Part 1. Multiple Choice Questions (60%).

Answer all questions. There is only one correct answer so you must choose the best answer. Answer A, B, C… (Capital letters). A correct answer gives for each of the problems **4 percentage points (4%)** in total towards the final score. Incorrect answers will be awarded **-1 percentage points (-1%)**, blank (unanswered) questions, or multiple answers to the same question will be awarded **0 points (0%)**.

Only the answer will be marked.

Write the answers for the multiple choice questions on the answer sheet you turn in using a table similar to the following (note that the answers in this table are examples of how you should do it – not the real correct answers!):

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	D	C	A	B	E	A	C	A	E	D	B	A	A	A	C

Good luck!

Problems:

Part I (multiple choice)

1. Recall the world consumption graph. What is the part of renewables (hydro and nuclear including) according to the world consumption graph?

A. 4%
B. 7%
C. 15%
D. 30%

2. What is the part of nuclear energy according to the world consumption graph?

A. 2%
B. 4%
C. 7%
D. 9%

3. According to the latest statistical report of BP 2022, what are the three countries with the biggest total proved reserves of oil?

A. Venezuela, United Arab Emirates, Iran
B. Norway, Iraq, Iran
C. Venezuela, Saudi Arabia, Canada
D. Saudi Arabia, Canada, Iraq

4. What country is a net exporter of bioethanol?

A. USA
B. Argentina
C. Brazil
D. UK

5. A bicyclist expends energy at the rate of 60 Watt. How many calories of energy will he expend in 10 minutes of driving?

A. 120
B. 3600
C. 7200
D. 8600

6. With an albedo of 0.3 and an atmosphere with a long-wavelength transmission of 0.15 and a short wavelength transmission of 0.85 we have seen that the equilibrium temperature of the Earth is around 287 K. A gas is introduced into the atmosphere that decreases the mean long wavelength transmission of the atmosphere from 0.15 to 0.12. If the mean short wavelength transmission of the atmosphere remains unchanged at 0.85 and the albedo remains at 30%, what is the resulting temperature of the Earth?

A. 287 K
B. 289 K
C. 293 K
D. 300 K

7. Calculate the wavelength (λ_{max}) for the maximum intensity of the black body radiation from a human being, assuming a surface temperature of 32°C.

A. 15 microns
B. 0.2 microns
C. 500 nm
D. 9.5 microns
E. 794 nm

8. A star generates energy by nuclear fusion reaction of H nuclei into helium

$$4p \rightarrow {}_{2}^{4}He + 2e^{+} + 2\nu + 18.3\ MeV.$$

It fuses 6×10^{8} tons of hydrogen per second. What is the total energy in MeV the star produces per second?

A. 3.14×10^{10} MeV per sec
B. 1.65×10^{39} MeV per sec
C. 2.06×10^{-11} MeV per sec
D. 6.02×10^{64} MeV per sec

9. The commercial nuclear power reactors are based on nuclear fission reactions induced by:

A. protons,
B. electrons,
C. photons,
D. neutrons.

10. The amount of energy released in the fusion process: $^{2}D + {}^{3}T \rightarrow {}^{4}He + n$?

A. 1.76 KeV
B. 17.6 KeV
C. 1.76 MeV
D. 17.6 MeV

11. What is the half-life of tritium in years?

A. 0.5
B. 12.3
C. 32
D. 64

12. During COVID in 2020 the world consumption of primary energy fell down to 13200 MTOE. Assume that the wind blows at 13m/s for 1/3 of the time (and that there is no wind at other times), that the efficiency of a wind turbine is 70% of the maximum theoretical value and the density of air is 1.2 kg/m^3. How many wind turbines with a diameter of 60m would be needed to supply this total energy?

A. $1.1\text{x}10^{4}$ turbines
B. $5.6\text{x}10^{7}$ turbines
C. $3.3\text{x}10^{7}$ turbines
D. $1.3\text{x}10^{8}$ turbines

13. What is the typical efficiency for commercial silicon solar cells?

A. 8-10 %
B. 15-18%
C. 28-30%
D. 45-48%

14. How large an area needs to be covered with solar cells to generate 11 TWh of electric energy in one year? Assume that the annual solar irradiation is 900 $kWh.m^{-2}$ and that the solar cell has a typical efficiency.

