2.3 Transfer of thermal energy

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

0 Vocabulary

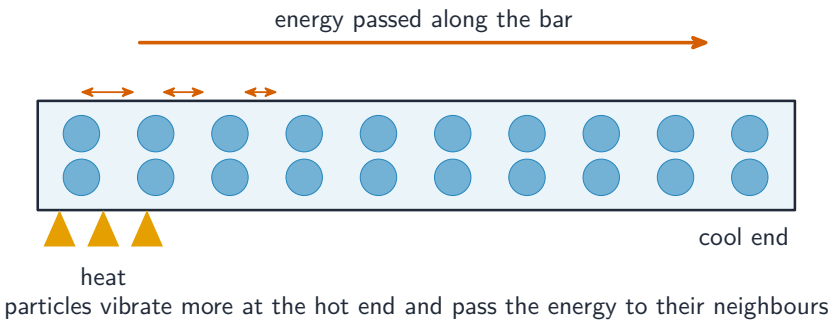
Word	Example
lattice /ˈlætɪs/ 晶格	The ions in salt sit in a regular **lattice**. 盐中的离子排列成规则的**晶格**。
transfer of thermal energy 热能传递 /ˈtrænsfɜː ɒv ˈθɜːml ˈenədʒi/	The **transfer of thermal energy** always goes from hot to cold. **热能传递**总是从高温处到低温处。
conduction /kənˈdʌkʃn/ 热传导	Metal pans heat food by **conduction**. 金属锅通过**热传导**加热食物。
delocalised electrons 自由电子 /dɪˈlɒkəlaɪzd ɪˈlektrɒnz/	Metals have **delocalised electrons** that carry heat fast. 金属中的**自由电子**能快速传递热量。
thermal conductor 热导体 /ˈθɜːml kənˈdʌktə/	Copper is a good **thermal conductor**. 铜是一种良好的**热导体**。
thermal insulator 热绝缘体 /ˈθɜːml ˈɪnsjuːleɪtə/	Plastic is a good **thermal insulator**. 塑料是一种良好的**热绝缘体**。
convection /kənˈvekʃn/ 对流	**Convection** carries warm air up from a heater. **对流**把暖空气从加热器向上输送。
potassium permanganate 高锰酸钾 /pəˈtæsɪəm pəˈmæŋgəneɪt/	**Potassium permanganate** shows the convection current in the water. **高锰酸钾**可以显示水中的对流。
thermal radiation 热辐射 /ˈθɜːml ˌreɪdɪˈeɪʃn/	The Sun warms us by **thermal radiation**. 太阳通过**热辐射**使我们感到温暖。
infrared /ˌɪnfrəˈred/ 红外线	A TV remote uses **infrared** light. 电视遥控器使用**红外线**。
dull /dʌl/ 暗淡	A **dull** black surface is a good radiation absorber. **暗淡**的黑色表面能很好地吸收辐射。
emitter /ɪˈmɪtə/ 发射体	A black surface is a good **emitter** of heat. 黑色表面是良好的热辐射**发射体**。

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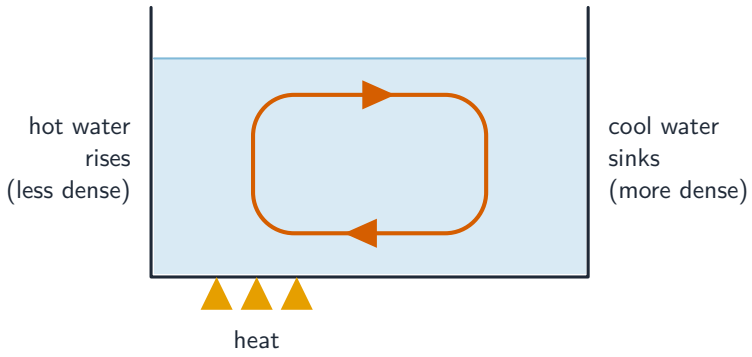
Word	Example
absorber /əb'sɔ:bə/ 吸收体	A black surface is a good **absorber** of heat. 黑色表面是良好的热辐射**吸收体**。
reflector /rɪ'flektə/ 反射体	A shiny surface is a good **reflector** of heat. 光亮的表面是良好的热辐射**反射体**。
Leslie cube /'lesli kju:b/ 莱斯利立方体	A **Leslie cube** has four different sides to compare heat radiation. **莱斯利立方体**有四个不同的侧面，用来比较热辐射。
atmosphere /'ætməsfɪə/ 大气	Water vapour leaves the leaf and goes into the **atmosphere**. 水蒸气离开叶片，进入**大气**。
radiator /'reɪdɪeɪtə/ 散热器	A **radiator** warms the room. **散热器**使房间变暖。
vacuum flask /'vækju:m flæsk/ 保温瓶	A **vacuum flask** keeps drinks hot for hours. **保温瓶**可以让饮料保温数小时。

1 Key knowledge and worked examples

■ Three transfer methods



Conduction: vibrating particles (and free electrons in metals) pass energy along



Convection: heated fluid expands, becomes less dense and rises; cooler fluid sinks

- **conduction:** energy passed by vibrating particles; metals conduct best (free electrons).
- **radiation:** infrared waves, no material needed; dull-black surfaces emit/absorb best.

■ Doing the experiments, and the Earth's balance

Comparing conductors. Fix a drawing pin with a little wax to one end of rods of copper, iron, glass and wood and heat the other ends equally. The pin drops first from the copper, then the iron, and last or never from the glass and wood. Metals win because free electrons carry energy as well as the vibrating **lattice** 晶格; gases and most liquids conduct badly because their particles are far apart and exchange energy only when they collide.

