Explanation Chapter 6

6.1 Does the cyclic integral of work have to be zero?

a) Yes

b) No

Ans: B. A system may produce more (or less) work than it receives during a cycle. A steam power plant, for example, produces more work than it receives during a cycle, the difference being the net work output.

6.2 What will be the net change in internal energy of the working fluid of the power cycle over the complete cycle?

a) No net change in internal energy of working fluid

b) Net change in internal energy of working fluid will be negative

c) Net change in internal energy of working fluid will be positive

d) None of the above

Ans: A. Internal energy is a state function and in a cyclic process. That means that the end state is the same as the initial state.

6.3 The door of a running refrigerator inside a room was left open. Which of the following statements is correct?

a) The room will be cooled to the temperature inside the refrigerator.

b) The room will be cooled but not reach the temperature inside the refrigerator.

c) The room will be gradually warmed up.

d) The temperature of the air in the room will remain unaffected.

e) Any one of the above is possible depending on the capacity.

Ans: C. The room will warm up due to the work done by the compressor in the refrigerator. Since the door is open, the heat exchangers of the refrigerator do not affect the overall room temperature.

6.4 1) Is it possible for a heat engine to operate without rejecting any waste heat to a low temperature reservoir?

2) Also, in the absence of any friction and any other irreversibilities can a heat engine have an efficiency of 100%?

a) 1) No, 2) No

b) 1) No, 2) Yes

c) 1) Yes, 2) No

d) 1) Yes, but only if it's reversible, 2) Yes

e) 1) Yes, 2) Yes

Ans: A. 1) and 2) both no; both engines violate the Kelvin-Planck statement of the second law of thermodynamics. Also, reversible engines have to reject heat to a low temperature reservoir and can never have an efficiency of 100%.

6.5 Does a heat engine that has a thermal efficiency of 100% necessarily violate (1) the first law of and/or (2) the second law of thermodynamics?

a) 1) Yes, 2) Yes
b) 1) Yes, 2) No
c) 1) No, 2) Yes
d) 1) No, 2) No
e) 1) No, 2) No, but only if it's reversible

Ans: C. (1) No and (2) Yes, according to the second law, no heat engine can have and efficiency of 100% also reversible engines (no friction or any other irreversibility's) always have to reject heat to a low temperature reservoir making them less efficient than 100%.

6.6 What is a heat engine?

a) Any cyclic device
b) A cyclic device that receives heat from a source, converts some of it to work, and rejects the rest to a sink.
c) Any device that receives heat from a source and converts all of it to work.
d) A device that transfers heat from a lower temperature to a higher temperature source.
e) A device that is used for heating.

Ans: B. Heat engines are cyclic devices that receive heat from a source, convert some of it to work, and reject the rest to a sink (for example, steam power plants, gas turbines, combustion engines, Stirling engine). Not all cyclic devices are heat engines. There are also cyclic devices that transfer heat from a lower temperature to a higher temperature source (refrigeration and heat pump cycles) (answer d). A heat engine cannot convert all received heat into work. A device used for heating is a heater of radiator, not a heat engine, a heat engine produces work.

6.7 Which device is not a heat engine?

a) A wind turbine
b) A gas turbine
c) A steam power plant
d) An internal combustion engine (i.e., Otto/Diesel engine)
e) A Stirling engine

Ans: A. Heat engines are cyclic devices that receive heat from a source, convert some of it to work, and reject the rest to a sink (for example, steam power plants, gas turbines, combustion engines, Stirling engine). A wind turbine does not involve a thermodynamic cycle. A wind turbine converts kinetic energy of the wind into electricity using a generator.

6.8 The cycle which consists of two reversible isotherms and two reversible isochores is called a:

a) Rankine cycle
b) Stirling cycle
c) Ericsson cycle
d) Carnot cycle

Ans: B.

6.9 What is the formula for efficiency of vapour power cycle?

a) $\eta_{cycle} = \frac{WT-WP}{Q_{in}}$

b) $\eta_{cycle} = \frac{Q_{in}-Q_{out}}{Q_{in}}$

c) $\eta_{cycle} = \frac{W_{net}}{Q_{in}}$

d) All of the above

Ans: D. In all these formulas, we are trying to find the ratio of net work output and heat input.

