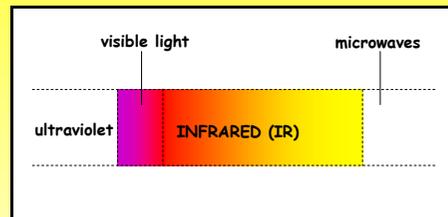


- All objects emit and absorb thermal radiation.
- The hotter an object is the infrared radiation it radiates in a given time.
- Dark, matt surfaces are good absorbers and good emitters of radiation.
- Light, shiny surfaces are poor absorbers and poor emitters of radiation.
- Light, shiny surfaces are good reflectors of radiation.

### INFRARED RADIATION

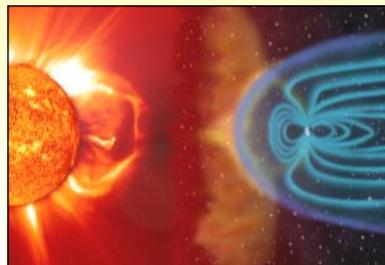
Infrared radiation is the transfer of heat energy by electromagnetic waves.

- It consists of **electromagnetic** waves of wavelength greater than that of red light.



- It travels in **straight lines** at the speed of light ( $3.0 \times 10^8$  m/s).

- It can travel through a vacuum. This is how the Sun's heat reaches us through the vacuum of space.



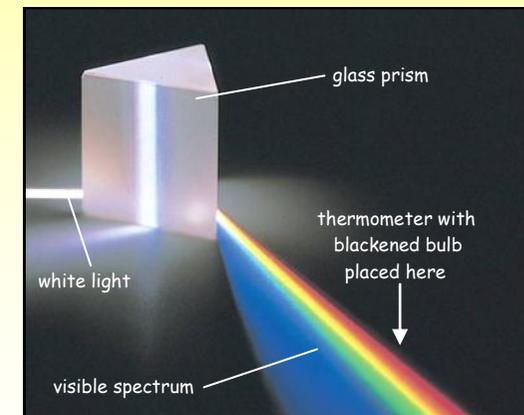
- It only travels through **transparent** substances (e.g. air, glass ..) **Opaque** substances absorb the infra red radiation and heat up.

- It is continually being transferred **to** and **from** all objects. The **hotter** the object is the **more infrared** it radiates. Cooler objects **absorb** infra red radiation.
- The amount of infra red emitted by an object depends on :
  - The **nature of its surface**.
  - Its **shape**.
  - Its **dimensions**.

### DETECTING THERMAL RADIATION

- The triangular, glass prism is used to split A narrow beam of white light into the colours of the spectrum.

A thermometer whose bulb has been blackened (so as to increase the absorption of IR) is placed just beyond the red end of the spectrum. The thermometer bulb absorbs IR radiation and shows an increased reading.



## PASSIVE INFRA RED SENSOR (PIR)

- This is an electronic device that **measures infra red radiation** coming from objects in its field of view.

Apparent motion is detected when an IR source with one temperature (e.g. a person intruding on private property) passes in front of an IR source with a different temperature (e.g. a fence or a hedge).

The sensor will then switch on powerful lights or even sound an alarm.



- Fire fighters** use thermal imaging cameras to locate people trapped in a smoke-filled building. Following an earthquake, people trapped under the rubble of collapsed buildings are also located using TICs.
- Police helicopters** are equipped with thermal imaging cameras so that fleeing law breakers are 'visible' even when they try to hide in a heavily wooded area.



## Spotting the flu

Some airports are using thermal imaging cameras to see if travelers have fevers.

## Feeling the heat

Thermal cameras work just as regular cameras, except are sensitive to heat

## Screening passengers

1 Infrared energy is emitted relative to the temperature of an object

Face emits most energy



Thermal camera

2 Energy focused onto infrared lens

3 Information transferred into a **thermogram** or a temperature pattern image

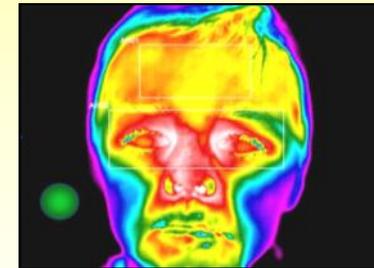
4 Pointer shows hottest point on screen; area shown in red

## Not a perfect screen

- A fever doesn't mean the flu
- Running for a flight increases body temperature
- Airports must do further screening once passengers with higher temperatures are detected

- Thermal imaging** is also used extensively in **medical diagnosis**.

