47202 Introduction to Future Energy - Ordinary exam - Fall 2023

Der anvendes en scoringsalgoritme, som er baseret på "One best answer"

Dette betyder følgende:
Der er altid netop ét svar som er mere rigtigt end de andre
Studerende kan kun vælge ét svar per spørgsmål
Hvert rigtigt svar giver 1 point
Hvert forkert svar giver 0 point (der benyttes IKKE negative point)

The following approach to scoring responses is implemented and is based on "One best answer"
There is always only one correct answer – a response that is more correct than the rest
Students are only able to select one answer per question
Every correct answer corresponds to 1 point
Every incorrect answer corresponds to 0 points (incorrect answers do not result in subtraction of points)

Q1. Introduction i.

A thermal power plant operates between at hot thermal reservoir at 350 degrees Celsius and a cold reservoir at 10 degrees Celsius.

What is the thermodynamic maximum heat-to-useful work (electricity) conversion efficiency (Carnot efficiency) of such a plant?

Vælg en svarmulighed

- A: 3.50 (350%)
- B: 0.971 (97.1%)
- C: 0.546 (54.6%)
- D: 0.35 (35.0%)
- E: 0.312 (31.2%

Q2. Introduction ii.

If a country wants to supply 50% of its 10 GW average power need, from a source which has a capacity factor of 20%, how much (peak) power of said source must be installed?

Vælg en svarmulighed

- A: 25 GW
- B: 10 GW
- C: 5 GW
- D: 4 GW
- E: 1 GW

Q3. Wind i.

An old small wind turbine with a rotor diameter of $D = 52$ m and a rated power of $P = 850$ kW at a rated wind speed of $v_R = 10$ m/s is replaced by a new wind turbine with a rotor diameter of $D = 150$ m. What is the power produced by the new wind turbine at rated wind speed if the rated wind speed v_R and the power coefficient C_P is assumed the same as the old wind turbine?

Vælg en svarmulighed

- A: 0-2000 kW
- B: 2000-4000 kW
- C: 4000-6000 kW
- D: 6000-8000 kW
- E: 8000-10000 kW

Q4. Wind ii.

A wind turbine with a rated power of $P = 15$ MW and rotor diameter of $D = 236$ m is installed in an offshore wind farm, where the capacity factor CF is expected to be $CF = 0.55$. What is the expected Annual Energy Production(AEP) of the turbine?

Vælg en svarmulighed

- A: 20-50 GWh/year
- B: 50-80 GWh/year
- C: 80-110 GWh/year
- D: 110-140 GWh/year
- E: 140-170 GWh/year

Q5. Water i.
What is the potential energy of 1000 m^3 water at a height of 1000 m? The density of water is roughly 1000 kg/m^3.

Vælg en svarmulighed

- A: 9.8 MJ
- B: 98 MJ
- C: 980 MJ
- D: 9800 MJ
- E: 0.98 MJ

Q6. Water ii.

Which one of the following technologies utilizes the thermal energy stored in water?

Vælg en svarmulighed

- A: Hydro power
- B: Wave power
- C: Osmotic power
- D: Geothermal energy
- E: Tidal power/ocean current power

Q7. Nuclear i. Which particles carry most of the energy following a fission event?

Vælg en svarmulighed

- A: gammas
- B: neutrons
- C: neutrinos
- D: fission products
- E: e^+/e^-

Q8. Nuclear ii. In a fast reactor neutrons thermalize in the

Vælg en svarmulighed

- A: uranium fuel
- B: moderator
- C: reflector
- D: control rods
- E: none of the above

Q9. Solar i.

If a solar cell has an light-to-electricity conversion efficiency of 20% under standard sunlight (AM1.5G, i.e. 1000 W/m^2) and an open circuit voltage of 0.7 volt and a short circuit current density of 37 mA/cm^2, what is the fill factor (FF) of the solar cell?

Vælg en svarmulighed

- A: 7.722
- B: 0.772
- C: 0.077
- D: 0.259
- E: 0.026

Q10. Solar ii.

What is the main advantage and what is the main limitation of CSP?

Vælg en svarmulighed

- A: The price per watt is lower than photovoltaics, but CSP requires scarce minerals.
- B: The price per watt is lower than photovoltaics, but price per kWh is higher.
- C: The price per watt is lower than photovoltaics, but the efficiency is lower.
- D: That heat storage permits electricity generation at night; but CSP requires direct solar light.
- E: That heat storage permits electricity generation at night; but CSP requires scarce minerals.

Q11. Biomass i. What is biomass primarily used for in the current Danish energy system?

Vælg en svarmulighed

- A: Production of biogas
- B: Production of liquid fuels
- C: Production of heat for industry
- D: Production of heat and power
- E: For biomass stoves in households

Q12. Biomass ii. Calculate the conversion energy efficiency of the chemical reaction 3 H2 + CO -> CH4 + H2O given the following heating values: LHV_H2 = 241.8 MJ/kmol, LHV_CO = 283 MJ/kmol, LHV_CH4 = 802.3 MJ/kmol

Vælg en svarmulighed

- A: 85.1 %
- B: 80.0 %
- C: 83.0 %
- D: 78.2 %
- E: 100 %

Q13. Thermodynamics and electrochemistry i.
What is the lower heating value of propane (C_3H_8)?
It is combusted by the following process:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Thermodynamic values for selected species are given below.