A. 42 km^2
B. 81 km^2
C. 102 km^2
D. 1640 km^2

15. The mechanism of extracting energy from biomass is
A. fusion
B. fission
C. combustion
D. emission of radiation

Part 2. Calculations (40%)

Answer all questions. The number in brackets represents the contribution of each sub-question to the total score. Each problem counts for 10 points.
All questions should be answered. NO CREDIT will be given for a correct numerical answer unless the work is shown in all details!
The answers can be written by hand.

1. The oceans contain about 1.3×10^{24} cm^3 of water. Deuterium constitutes 0.028% by mass of natural hydrogen.

a) What is the total energy in Joules available from this Deuterium by D-D fusion? Assume 4. 0 MeV per fusion event. (5)

b) For how many years could fusion reactors with 50% efficiency supply 2.0 million MW? (5)

2. Calculate the power in megawatts during outflow from a tidal power plant that encloses a rectangular area of 1×2.5 km, and which fills to a height of 3.6 m above the outlet. Assume an efficiency of 94%, and an emptying time of 1.5 hour. (10)

3. The world primary energy consumption 5 years ago was approximately 13 000 Mtoe. Assuming that flat panel solar cells at a sunny location in Spain can harvest 8 kWh/m^2/day, what area is required (at that location) to supply the energy needs of the earth? (10)

4. In a submitted patent an inventor claims to have developed a novel heat engine that operates with a not so hot nonpolluting flame at 150C and transfers waste heat to the environment at 20C. His promotional flyer claims that 45% of the fuel energy is converted into useful work. Calculate the maximum efficiency of such an engine and compare it to the claim. (10)

APPENDIX

Energy conversion factors

	J	kWh	Btu	toe
1 Joule (J)	1	2.78×10^{-7}	9.5×10^{-4}	2.38×10^{-11}
1 kilowatt-hr (kWh)	3.6×10^{6}	1	3413	8.6×10^{-5}
1 calorie (cal)	4.184	1.16×10^{-6}	3.97×10^{-3}	1×10^{-10}
1 British thermal unit (Btu)	1055	2.93×10^{-4}	1	2.5×10^{-8}
1 Electron volt (eV)	1.6×10^{-19}	4.45×10^{-26}	1.52×10^{-22}	3.8×10^{-30}

Storage material	MJ per kilogram	MJ per liter (litre)
Deuterium–tritium	330 000 000	0.14
Uranium-235	83 140 000[3]	1 546 000 000
Hydrogen (compressed at 70 MPa)	123	5.6
Gasoline (petrol) / Diesel	~46	~36
Propane (including LPG)	46.4	26
Fat (animal/vegetable)	37	
Coal	24	
Carbohydrates (including sugars)	17	
Protein	16.8	
Wood	16.2	

Density of water $1.02 \times 10^{3} kg/m^{3}$
density of air $\sim 1.2\ kg/m^{3}$
acceleration due to gravity $9.8\ m/sec^{2}$
Avogadro's number 6.02×10^{23}(# per mole)

Formulas

$$P(t) = \frac{1}{\beta}\left(1 - \frac{Q(t)}{Q_\infty}\right)Q(t)$$

$$Q(t) = \frac{Q_\infty}{1 + Ae^{-t/\beta}}$$

$$P(t) = P_0\left(\frac{Q_\infty}{Q_0}\right)^2 \frac{e^{-t/\beta}}{(1 + Ae^{-t/\beta})^2}$$

$$\beta = (Q_\infty - Q_0)\frac{Q_0}{Q_\infty P_0}$$

$$t_m = \left(1 - \frac{Q_0}{Q_\infty}\right)\frac{Q_0}{P_0}\ln\left(\frac{Q_\infty}{Q_0} - 1\right)$$

$$P_m = P(t_m) = \frac{Q_\infty{}^2 * P_0}{4Q_0(Q_\infty - Q_0)}$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\eta = 1 - \frac{Q_L}{Q_H}$$

$$\eta_{carnot} = 1 - \frac{T_L}{T_H}$$

$$COP = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}$$

$$E = \frac{hc}{\lambda}; \quad hc = 1.98x10^{-25}\, J.m$$

$$hc = 1.23x10^{-6}\, eV \cdot m$$

$$P = I^2 R$$

$$\frac{P}{A} = \varepsilon\sigma T^4 \qquad \sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$$