The thermal image shown opposite is that of a patient running a high fever. The **red** and **white** areas indicate the **highest temperature**.

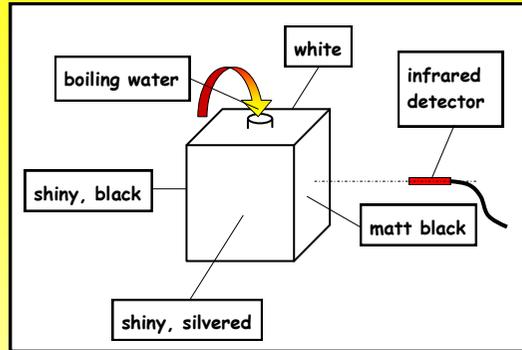


A person suffering from **multiple sclerosis** has poor blood circulation and this can be identified from a thermal image of the hands.



EFFECT OF SURFACE ON EMISSION OF INFRARED RADIATION

Boiling water is poured into a cubical, metal vessel whose four vertical faces each have a different surface.



An infrared detector is then placed at the same distance from each face in turn and the reading indicated is noted.

RESULTS

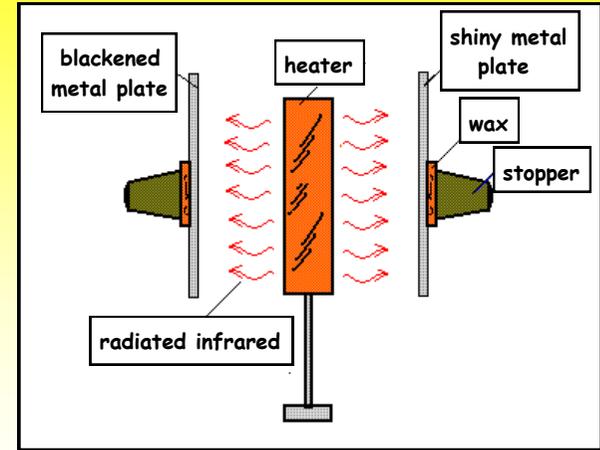
TYPE OF SURFACE	IR-DETECTOR READING
Matt black	
Shiny black	
White	
Shiny silvered	

The results show that the ..... surface is the **best thermal radiator** and the ..... surface is the **worst thermal radiator**.

EFFECT OF SURFACE ON ABSORPTION OF INFRARED RADIATION

- The heater is placed midway between the two plates as shown opposite.

The wax holding the stopper onto the ..... metal plate melts first and so this stopper drops off first.

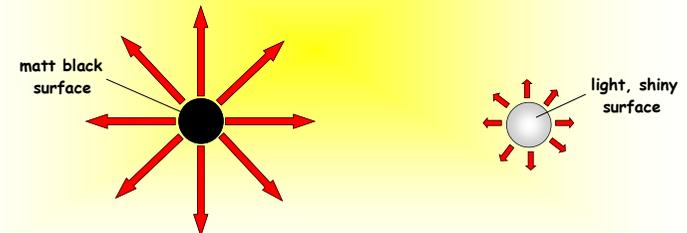


This shows that ..... surfaces are **better absorbers** of thermal radiation than ..... surfaces.

INFRARED EMITTERS AND ABSORBERS - SUMMARY

EMISSION OF INFRARED RADIATION

- For surfaces at the same temperature, **dark, matt** surfaces are **better emitters** of thermal radiation than **light, shiny** surfaces.



For this reason :

- Teapots are **light and silvery** so that they emit less infrared radiation (heat) and so keep the tea hot for longer.
- The pipes at the back of a fridge are **matt black** so that they get rid of the heat extracted as effectively as possible.

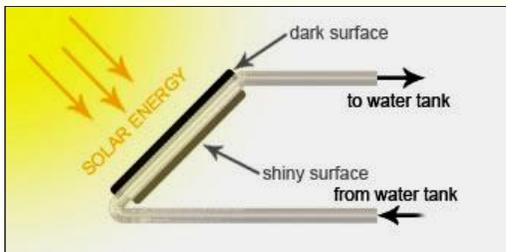


**ABSORPTION OF THERMAL RADIATION**

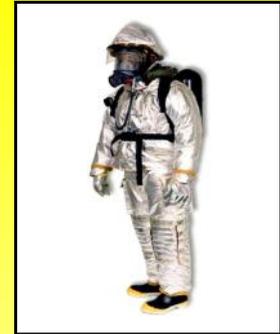
- **Dark, matt surfaces are the best absorbers (worst reflectors)** of thermal radiation.
- **Light, shiny surfaces are the worst absorbers (best reflectors)** of thermal radiation.

