Changes of temperature and state

The two extracts below are from a basic technical training course for the customer service staff of a manufacturer of heating boilers.

As you know, **temperature** is measured in **degrees Celsius** (°C). But **heat** is energy, so it's measured in joules. To calculate the amount of energy needed to raise the temperature of a substance, you need to know the mass of the substance being **heated**, and also its **specific heat capacity** - in other words, the amount of energy, in joules, required to raise the temperature of one kilogram of the substance by one degree Celsius.

What happens when substances change **state**? Well, heat energy is needed to make a solid **melt** and become a liquid. It's also needed to turn liquid into **vapour** – it takes energy to make a liquid **boil**, so that it **evaporates** (or **vaporizes**) and becomes a gas. That's because **melting** and **evaporation** are **endothermic** processes. That means they take in heat energy – they need to **absorb** heat from a **heat source**, such as a flame. And it's the opposite when a substance **cools**. As a gas **condenses** to become a liquid, or as a liquid **solidifies** to become a solid, the process is **exothermic** – heat is **emitted**. The amount of energy absorbed or emitted while a substance changes state, in joules per kilogram, is called **latent heat**. During melting it's called **latent heat of fusion**, and during vaporizing it's called **latent heat of vaporization**.

Vapour, cooling and thermal inertia

Gas and vapour

A gas can also be called a **vapour** – for example, **water vapour.** The definition of a vapour is a gas which is below its critical temperature. This means the gas can be condensed by putting it under pressure. Above the critical temperature (374 °C in the case of water), the gas can no longer be condensed by pressure.

Steam

Water vapour is often called **steam.** When it is extremely hot – such as in electricity-generating turbines – it is called **superheated steam.**

Cooling and thermal inertia

Radiators are widely used in **cooling systems** – for example, in vehicle engines. Liquid – called **coolant** – is pumped around the hot engine to absorb heat, and travels through a radiator positioned at the front of the vehicle. As the vehicle moves, air flows over the radiator. The **airflow** cools the radiator and the coolant inside it. Without a cooling system, the engine would **overheat.** However, this would not happen immediately after starting the engine, due to **thermal inertia** – the fact that it takes time to change the temperature of a heavy mass of material (such as an engine), either when it is heated or cooled. An object with a high level of thermal inertia can be described as a **heat sink.**

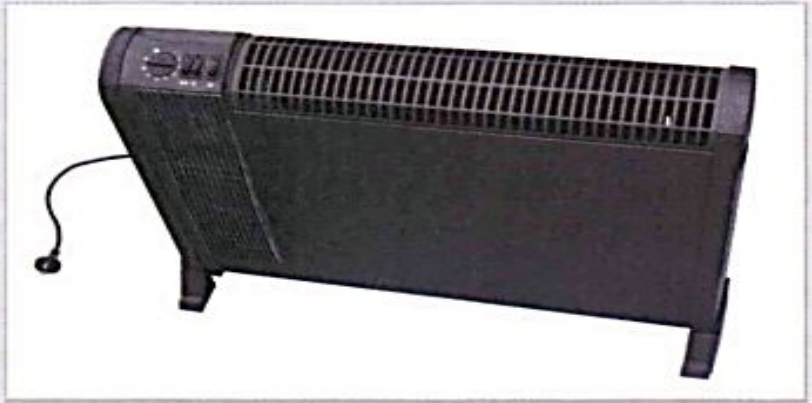
Complete the sentences about water using words from A opposite. Sometimes there is more than one possible answer.

1 When the temperature of ice reaches 0 °C, it changes ..... – it ..... to become water.
2 At 100 °C, water ..... .
3 When water is ..... to 0 °C or below and ..... to become ice, it is said to freeze.
4 In gas form, water is called ..... or ....
5 Between 100 °C and 374 °C water is a ..... because it is below its critical temperature.
6 Extremely hot water vapour is called ....

Heat transfer

The textbook extract below looks at **heat transfer** – how heat travels.