6.10 Which of the following is NOT a heat engine cycle?

a) Refrigerator

b) Steam power plant

c) Mass of gas confined in a cylinder and piston machine

d) None of the above

Ans: A. A refrigerator generates cooling by consuming work but a heat engine produces work from heat.

6.11 A thermodynamic cycle in which net heat is transferred to the system and net work is transferred from the system is called:

a) refrigeration cycle

b) Heat engine cycle

c) Both a) and b)

d) None of the above.

Ans: B. A heat engine converts heat into work.

6.12 Electric resistance heaters can be used for space heating. A manufacturer claims that his heater has a conversion efficiency of 100%. Is this claim in violation with any thermodynamic law?

a) Yes, with the zeroth law of thermodynamics

b) Yes, with the second law of thermodynamics

c) Yes, with both the zeroth and the second law of thermodynamics

d) Yes, with both the second and the third law of thermodynamics

e) No

Ans: E. No, because 100% of the work (electricity) can be converted to heat, however not all heat can be converted to work.

6.13 An inventor claims to have a heat pump that absorbs energy from a cold space and transfers it to a warmer space. It supplies 2.5 kWh of heat energy to the warmer space for each kWh of electricity it consumes. Is this a reasonable claim and why?

a) Yes, this is reasonable for a heat pump
b) No, as it creates energy (violation of the first law of thermodynamics)
c) No, as it transfers energy from a cold to a warmer space (violation of the second law of thermodynamics)
d) No, as it transfers energy from a cold to a warmer space (violation of the second law of thermodynamics) as well as it creates energy (violation of the first law of thermodynamics).
e) You need more information to determine this.

Ans A. The claim is valid, this is reasonable for a heat pump. The coefficient of performance (COP) is 2.5. The first law of thermodynamics is not violated because the heat pump consumes work (electricity) to accomplish this task. Also, the second law of thermodynamics is not violated. The heat pump captures energy from a cold medium and carries it to a warm medium. It does not create it.

6.14 An inventor claims to have developed a resistance heater that supplies 1.2 kWh of energy to a room for each kWh of electricity it consumes. Is this a reasonable claim and why?

a) Yes, the COP can be larger than 1
b) Yes, electricity is high quality energy
c) This depends on the temperature of the room.
d) No, this device does not reject heat and thus it is a perpetual motion machine of the second kind.
e) No, this device creates energy and thus it is a perpetual motion machine of the first kind.

Ans E. In an electric heater 100% of the input energy is converted into heat. Thus 1.0 kWh input would result in 1.0 kWh energy in the form of heat. The inventor claims the output energy is 1.2 kWh output. This is not possible, his device created energy and is called a perpetual motion machine of the first kind.

A heat pump can supply 1.2 kWh of energy to a room for each kWh of electricity it consumes, when its COP is larger than 1 (it should be 1.2 as COP = heat released / energy consumed), however this device is not a heat pump.

6.15 A refrigerator receives 50 kW from a cold space and uses 15 kW of power for this. How much heat is rejected to the hot space?

a) 65 kW
b) 60 kW
c) 50 kW
d) 35 kW
e) 15 kW

Ans: A. The heat rejected to the hot space is Q_H. The first law of thermodynamics (conversation of energy) for the refrigeration system shown in the picture is: $Q_L + W_{in} = Q_H$. $Q_L = 50$ kW and $W_{in} = 15$ kW. This gives $Q_H = 65$ kW.

6.16 Consider an ideal vapor compression refrigeration cycle. If the throttling process is replaced by an isentropic expansion process, keeping all the other processes unchanged, which one of the following statements is true for the modified cycle?

a) The coefficient of performance is the same as that of the original cycle.
b) The coefficient of performance is lower than that of the original cycle.
c) The coefficient of performance is higher than that of the original cycle.
d) The refrigerating effect is lower than that of the original cycle.

Ans: C. When the throttling process is replaced by an isentropic expansion process, keeping all the other processes unchanged, then the heat absorbed by the evaporator (desired effect) will increase therefore, the COP will increase.

