weight the period of time with higher wind speed? What is cut-in speed? Cut-out speed? How is the capacity factor defined and what is a typical value for wind turbines? If you knew the wind speed distribution function and available land area for placement of a wind farm, how would you estimate the average and peak power production from the wind farm?

8. How does concentrated solar power (CSP) work? What is the concentration factor? How does this determine the temperature of the target of the power plant? Why does such a power plant require a narrow acceptance angle of light input from the sun? What is DNI? DHI? How can you estimate the amount of DNI in an atmosphere with scattering particles (e.g. dust, aerosols, clouds, fog, etc…)? How would thermal storage be incorporated into CSP system? How would an auxiliary heat source be incorporated into a CSP system? What advantages would such additions give a CSP plant over a solar photovoltaic plant?

9. What does a solar photovoltaic cell (PV) look like schematically? How is it connected to an external load? What does the mobile charge density look like in an un-illuminated solar cell (i.e. a diode)? How does the minority carrier density at the interface between the junction and the quasineutral region change when a forward bias voltage is applied to the diode? What resulting current v. voltage plot look like? Explain how the charges move through the device as the voltage is changed, and how this leads to the I(V) characteristic of a diode. What happens when this diode is now illuminated? Where does light absorption lead to production of electron-hole pairs that then produce the electric current of the PV cell? What is the short-circuit current? How would it change if the minority carrier lifetime was changed up or down? If the diffusion length changed? If the thickness of the cell was changed? What is the open-circuit voltage? What is the form factor? How would you use these quantities to estimate the PV cell efficiency?

10. What are some of the technological factors that influence how much time-varying renewable energy that can be incorporated into an electrical power grid? What are the economic factors that influence this? What is the merit order effect and how does it impact renewable energy integration?

11. What is the typical timescale that has been required for previous primary energy source substitutions (i.e. wood to coal, coal to petroleum, etc…)?

What does the market share for technological substitutions usually look like as time goes on? What is the rate of adoption of renewable energy? What implications does this rate of adoption have for the period of time that these new technologies will need before their market fraction growth begins to slow down and eventually go to zero?