To help understand heat transfer, homes provide everyday examples. The **heating systems** in homes often have electric **convector** heaters. These heat the air and make it **circulate**, so that it moves in a circle – first rising, then cooling and sinking before rising again. This is called **convection**, where warm gas or liquid moves around and **dissipates** heat, **transferring** it to the rest of the gas or liquid.



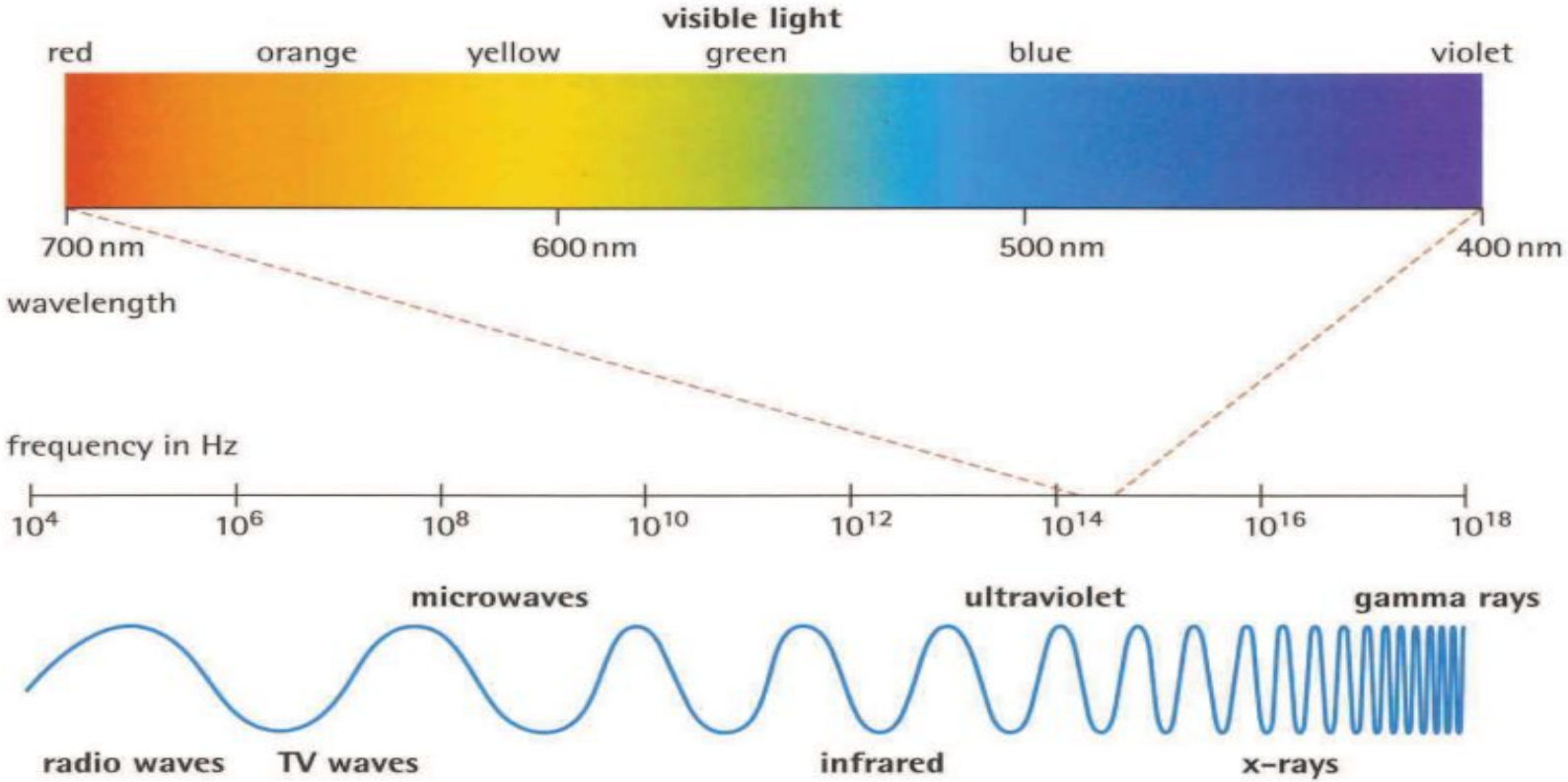
An electric convector heater

Alternatively, the heating system in a home may circulate hot water through **radiators**. The radiators act as **heat exchangers** – devices that transfer heat – in this case, from the hot water inside to the cooler air outside. This happens by **conduction** – heat transfer through solid material. After the heat has been **conducted** through the metal of the radiator, the heat is dissipated by convection.

