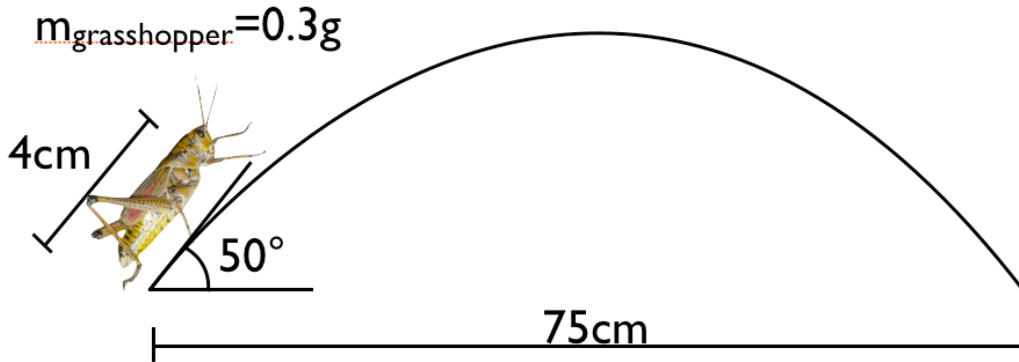


2013 OAPT Conference: Biophysics in the Classroom

Grasshoppers:

Question: A grasshopper of mass 0.3g has hind legs that extend 4cm during takeoff at an angle of  $\theta=50^\circ$  to the horizontal. The total distance of the jump is 75cm. What power does the grasshopper exert during the jump?



Solution (answer:  $P=0.78\text{W}$ ):

Comparing grasshoppers to humans: How much power does Mike, the 100kg human, exert while competing in the long jump competition? Mike's legs extend 0.5m during the jump at an angle of  $35^\circ$  and he is able to jump a horizontal distance of 4m. (answer:  $P=1.3 \times 10^4\text{W}$ )

Geckos:

Questions:

- 1) How much force/ $\text{mm}^2$  does it take for a 55g gecko to hang upside down if each foot is  $115\text{mm}^2$ ? (answer:  $1.2 \times 10^{-3}\text{N/mm}^2$ )
  - 2) Each gecko foot contains setae ( $14\,400$  setae/ $\text{mm}^2$ ). Each setae can withstand up to  $200\mu\text{N}$ . What is the minimum surface contact that a gecko must have to hang upside-down? (answer:  $0.19\text{mm}^2$ )
  - 3) If all four feet are in full contact how much mass could a gecko theoretically hold? (answer: 130kg)
- Source: W. R. Hansen and K. Autumn. Evidence for self-cleaning in gecko setae. *PNAS*, 102 (2005).

Diffusion qualitative experiment:

Observe the difference in how food colouring diffuses in cold vs. hot water.

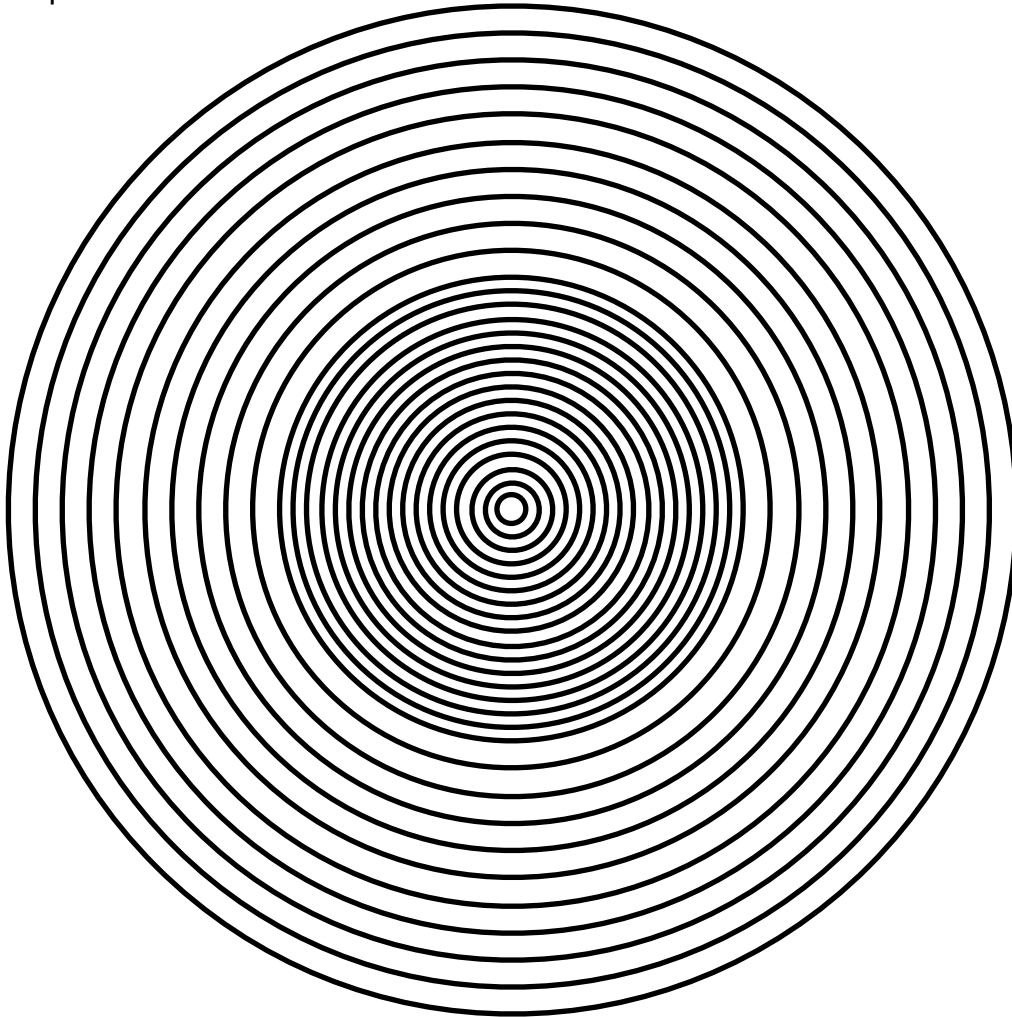
Equating the kinetic energy (equipartition) we see that velocity of the particles scales with the temperature:

$$E_k = \frac{1}{2}mv^2 \propto kT \rightarrow \langle v^2 \rangle \propto kT/m$$

Diffusion quantitative experiment:

Measure the radius as a function of time (2D). Dye molecules perform random walk,  $r \propto \sqrt{t}$ . Students can test the random walk scaling using a coin on a 1D axis - one step right for heads and one step left for tails. After  $x$  flips the square root of the average squared distance from the origin (root mean squared) will be  $\sqrt{x}$ . Each step is equivalent to one time step.

Equipment: clear petrie dish or pyrex container, food colouring, paper to measure radius (see below), stop watch.



small rings: 1.8 mm apart  
large rings: 3.6 mm apart