6.17 How can the thermal efficiency of a Carnot heat engine be increased?

a) Use a different cycle
b) Use a different working fluid
c) Decrease friction and other irreversibilities
d) Increase the high temperature or decrease the low temperature
e) Add feed water heating or regeneration

Ans: D. The thermal efficiency of all the reversible heat engines (so no friction or irreversibilities), referred to as Carnot engines, operating between two reservoirs with the same high and low temperature are equal. This is independent of the cycle (e.g., turbine or combustion engine) or the working fluid (e.g., water or gas). Adding feed water heating or generation is not possible as all heat is added at a constant high temperature while all heat is rejected at a constant low temperature. Only a higher high temperature and / or a lower low temperature will increase the efficiency.

6.18 The expressions: “(1) the thermal efficiency of an irreversible heat engine is lower than the efficiency of a reversible heat engine operating between the same two reservoirs, and (2) the thermal efficiency of all the reversible heat engines operating between the same two reservoirs are equal” are known as the….

a) Clausius inequalities
b) basic thermodynamic principles
c) Carnot principles
d) principles of reversibility
e) Clausius statement

Ans: C. These are the Carnot principles. The Clausius statement states that it is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body. The Clausius inequality is the expression that state that the cyclic integral of $\frac{\delta Q}{T}$ is always less than or equal to zero is. The basic thermodynamic principles and principles of reversibility are nonsense.

6.19 Does this statement violate the Clausius inequality: Consider a cycle for which holds $\oint \delta Q > 0 \oint \delta Q > 0$. Clausius Inequality $\rightarrow \oint \delta QT \leq 0 \rightarrow \oint \delta QT \leq 0$?

a) Yes
b) No

Ans: B.

6.20 The expression: “It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work”, is known as the….

a) 0^{th} law of thermodynamics
b) basic law of thermodynamics
c) Kelvin-Planck statement
d) Clausius statement
e) State postulate

Ans: C. The 0^{th} law states that if two systems are both in equilibrium with a third system, they are in thermal equilibrium with each other, it forms the basis for temperature measurement.
The Clausius statement states that it is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body.
The state postulate states that the state of a simple compressible system is completely specified by two independent, intensive properties
The basic law of thermodynamics doesn’t exist, it is nonsense.

6.21 The expression: “It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body”, is known as the….

a) State postulate
b) 0^{th} law of thermodynamics
c) Kelvin-Planck statement
d) Clausius statement
e) Basic law of thermodynamics

Ans: D. The 0^{th} law states that if two systems are both in equilibrium with a third system, they are in thermal equilibrium with each other, it forms the basis for temperature measurement.
The Kelvin-Plank statement states that it is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work.
The state postulate states that the state of a simple compressible system is completely specified by two independent, intensive properties
The basic law of thermodynamics doesn’t exist, it is nonsense.

6.22 The expression given below: “The cyclic integral of $\frac{\delta Q}{T}$ is always less than or equal to zero”, is known as the:

a) Clausius inequality
b) Clausius statement
c) Kelvin-Plank statement
d) Kelvin temperature scale
e) Conservation of heat

Ans: A. The Clausius statement states that it is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body. In the Kelvin-Plank statement it is stated that it is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work. Both are alternative statements of the second law of thermodynamics. The Kelvin temperature scale is the absolute temperature scale that is independent of the properties of the substance. Conservation of heat is nonsense.

6.23 The Clausius statement and the Kelvin-Planck statement are expressions of the:

a) 0^{th} law of thermodynamics
b) 2^{nd} law of thermodynamics
c) State postulate
d) Clausius inequality
e) Kelvin temperature scale

Ans: B. The Clausius statement states that it is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body. In the Kelvin-Plank statement it is stated that it is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work.

Both are alternative statements of the second law of thermodynamics.

The Clausius inequality is the expression that state that the cyclic integral of $\frac{\delta Q}{T}$ is always less than or equal to zero is.

The zeroth law states that if two systems are both in equilibrium with a third system, they are in thermal equilibrium with each other, it forms the basis for temperature measurement. The Kelvin temperature scale is the absolute temperature scale that is independent of the properties of the substance.