Heat – Thermal Conduction

A Physics

Data ...

$k_{air} = 0.03\ Wm^{-1}K^{-1}$

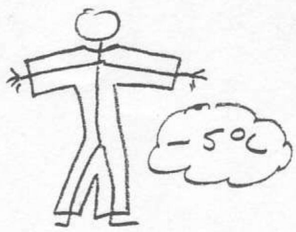
$k_{glass} = 0.8$ "

$k_{wood} = 0.2$ "

$k_{brick} = 1.0$ "

U value $= \dfrac{k}{l}\ Wm^{-2}K^{-1}$

1. An explorer is testing his new thermal suit.



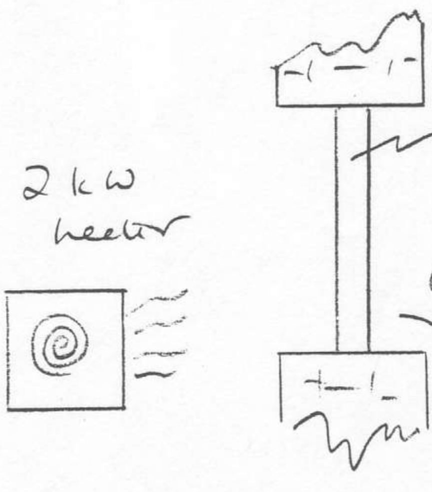
Total area $2m^2$
thickness 3cm

(a) At what rate must his body generate heat, to maintain a body temperature of 37°C? (3)

(b) What thickness should the suit be, if he is to maintain a 37°C body temperature with a body heat output of 50 watts? (3)

(c) In case (b) how much body heat will the explorer lose in 1 hour? (2) $\boxed{8}$

2. A Physics student doing her homework estimates the heat loss through her window.



(a) How much heat energy does the heater produce each second? (1)

(b) Assuming all the heat is lost through the window, what should the temperature difference across the glass be? (3)

(c) What should the room temperature be? (1)

(d) The student measures room temperature, and finds it a lot higher than she calculated. Explain why. (hint: "boundary layer.") (4) $\boxed{9}$

3. (a) Show that U-value $= k/l$ for any material. (2)

(b) Calculate U-values for ... (i) brick 10 cm thick (2)
(ii) window glass 4 mm thick (2) (iii) plywood 1 cm thick. (2)

(c) A garden shed is a box 3 m × 3m × 2 m high, made of 1cm thick plywood, with 2 windows 1m × 1m each, with 4 mm glass. Use your U-values to calculate the heater power needed to keep it 25°C inside on a night when it is just freezing. (4) $\boxed{10}$

TRN
2.99

Thermal Conduction – Answers — A Physics

1. (a) start with $Q/t \text{ (watts)} = \frac{kA\Delta\theta}{l}$ (1) $= 0.03 \times 2 \times (37 - -5)/3\times10^{-2}$ (1)

$= \underline{84}$ (1) watts (or J/s) (3)

* assume suit is full of air

(b) rearranging.. thickness $l = kA\Delta\theta/(Q/t)$ (1) $= 0.03 \times 2 \times 42/50$ (1)

$= 0.05$ m $= \underline{5 \text{ cm}}$ (1) (3)

(c) All body heat is lost to the environment (1), at the rate of 50 J/s

So in 1 hr, the explorer loses $[(50 \times 60) \times 60] = \underline{180 \text{ kJ}}$ (1)

J/min J/hr

$\boxed{8}$

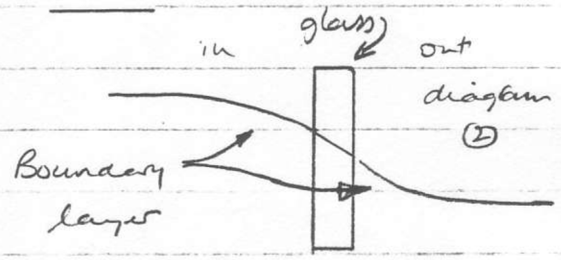
2. (a) 2 kJ heat / sec (1)

(b) Using $Q/t_{(J/s)} = \frac{kA\,\Delta\theta}{l}$ so $\Delta\theta = \frac{Q/t \times l}{kA} = \frac{2000 \times 4\times10^{-3}}{0.8 \times \underbrace{(0.9 \times 2)}_{(1)}}$ (1) $= \underline{5.6°C}$

The temperature difference should be 5.6 °C (1) (3)

(c) Room temp. should be $5.6 + 10 = \underline{15.6 \text{ °C}}$ (1)

(d) With still air there is a boundary layer (1) of air each side of the glass. These provide some insulation (1), and carry a temperature difference. (1)



So the temperature difference across the glass is smaller than calculated

(4) max

$\boxed{9}$

3. (a) U-value is the heat lost / sec through a 1 m² area with $\Delta\theta = 1°C$

So U-value $= Q/t = \frac{kA\,\Delta\theta}{l} = \frac{k}{l}$ since $A = 1\text{ m}^2$, $\Delta\theta = 1°C$ (2)

(b) (i) $U_{brick} = k_{brick}/l = \frac{1.0}{0.1} = \underline{10 \text{ W/m}^2\text{/K}}$ (2)

ii) $U_{glass} = k_{glass}/l = 0.8/4\times10^{-3} = \underline{200}$ W/m²/K (2)

iii) $U_{plywood} = 0.2/1\times10^{-2} = \underline{20 \text{ W/m}^2\text{/K}}$ (2)

(c) Total heat loss / sec = sum of U-values

$= (U_{plywood} \times A_{plywood} \times \Delta\theta) + (U_{glass} \times A_{glass} \times \Delta\theta)$ (1)

$A_{plywood} = A_{roof} + 4 \times A_{side} - A_{windows} = 3\times3 + 4\times(3\times2) - 2 = 31 \text{ m}^2$ (1)

$A_{glass} = 2 \text{ m}^2$ (1)

So total heat loss $= (20 \times 31 \times 25)\ (+\ 200 \times 2 \times 25)$

$= 15{,}500 + 10{,}000 = 25{,}500 = \underline{25.5}$ (1) kW !! (4)

$\boxed{10}$

TJN

2.99.

Q... 1. /8. 2. /9. 3. /~~10~~ 12. Total /29.