$$I_0 \frac{\pi R^2}{4\pi R^2} = 342\ W/m^2$$

$$\tfrac{1}{4} I_0 = \tfrac{1}{4}\alpha I_0 + I_A$$

$$\lambda_m[\mu m] = \frac{2898}{T(K)}$$

$$E_{pot} = mgh = \rho V g h$$

$$E_{kin} = \frac{1}{2}mv^2$$

$$\frac{P}{A} = 6.1x10^{-4} v^3 [kW/m^2]$$

$$A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2$$

$$\frac{\Delta Q}{\Delta t} = \frac{A}{R}\Delta T = AU\Delta T$$

$$R = 1/k$$

$$Q = mC\Delta T$$

$$m = \rho V$$

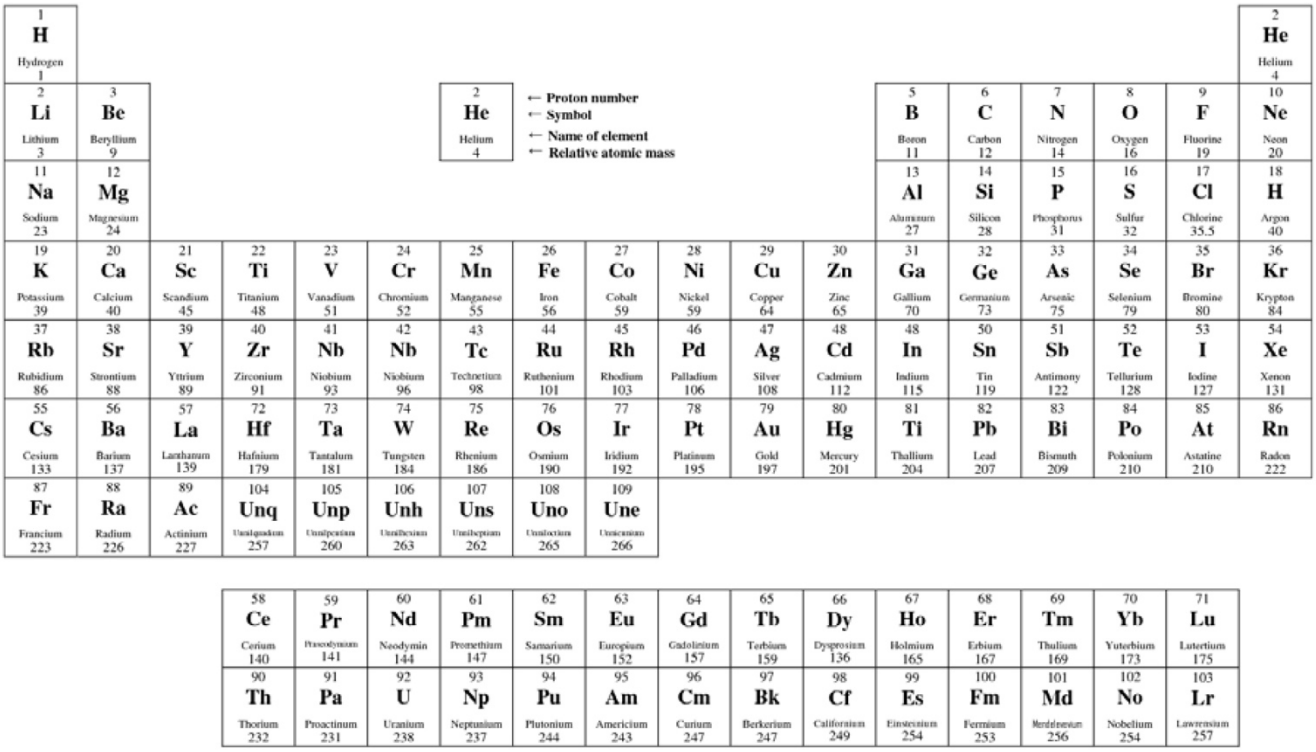
$$F = ma = m\frac{\Delta v}{\Delta t}$$

$$V = IR$$

$$J = E^* cg \sim 1\ kW/m^3 s\ ^* T H^2$$

$$P = 0.59\ A/2(\rho u^3)$$

Periodic Table of the Elements



Heat of combustion (calorific value) of various fuels.

Fuel	MJ/kg	MJ/L
Wood green	~ 8	~ 6
Wood oven dry	~ 16	~ 12
Methane	56	0.038
petrol/gasoline	47	37
crude oil	44	35
Coal	27	