

Lizard Energy Budget

1) Radiation inflow term (Q_a) – not calculated, provided as a constant.

2) Radiation outflow term

$$Q_{out} = \varepsilon \sigma T_r^4$$

where ε is the emissivity (0-1), σ is 5.67E-8, and T_r (body surface temperature) has kelvin units.

3) Convection term (C)

$$C = h_c (T_r - T_a) \quad h_c = k_1 \sqrt{\frac{V}{D}}$$

where T_a is the air temperature, h_c is a convection coefficient that depends on wind speed (V), object size (D), and a shape factor $k_1 = 3.49$ for a cylinder.

4) Metabolic energy term (M) – units are watts per kilogram of lizard.

$$M = 0.0258 e^{T_b/10}$$

where T_b is the body core temperature.

5) Evaporative cooling term (E) – units are watts per kilogram of lizard

$$\begin{array}{lll} T_b \leq 20 & 20 < T_b < 36 & T_b \geq 36 \\ E = 0.27 & E = 0.08 e^{0.0586 T_b} & E = 0.00297 e^{0.1516 T_b} \end{array}$$

Note that if you are using Python if statements, here, you can either say:
if ($20 < T_b < 36$), or if(($T_b > 20$) and ($T_b < 36$))

6) Effect of insulation resistance (I)

$$M - E = \frac{T_b - T_r}{I}$$

7) Combining all terms into a budget (and converting Celsius units to kelvin in the radiation term):

$$M - E + Q_a - \varepsilon \sigma (T_r + 273.15)^4 - h_c (T_r - T_a) = 0$$

8) Solve the insulation equation (see step 6 above) for T_r and substitute into the budget shown in step 7, giving the final energy budget:

$$M - E + Q_a - \varepsilon \sigma [T_b + 273.15 - I(M - E)]^4 - h_c [T_b - T_a - I(M - E)] = 0$$

9) For convenience in programming, the final budget in step 8 can be broken up into parts:

$$M = 0.0258 e^{T_b/10}$$

$$E = (\text{see above step 5})$$

$$Q_a = (\text{supplied in exercise})$$

$$Q_{out} = \varepsilon \sigma [T_b + 273.15 - I(M - E)]^4$$

$$C = h_c [T_b - T_a - I(M - E)]$$

with the total budget then:

$$M - E + Q_a - Q_{out} - C = 0$$

Note: The terms for M and E give units of W / kg and we want W / m². So both terms need to be multiplied by the mass to surface area ratio of the lizard to convert to an area basis.

Note: Some computer programming languages may interpret a variable called “ I ” as referring to complex numbers (remember that square root of -1 stuff?). So you might want to use some other variable name for the lizard insulation resistance.

Here is a “test case” that can be used to verify the correctness of a program used to solve the lizard budget.

Input variables:

$$Q_a = 800 \text{ W/m}^2$$

$$V = 1.5 \text{ m/s}$$

$$D = 0.01 \text{ m}$$

$$I = 0.002 \text{ }^\circ\text{C m}^2 \text{ W}^{-1}$$

$$\varepsilon = 0.95$$

$$T_a = 35 \text{ }^\circ\text{C}$$

$$\text{Lizard mass} = 0.067 \text{ kg}$$

$$\text{Lizard area} = 0.018 \text{ m}^2$$

Output:

$$T_b = 41.39 \text{ }^\circ\text{C}$$

$$Q_{out} = 527.21 \text{ W/m}^2$$

$$C = 272.94 \text{ W/m}^2$$

$$E = 5.87 \text{ W/m}^2$$

$$M = 6.02 \text{ W/m}^2$$