The third way that heat is transferred is by **radiation**. This is heat that travels as **electromagnetic waves**. An example is the heat from the sun. So the radiators that circulate water have a misleading name, as they don't really function by radiation.

The electromagnetic spectrum

The diagram below shows the types of wave in the electromagnetic spectrum.



Match the two parts to make correct sentences. Look at A and B opposite, and Appendix VII on page 109 to help you.

1 A liquid pumped onto a workpiece that is being machined, to stop it overheating, is called a
2 The form of heat transfer that occurs with infrared heat – a form of electromagnetic wave – is called
3 The metal fins (plates) around air-cooled engines, intended to maximize the surface area of the hot engine that is in contact with the cooler air, are designed to act as a
4 Thick, dense, internal walls inside an energy-efficient house, which are intended to absorb heat energy during the day and store some of it to be emitted at night, function as a
5 The soil and rocks on the surface of the earth remain warm at night in summer, due to the principle of

a radiation.
b coolant.
c heat sink.
d thermal inertia.
e heat exchanger.

Circle the correct words to complete the article about condensing boilers. Look at A and B opposite to help you. The first one has been done for you.

Condensing boilers are becoming increasingly popular in homes, as they use up to 40% less gas than traditional boilers. How do they work? By exploiting the fact that when a liquid condenses, due to the principle of latent heat of (1) *fusion/vaporization*, the process is (2) *endothermic/exothermic*. This means heat is (3) *absorbed/emitted*, and can thus be (4) *circulated/conducted* via the water inside the radiators in the home.

A condensing boiler burns natural gas (hydrocarbon fuel) to (5) *heat/cool* water, just like a conventional boiler. However, it achieves greater efficiency by recovering energy from water vapour. This is present in the hot, waste gas that's produced when natural gas is burned. In a traditional boiler the (6) *heat/temperature* energy from the gas, which is at a (7) *heat/temperature* of 180 °C or more, would be (8) *dissipated/radiated* into the atmosphere by (9) *conduction/convection*, and the water vapour within it would condense in the outside air. But in a condensing boiler the hot gas passes through a (10) *heat/temperature* exchanger. This allows the heat from the gas to be (11) *absorbed/emitted* by the cool water that's returning to the boiler after passing through the radiators in the home's (12) *cooling/heating* system – heat transfer takes place from hot gas to cool water by (13) *conduction/radiation* through the metal of the heat exchanger. In addition, when the temperature of the gas has fallen to a certain point, the water vapour within it (14) *condenses/solidifies*. And it is this process that enables significant amounts of heat to be transferred, due to the principle of (15) *latent/specific* heat.

INDUSTRIAL EQUIPMENT: HEAT EXCHANGE

1. Read and translate the international words

Contact, natural, perpendicular, maximize, turbulence, fluid, gas, conditioning, minimize, elastomer, design, parallel, typical, channel, effective, configuration, coefficient, construction, optimum, material.

2. Read and translate the verbs

To build, to mix, to classify, to enter, to design, to maximize, to minimize, to affect, to consist of, to heat, to cool, to differ, to stamp, to induce, to occupy.