Showing convection. Drop a crystal of purple potassium permanganate into a beaker of water and heat gently below it: a coloured stream rises above the heat, spreads across the top and sinks at the sides. Explain it by density: heated fluid expands, so the same mass fills a larger volume, its density falls and it rises; cooler, denser fluid sinks to replace it.

Comparing emitters and absorbers. Fill a dull black can and a shiny silver can with hot water at the same temperature: the black one cools faster, so it is the better emitter. Fill both with cold water and place them equally far from a heater: the black one warms faster, so it is the better absorber. The rate of emission is greater when the surface is **hotter** and when it is **larger**.

The Earth's temperature. The Earth absorbs radiation from the Sun and emits infrared back into space. Its average temperature stays constant only while the two rates are equal: absorb faster and it warms, emit faster and it cools. Greenhouse gases in the atmosphere absorb some of the emitted infrared and send part back down, so more of them means a warmer Earth.

Everyday examples. A kitchen pan has a metal base (conduction into the food) and a plastic handle (an insulator). A radiator warms a room by convection. You feel a fire's radiation at once, because radiation needs no material. A vacuum flask blocks all three: the vacuum stops conduction and convection, the shiny surfaces stop radiation.

2 Practice

2.1 State why metals are good conductors of thermal energy. [1]

metals

2.2 State which surface is the best emitter of infrared radiation. [1]

infrared emitter

2.3 Describe an experiment to show which of two solids is the better thermal conductor. [3]



2.4 Explain, in terms of density, why heated water rises in a beaker. [2]



2.5 State two factors that increase the rate at which a surface emits radiation. [2]

rate of emitting radiation

3 Exam-style questions

3.1 Convection cannot take place in a solid because: [1]

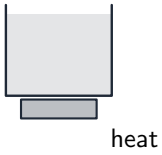
convection

- ☐ **A** solids have no particles
- **B** the particles cannot move from place to place
- **C** solids are too cold
- **D** solids do not conduct

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3.2 A beaker of water is heated at the bottom.

(a) Explain how a convection current forms. [3]



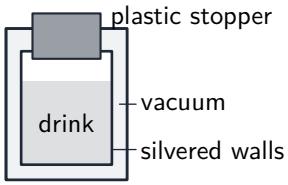
(b) State why heating at the top would not set up a convection current. [1]

3.3 Two metal cans are filled with hot water; one is dull black and one is shiny silver. State and explain which cools faster. [2]



3.4 A vacuum flask keeps a hot drink hot. It has double glass walls with a vacuum between them, and both glass surfaces are silvered.

(a) Explain how the vacuum reduces the energy lost by conduction and by convection. [2]



(b) Explain how the silvered surfaces reduce the energy lost by radiation. [2]

(c) The stopper is plastic. Explain why plastic is used rather than metal. [2]

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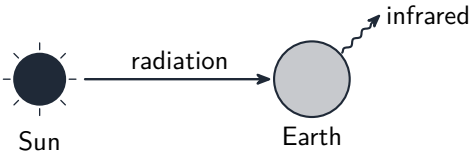
(d) A student leaves the same drink in an open metal mug. State the main way energy leaves the surface of the drink, and one way to reduce it. [2]

3.5 The Earth absorbs radiation from the Sun and emits infrared radiation into space.

(a) State the condition for the average temperature of the Earth to stay constant. [1]

(b) Explain how an increase in greenhouse gases raises the average temperature. [2]

(c) A dark tarmac road and the air above it both become hotter on a sunny day. Explain how the road gets hot, and how the air above it then gets hot. [3]



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Solutions

Each answer shows the steps, then the **result**.

2.1

- they contain free (delocalised) electrons that carry energy quickly

2.2

- a dull, black surface

2.3

- fix a drawing pin to one end of each rod with wax
- heat the other ends equally
- the pin on the better conductor falls first, because energy reaches its end sooner

2.4

- heated water expands, so the same mass occupies a larger volume and its density falls
- the less dense water floats up through the denser water around it

2.5

- a higher surface temperature
- and a larger surface area
- *(a duller, blacker surface also emits faster)*

3.1 B

- in a solid the particles vibrate in fixed positions and cannot move from place to place

3.2

(a) the water at the bottom is heated, expands and becomes less dense

- it rises, and cooler, denser water sinks to replace it
- this circulation is a convection current

(b) hot (less dense) water would already be at the top, so there is nothing to make it rise – no current forms

3.3

- the dull black can cools faster
- because a dull, black surface is a better emitter of infrared radiation

3.4

(a) conduction and convection both need particles

- the vacuum has almost none, so neither can carry energy across the gap

(b) shiny silver surfaces are poor emitters, so little infrared leaves the inner wall

- they are good reflectors, so radiation crossing the gap is reflected back

(c) plastic is a poor conductor, so little energy is conducted out through the stopper

- a metal stopper would conduct energy away quickly

(d) evaporation from the surface, or convection of the warm air above it

- put a lid on the mug

3.5

(a) it absorbs energy at the same rate as it emits it

(b) greenhouse gases absorb some of the infrared emitted by the Earth

- and re-emit part of it back towards the surface, so less energy escapes and the Earth warms until the rates balance again

(c) the road absorbs radiation from the Sun, and a dull black surface is a good absorber, so its temperature rises

- the air touching the road is warmed by conduction
- that warmed air expands, becomes less dense and rises, carrying energy upwards by convection while cooler air moves in