For this reason :

- Solar panels used to provide hot water in some houses are **matt black** on the outer surface so as to absorb as much infrared radiation as possible. The inner surface is **shiny** so as to reflect infrared radiation back onto the pipes carrying the water.

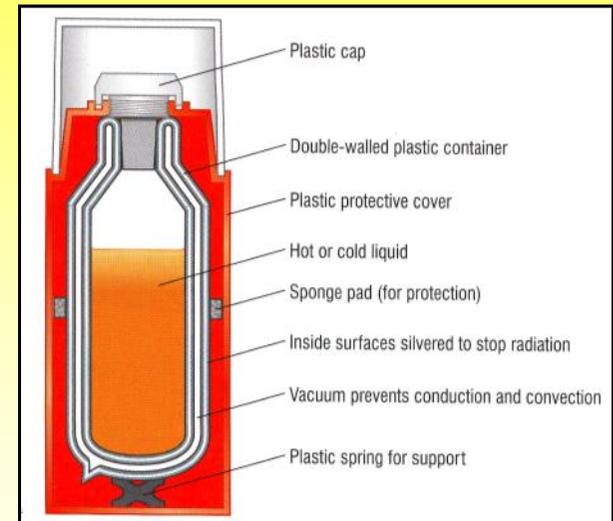


- Fire-fighting suits are made of **shiny, silvery** material so as to reflect as much infrared radiation as possible, thus enabling the fire fighter to walk close to a raging fire in relative safety.



**THE VACUUM FLASK** (Invented by Sir James Dewar in 1892)

Vacuum flasks are generally used to keep beverages at a desired temperature for some time (e.g. keeping coffee hot or juice cold). It mainly consists of a double-walled glass container which has had the air removed from the space between the walls.



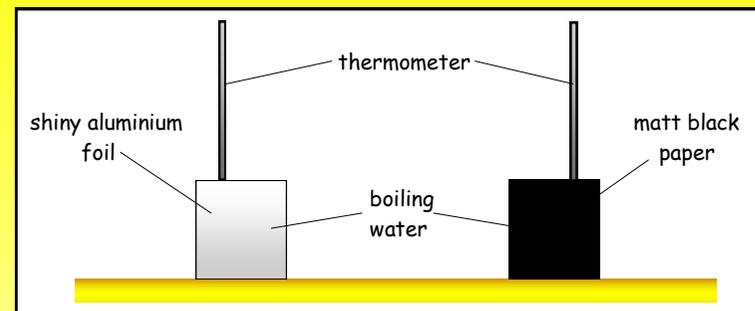
- The partial vacuum between the walls minimises thermal energy transfer by ..... and .....
- Glass is a poor heat ..... so there is very little thermal energy transfer by .....
- Thermal energy transfer by ..... is also minimised by silvering the inside surfaces of the double walls.
- The outer cover, the cap and the protective supports are all made of heat insulating material so as to further reduce thermal energy transfer by .....

## THE CAR RADIATOR



- Most car engines are cooled by cold water which is pumped around the engine and this transfers the thermal energy (heat) to the radiator which in turn transfers the heat to the environment.
- The radiator is **flat** and **corrugated** so that it can have as large a ..... as possible. This ensures that it loses as much thermal energy as possible through ..... and ..... in the air around it.
- The radiator is painted **matt black**, because this kind of surface is the best infrared radiator.
- When the car is stationary with the engine running, there is no air flow over the radiator and the engine can overheat. In this situation the **cooling fan** switches on automatically.

## PRACTICAL INVESTIGATION - Which surface is the best emitter ?



**AIM** : To compare the infrared emission capacities of **shiny, silvery** and **matt black** surfaces.

**PROCEDURE** :

- Remove the lids and fill both beakers to the same level with boiling water.
- Replace the lids and measure the initial water temperature.
- Start the stop-clock and measure and record the water temperature every minute for 20 minutes.

**GRAPHS** : Use the results obtained to plot **temperature/time** graphs for the **aluminium foil** and the **black paper** wrapping. Plot both graphs on the same set of axes.

**CONCLUSION** :

- Which surface caused the water to **cool down fastest**?
- Which surface is the **best thermal emitter**?