3. Match the English word combinations in column A to their Russian equivalents in column B

A		B	
1.	heat exchanger	a)	площадь поверхности
2.	power plant	b)	противоточный
3.	natural gas	c)	рифление
4.	parallel-flow heat exchanger	d)	нефтеперерабатывающий завод
5.	counter current	e)	обогрев помещений
6.	cross-flow heat exchanger	f)	жидкость
7.	surface area	g)	ребро
8.	tube bundle	h)	турбулентность
9.	according to	i)	теплообменник
10.	flow arrangement	j)	в соответствии с
11.	petroleum refinery	k)	пучок труб
12.	space heating	l)	электростанция
13.	fluid	m)	теплообменник с параллельным током
14.	turbulence	n)	теплообменник с перекрестным током
15.	corrugation	o)	организация потока
16.	fin	p)	природный газ

4. Read and translate

A heat exchanger is a device built for efficient heat transfer from one fluid to another, whether the fluids are separated by a solid wall so that they never mix, or the fluids are directly contacted. They are widely used in petroleum refineries, chemical plants, petrochemical plants, natural gas processing, refrigeration, power plants, air conditioning and space heating.

Heat exchangers may be classified according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

5. Choose the Russian equivalents for the types of heat exchangers

Types of Heat Exchangers	Виды теплообменных аппаратов
1) tube heat exchanger	a) пластинчатый теплообменник
2) lumped heat exchanger	b) трубчатый теплообменник
3) plate heat exchanger	c) спиральный теплообменник
4) coiled heat exchanger	d) оребренный теплообменник
5) spiral heat exchanger	e) змеевиковый теплообменник
6) finned heat exchanger	f) блочный теплообменник

6. Choose the following expressions to fill the gaps in the text:.
plates, tube bundle, plate heat exchanger, fins, tube heat exchanger, heat transfer, surface.

A typical heat exchanger, usually for higher-pressure applications, is the _____ which consists of a series of tubes, through which one of the fluids runs. The second fluid runs over the tubes to be heated or cooled. The set of tubes is called _____, and may be composed of several types of tubes: plain, longitudinally finned, etc. Another type of heat exchanger is the _____. One is composed of multiple, thin, slightly-separated plates that have very large _____ areas and fluid flow passages for_____. This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Plate heat exchangers differ in the types of _____ that are used, and their configurations. Some plates may be stamped with “chevron” or other patterns, where others may have machined _____ and grooves.

7. Decide whether the statements below are true or false according to the information in exercises 4 and 6

1. Heat exchangers may be classified according to the temperature of flow.
2. Fins and grooves on the heat exchanger surface intensify the heat transfer process.
3. In parallel-flow heat exchangers, two fluids enter the exchanger from opposite ends.
4. Tube heat exchanger is composed of multiple, thin, slightly-separated plates that have very large surface areas.
5. Tube heat exchanger is usually used for higher-pressure applications.

8. Read and translate

Теплообменный аппарат – устройство, в котором осуществляется передача теплоты от горячего теплоносителя к холодному. Теплоносителями могут быть газы, пары, жидкости. Одним из видов теплообменных аппаратов являются кожухотрубчатые теплообменники, основными элементами которых являются пучки труб. Концы труб крепятся в трубных решетках. Для увеличения скорости движения теплоносителей с целью интенсификации теплообмена нередко устанавливают перегородки, как и трубном, так и межтрубном пространствах. Кожухотрубчатые теплообменники могут быть вертикальными и горизонтальными. Кожухотрубчатые теплообменники нашли широкое применение в химической, энергетической, металлургической, пищевой и других отраслях промышленности.

9. Read the text and name the main characteristics of plate and tube heat exchangers in the English language

In forming a comparison between plate and tubular heat exchangers there are a number of guidelines which will generally assist in the selection of the optimum exchanger for any application. In summary, these are:

