Physics

Tanishka

SECTION A

A1. Both are at the same room temperature, which is lower than skin temperature. The difference is in thermal conductivity. Steel is a very good conductor so it pulls heat out of the fingertips quickly, & the skin surface cools down fast. Wood is a poor conductor (an insulator), so the skin touching it stays warm & very little heat flows out. Our skin senses the rate of heat loss, not the actual temperature so steel feels cold.

A2. • Natural Convection: fluid moves only because of density differences caused by heating (warm fluid rises). Example: warm air next to the skin rises & forms a rising layer of air around a person standing in still air

• Forced Convection: fluid is pushed by an external agent such as a fan, wind or a pump. Example: wind blowing over skin, or blood pumped by the heart carrying heat from the core to the skin

A3. When the air is hotter than the skin, heat flows from the air into the body, so conduction, convention & radiation all add heat instead of removing it. Evaporation of sweat is the only way left to lose heat, because each kg of water evaporating takes away about 2.43×10^6 J
In high humidity the air is already almost saturated with water vapour, so sweat cannot evaporate properly. It just drips off without cooling the body. Heat then builds up & the core temperature rises, which can cause heat exhaustion or heat stroke

A4. BMR is the minimum rate at which the body uses energy (& produces heat) just to keep vital functions going, such as breathing heartbeat, brain activity, ion pumping & maintaining body temperature

Conditions: Person is awake but lying completely relaxed (physical & mental rest), fasting for about 12 hrs & in a comfortable, thermoneutral room (20-25°C)

Typical Value: about 80 W for adult (1600 - 1900 kcal/day)

AS. In fever, the hypothalamus thermostat (set point) is raised by pyrogens released during infection, so the body actively works to reach the higher temperature (shivering, vasoconstriction)
In hyperthermia (heat stroke), the set point is normal, but heat gain from the environment or exercise is more than the body can lose, so the body actively works to reach the higher temperature (shivering, vasoconstriction)
In hyperthermia (heat stroke), the set point is normal, but heat gain from the enviroment or exercise is more than the body can lose, so the body overheats even though it is trying to cool down
Paracetamol blocks prostaglandin production in the hypothalamus & brings the raised set point back to normal, so it works in fever. In hyperthermia the set point is not raised, so it has no effect there, that case needs physical cooling: shade, cold water or ice packs & fluids.

Section B

B1. Heat balance equation of the human body

$$S = M - W \pm R \pm C - E$$

Effects

1. Sweating increases heat loss through evaporation
2. Vasodilation increases blood flow to the skin and helps release heat.
3. Shivering increases heat production through muscle activity.

B2

(a) Muscle efficiency is around 20% because some energy is used for muscle contraction, while the remaining energy is released as heat.

ATP provides energy for muscle activity, but not all of it's energy is converted into mechanical work

(b) Muscle is not a heat engine. It used chemical energy from ATP directly to produce movement. Therefore, the Carnot efficiency limit does not apply to it in the same way. It does not violate the Second law of thermodynamics

Section C

C1. wool = $L = 0.008m$ $K = 0.040$

Air = $L = 0.004m$, $K = 0.023$

Area = $1.6 m^2$

Temp differena = $33 - 3 = 30^{\circ}C$

(a) $R_1 = \frac{0.008}{0.040 \times 1.6}$ $= R_1 = 0.125 K/W$

Air $R_2 = \frac{0.004}{0.023 \times 1.6}$

$R_2 = 0.109 K/W$

$R = 0.125 + 0.109 = 0.234 K/W$

(b) $Q = \frac{\Delta T}{R}$ $= Q = \frac{30}{0.234}$ $= Q = 128.2 W$

(c) $\Delta T_1 = Q \times R_1 = 128.2 \times 0.125 = 16.03^{\circ}C$

C2. Area = $1.6 m^2$

Skin temp = $34^{\circ}C = 307.15 K$

Room temp = $20^{\circ}C = 293.15 K$

Emissivity = 0.97

$h = 5 W/m^2K$

(a) $Q = \epsilon \sigma A (T_s^4 - T_\infty^4)$

$Q = 0.97 \times 5.67 \times 10^{-8} \times 1.6 (307.15^4 - 293.15^4)$

$\boxed{Q = 133.3 W}$

(b) $Q = hA(T_S - T_\infty)$

$= 5 \times 1.6 \times (34 - 20)$

$Q = 112\ W$

(c) $Q = 133.3 + 112$

245.3 W

C3. Mechanical power = 120W

Oxygen consumption = 1.6 L/min

Resting metabolic rate = 85W

(a) $M = \frac{1.6 \times 20,000}{60} = 533.3\ W$

(b) $\frac{120}{533.3} \times 100 = 22.5\%$

$\frac{120}{533.3 - 85} \times 100 = 26.8\%$

(c) $Q = M - W$

$533.3 - 120 = 413.3\ W$

Cy Age = 20 years

weight = 55 kg

Height = 160 cm

S = -161

(a) BMR = 10m + 6.25h - 5a + S

= 10 (55) + 6.25 (160) - 5 (20) - 161

= 550 + 1000 - 100 - 161

BMR = 1289 kcal/day

$$\frac{1289 \times 4186}{86400} = 62.45 W$$

(b) BMR X PAL

= 1289 X 1.6 = 2062.4 kcal/day

(c) = 2300 - 2062.24 = 237.6

= 237.6 x 90 = 21384 kcal

$$\frac{21384 \times 4186}{32000000} = \boxed{2.81 cg}$$