SHINY ALUMINIUM		MATT BLACK	
TIME/min	TEMPERATURE/°C	TIME/min	TEMPERATURE/°C
0		0	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	
11		11	
12		12	
13		13	
14		14	
15		15	
16		16	
17		17	
18		18	
19		19	
20		20	

1 Complete the following sentences by underlining the correct words.

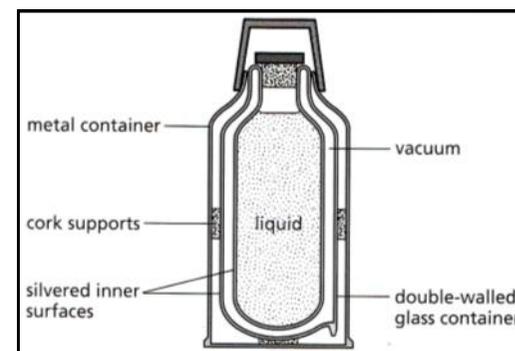
- Dark, matt surfaces are *good/poor* absorbers and *good/poor* emitters of thermal radiation.
- The best surfaces for radiating thermal energy are *good/poor* absorbers and *good/poor* emitters.
- The best materials for making survival blankets are *good/poor* absorbers and *good/poor* emitters.
- The best surfaces for solar hot water panels are *good/poor* absorbers and *good/poor* emitters.

2 Explain each of the following in terms of **thermal energy (heat)** transfer :

- (a) People in very hot climates wear **white** clothing in order to stay cool.
- (b) **Clean** snow does not melt quickly in bright sunshine, whereas **dirty** snow does.
- (c) After finishing the London marathon, athletes are wrapped in **aluminium-coated** plastic sheets.
- (d) Some casserole dishes which are used to cook food in ovens are **black**, but the outside of an electric kettle is **shiny**.

3 (a) Which labelled feature of the vacuum flask shown opposite reduces thermal energy transfer by **radiation**.

(b) **Explain** how this feature reduces thermal energy transfer by radiation.



HOMEWORK QUESTIONS (2)

1 The photo shows a motorcycle engine.  
Match the words **A, B, C** and **D** with the spaces **1, 2, 3** and **4** in the sentences.

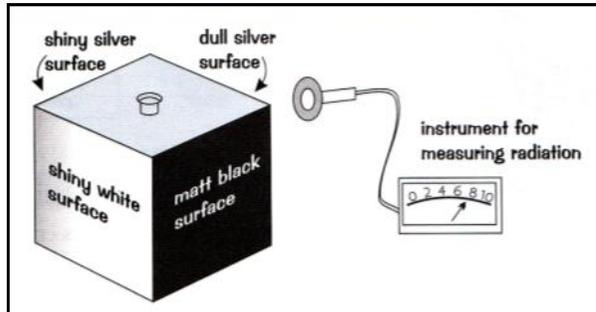


- A. Infra red radiation.
- B. Particles.
- C. Surface area.
- D. Temperature.

The engine becomes very hot, so it emits mainly .....**1**.....  
This process does not involve .....**2**.....  
The higher the .....**3**....., the more heat is lost.  
To make the loss of heat occur more quickly, the engine has fins so as to increase its .....**4**.....

2 A student did an investigation using the apparatus shown opposite.

Boiling water was poured into the hollow cube, each surface of which had a different combination of colour and texture.



The student measured the thermal radiation being emitted by each surface. His results are shown in the table.

- (a) Complete the table to show which was :
- (i) The **matt black** surface.
  - (ii) The **shiny silver** surface.
  - (iii) The **shiny white** surface.

Surface	Reading	Colour and Texture
A	10	
B	4	dull silver
C	4	
D	2	

(b) Based on his results, the student concluded that :

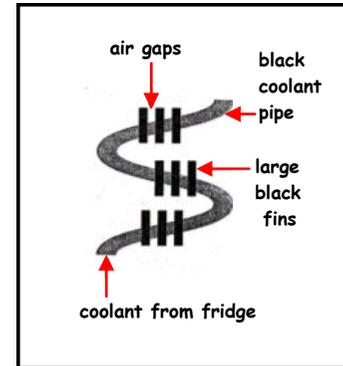
**"Dull silver and shiny white surfaces always emit the same amount of radiation"**

Explain what is wrong with this conclusion.

(c) Which of the surfaces **A to D** would be best to use for the **outside** of a refrigerator? Explain your answer.

3 The inside of a fridge is kept cool by the continual transfer of heat energy from inside the fridge to the outside.

A cooling element at the back of the fridge is designed to rapidly release this heat into the air. An example of such a cooling element is shown opposite.



(a) Identify two features of the element that help to increase the **heat loss by radiation**.

(b) Describe what is meant by **thermal radiation**.