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

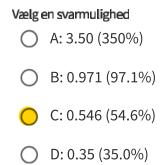
Every correct answer corresponds to 1 point

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?



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?

Vælge	en svarmulighe
0	A: 25 GW
0	B: 10 GW
0	C: 5 GW
0	D: 4 GW
\bigcirc	F· 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

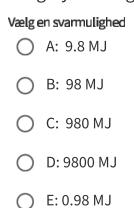
C: 80-110 GWh/year

O: 110-140 GWh/year

E: 140-170 GWh/year

Q5. Water i.

What is the potential energy of 1000 $\rm m^3$ water at a height of 1000 $\rm m$? The density of water is roughly 1000 $\rm kg/m^3$.



Q6. Water ii. Which one of the following technologies utilizes the thermal ener	gy stored in water?
Vælg en svarmulighed A: Hydro power	
O B: Wave power	
C: Osmotic power	
O: Geothermal energy	

O E: Tidal power/ocean current power

Q7. Nu	clear i. Which particles carry most of the energy following a fission event?
Vælg e	n svarmulighed
\circ	A: gammas
\circ	B: neutrons
\circ	C: neutrinos
	D: fission products
\circ	E: e ⁺ /e ⁻

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

Q10. Solar ii.

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

Vælg en svarmulighed			
0	A: The price per watt is lower than photovoltaics, but CSP requires scarce minerals.		
0	B: The price per watt is lower than photovoltaics, but price per kWh is higher.		
0	C: The price per watt is lower than photovoltaics, but the efficiency is lower.		
0	D: That heat storage permits electricity generation at night; but CSP requires direct solar light.		
0	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
O: 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



A: 85.1 %

B: 80.0 %

C: 83.0 %

O D: 78.2 %

C 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 ₃ H ₈	CO ₂	02	H ₂ O(l)	H ₂ O(g)
$\Delta h_{ m f}^0$ (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
$\Delta g_{ m f}^{ m 0}$ (kJ mol $^{ m -1}$)	-23.4	-394.4	0.0	-237.1	-228.8

 $h_{\rm f}^0$ = standard enthalpy of formation, s^0 = standard entropy, and $g_{\rm f}^0$ = 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
- O: +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
- O 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		
0	A: Lithium ion battery	
0	B: Natural gas	
0	C: Liquid hydrogen	
0	D: Hydrogen gas at 700 bar	
\bigcirc	E: Gasoline	

Q16. Storage ii.

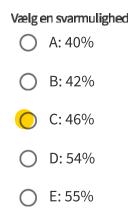
Up to today, which one of the following energy storage technologies has the largest installed capacity?

Vælg en svarmulighed		
\circ	A: Hydrogen storage	
0	B: Electro-chemical energy storage	
0	C: Pumped hydro energy storage	
0	D: Thermal energy storage	
\bigcirc	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)?



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

Vælg e	en svarmulighed A: Operating an electrolyzer
0	B: Conversion of hydrogen to methane
0	C: The making of sustainable aviation fuel (jet fuel) from wind energy
0	D: Operating a fuel cells
\bigcirc	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			
0	A: The operating temperature is constant because the heat it produces is completely removed by the cooling water		
0	B: The operating temperature is constant because the heat it produces is completely removed by the produced gasses		
0	C: An electrolyzer cannot be operated at the thermoneutral voltage. It is only an abstraction used for efficiency calculations		
0	D: An electrolyzer cannot be operated at the thermoneutral voltage. It will always need to be cooled actively		
0	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			
0	A: The overpotential for charge is the charging potential minus the equilibrium potential		
0	B: In a Zinc (Zn) - chloride (Cl ₂) cell, is Zn is the negative electrode		
0	C: During charging of a Li-ion battery, the oxidation takes place at the positive electrode		
0	D: It takes 2 hours to charge a battery at a C-rate of 2C		
0	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?

Vælge	en svarmulighed
0	A: 8 kWh is transferred, and the battery was initially at 30% of full capacity
0	B: 80 Wh is transferred, and the battery was initially at 45% of full capacity
0	C: 30 kWh is transferred, and the battery was initially at 42.5% of full capacity
0	D: 800 kWh is transferred, and the battery was initially at 55% of full capacity
0	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