1. For liquid/liquid duties, the plate heat exchanger will usually give a higher overall heat transfer coefficient and in many cases, the required pressure loss will be no higher.
2. The effective mean temperature difference will usually be higher with the plate heat exchanger.
3. Although the tube is the best shape of flow conduit for withstanding pressure it is entirely the wrong shape for optimum heat transfer performance since it has the smallest surface area per unit of cross-sectional flow area.
4. Because of the restrictions in the flow area of the ports on plate units it is usually difficult to produce economic designs when it is necessary to handle large quantities of low-density fluids such as vapors and gases.
5. A plate heat exchanger will usually occupy far less floor space than a tubular for the same duty.
6. From a mechanical viewpoint, the plate passage is not the optimum, and gasketed plate units are not made to withstand operating pressures much in excess of 20 kgf/cm^2.
7. For most materials of construction, sheet metal for plates is less expensive per unit area than tube of the same thickness.
8. When materials other than mild steel are required, the plate will usually be more economical than the tube for the application.
9. When mild steel construction is acceptable and when a closer temperature approach is not required, the tubular heat exchanger will often be the most economic solution since the plate heat exchanger is rarely made in mild steel.
10. Plate heat exchanger use is limited by the elastomer gasket.

10. Find the English and the Russian equivalents for the following phrases

трубчатый теплообменник	heat-transfer agent
листовой металл	plate heat exchanger
площадь поверхности	stacked-plate arrangement
сравнение	elastomer gasket
ограничения	tube bundle
жидкости с малой плотностью	tube sheet
рабочее давление	shell side
толщина	overall heat transfer coefficient
конструкция из малоуглеродистой стали	pressure loss
состоять из нескольких труб	limited by
управлять	

12. Answer the questions

1. What types of heat exchangers do you know according to their flow arrangement classification?
2. What type of heat exchangers is considered to be the most effective?
3. How can you intensify the process of heat transfer in the plate heat exchanger?
4. What is the main practical application of tubular heat exchangers?
5. What are the differences between tubular and plate heat exchangers?

13. Read and translate

1. Shell and tube heat exchangers consist of a series of tubes which is called tube bundle.
2. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical.
3. Plate heat exchangers differ in the types and configuration of plates.
4. Effects of fouling are more abundant in the cold tubes of the heat exchanger, than in the hot tubes.
5. Heat exchangers are widely used in industry both for cooling and heating large scale industrial processes.
6. The selection of type and size of heat exchanger depends on the type of fluid, its phase, temperature, density, viscosity, pressures, chemical composition and various other thermodynamic properties.
7. Heat exchangers may be classified according to their flow arrangement.
8. The effective mean temperature difference will usually be higher with the plate heat exchanger.
9. In many industrial processes there is waste of energy or heat that is being exhausted, heat exchangers can be used to recover this heat and put it to use by heating a different stream in the process.
10. From a mechanical viewpoint, the plate passage is not the optimum, and gasketed plate units are not made to withstand operating pressures much in excess of 20 kgf/cm^2.

14. Read and translate

1. Теплообменники подразделяют на поверхностные, где отсутствует непосредственный контакт теплоносителей, и смесительные, где теплоносители контактируют друг с другом.
2. В пластинчатом теплообменнике поверхность теплообмена образуется гофрированными параллельными пластинами.
3. Жидкости, между которыми происходит теплообмен, движутся в каналах между пластинами.
4. Компактными и эффективными теплообменниками считаются теплообменники с оребренной поверхностью.
5. Теплообменные аппараты широко используются на нефтеперерабатывающих заводах, в химическом производстве для обработки природного газа, на электростанциях и для кондиционирования и отопления помещений.
6. Увеличение площади поверхности стенок и уменьшение сопротивления жидкости, проходящей через теплообменный аппарат, позволяют интенсифицировать процесс теплообмена.
7. В теплообменниках применяются медные трубки, которые имеют оребрение внешней и внутренней поверхностей.
8. Эффективность теплопередачи повышается за счет оребрения поверхности теплообмена.
9. Между пластинами теплообменника образуются каналы, создающие турбулентный

15. Read and translate

Кожухотрубчатый теплообменник – plate hear exchanger – природный газ – parallel-flow heat exchanger – площадь поверхности – cross-flow heat exchanger – электростанция – counter current – пучок труб – to occupy – отличаться – turbulence – змеевиковый теплообменник – fins and grooves – блочный теплообменник – finned heat exchanger – интенсификация процесса теплообмена – compose of – межтрубное пространство – sheet metal – малоуглеродистая сталь – gasket – теплоноситель – according to.