	C_3H_8	CO_2	O_2	H_2O(l)	H_2O(g)
Δh_f^0 (kJ mol^{-1})	-103.8	-393.5	0.0	-285.8	-241.8
s^0 (J mol^{-1})	270.3	213.8	205.2	70.0	188.0
Δg_f^0 (kJ mol^{-1})	-23.4	-394.4	0.0	-237.1	-228.8

h_f^0 = standard enthalpy of formation, s^0 = standard entropy, and g_f^0 = standard free energy of formation
(l) and (g) for liquid and gas respectively.

Vælg en svarmulighed

- A: -2220 kJ mol^{-1}
- B: +2108 kJ mol^{-1}
- C: -2075 kJ mol^{-1}
- D: +2044 kJ mol^{-1}
- E: -531 kJ mol^{-1}

Q14. Thermodynamics and electrochemistry ii.
The electrochemical reactions in an electrochemical cell are:

Anode: $A \rightarrow B^{2+} + C + 2e^-$
Cathode: $B^{2+} + D + 2e^- \rightarrow F$
Total: $A + D \rightarrow C + F$

A-F are different chemical species (We don't need to know which).
The enthalpy of the reaction (Δh_r) is -290 kJ mol^{-1}
The Gibbs free energy of the reaction (Δg_r) is -230 kJ mol^{-1}
What is the theoretical cell voltage?

Vælg en svarmulighed

- A: 1.19 V
- B: 1.50 V
- C: 2.38 V
- D: 3.01 V
- E: 0.6 V

Q15. Storage i.
Which one of the following has the highest volumetric energy density (per unit of volume)?

Vælg en svarmulighed

- A: Lithium ion battery
- B: Natural gas
- C: Liquid hydrogen
- D: Hydrogen gas at 700 bar
- E: Gasoline

Q16. Storage ii.
Up to today, which one of the following energy storage technologies has the largest installed capacity?

Vælg en svarmulighed

- A: Hydrogen storage
- B: Electro-chemical energy storage
- C: Pumped hydro energy storage
- D: Thermal energy storage
- E: None of the above

Q17. Fuel cells and hydrogen i.
A hydrogen powered fuel cell is operated at 0.68 V. The product water is assumed to be liquid.
What is the efficiency (the voltage efficiency)?

Vælg en svarmulighed

- A: 40%
- B: 42%
- C: 46%
- D: 54%
- E: 55%

Q19. Power-to-X i.
Which of the following processes is **not** part of the *Power-to-X* concept?

Vælg en svarmulighed

- A: Operating an electrolyzer
- B: Conversion of hydrogen to methane
- C: The making of sustainable aviation fuel (jet fuel) from wind energy
- D: Operating a fuel cells
- E: Carbon capture

Q20. Power-to-X ii.
If an electrolyzer cell is operated at the thermo-neutral voltage, it means that:

Vælg en svarmulighed

- A: The operating temperature is constant because the heat it produces is completely removed by the cooling water
- B: The operating temperature is constant because the heat it produces is completely removed by the produced gasses
- C: An electrolyzer cannot be operated at the thermoneutral voltage. It is only an abstraction used for efficiency calculations
- D: An electrolyzer cannot be operated at the thermoneutral voltage. It will always need to be cooled actively
- E: At the thermoneutral voltage the electrolyzer is neither a net producer or net consumer of heat from its surroundings

Q21. Batteries i.
Which of the following statements about batteries is **false**:

Vælg en svarmulighed

- A: The overpotential for charge is the charging potential minus the equilibrium potential
- B: In a Zinc (Zn) - chloride (Cl_2) cell, is Zn is the negative electrode
- C: During charging of a Li-ion battery, the oxidation takes place at the positive electrode
- D: It takes 2 hours to charge a battery at a C-rate of 2C
- E: The energy and power density can be scaled independently in a flow battery

Q22. Batteries ii.
A battery electric vehicle (EV) pulls into a super charging station with a partially charged battery and charges it for 8 min. at 150 kW, 4 min at 100 kW and 4 min at 50 kW. The 80 kWh battery is now charged to 80% of its maximum capacity. How much energy was transferred during charging, and how much energy was already in the battery when it entered the charging station?

Vælg en svarmulighed

- A: 8 kWh is transferred, and the battery was initially at 30% of full capacity
- B: 80 Wh is transferred, and the battery was initially at 45% of full capacity
- C: 30 kWh is transferred, and the battery was initially at 42.5% of full capacity
- D: 800 kWh is transferred, and the battery was initially at 55% of full capacity
- E: 30 As is transferred, and the battery was initially at 10% of full capacity

Q23. Infrastructure i.

Suppose you have a project financed with 25% equity at a cost of 10% p.a., and 75% debt at a cost of 7% p.a.; and suppose that we ignore taxes (i.e. set the tax rate to zero).

What is the financial WACC and gearing for this project?

Vælg en svarmulighed

- A: WACC = 7.75% and gearing factor = 3
- B: WACC = 7.75% and gearing factor = 1.42
- C: WACC = 7.75% and gearing factor = 0.7
- D: WACC = 7.75% and gearing factor = 1.42
- E: WACC = 9.25% and gearing factor = 1.42

Q24. Infrastructure ii.

Suppose you have project planned which will last 5 years: t = {0,1,2,3,4}
The economic cost of the project in each of the five years is the set c = {10,2,2,2,2}
The economic revenue of the project is likewise the set r = {0,6,6,6,6}

Assuming that the WACC is 0.05 (i.e. 5% p.a.) what is the *net return on investment* and the *net present value* of the stated project?

Vælg en svarmulighed

- A: Net return on investment = 16 and Net present value = 5.71
- B: Net return on investment = 6 and Net present value = 5.71
- C: Net return on investment = 6 and Net present value = 5.24
- D: Net return on investment = 6 and Net present value = 4.19
- E: Net return on investment = 6 and Net present value = 3.99