Natural Sciences (Physical)

Here are some questions that test qualities we are looking for in the interview. The style of these questions is different to those we use in the interview as there we have the chance to have a discussion with the candidate about their methods.

1. Plot $y = e^{-2x} + 3x - 2$ and find:

   a) when the curve crosses the x-axis

   b) the lowest value for y in the range $-2 \leq x \leq 2$.

2. $2^{\ln 3} = 3^{\ln 2}$. True or false? Explain your answer.

3. Sketch the graphs of $y = \ln|x|$ and its integral, labelling as many features as you can.

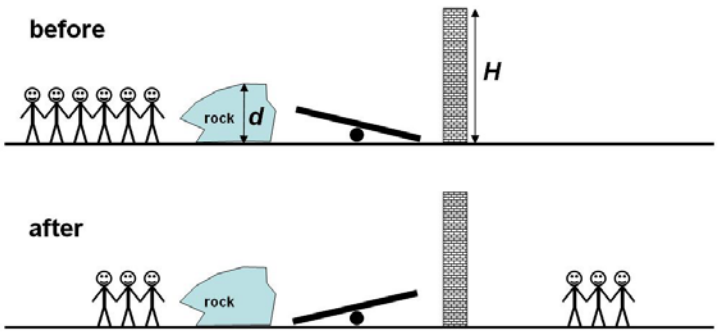
4. Show that:

$$\frac{1}{\sqrt{k}} > \sqrt{k} - \sqrt{k-1},$$

   for $k \geq 2$, and use this to show that:

$$\sum_{k=1}^{n} \frac{1}{\sqrt{k}} > \sqrt{n}.$$

5. Using a see-saw, six prisoners of similar height and weight would like to help their friends jump to the other side of a prison wall of height *H*. The rock nearby has a height of *d* (see figure below). Assuming that the see-saw is ideal, find the maximum ratio of *H*/*d* that still allows three prisoners can escape.



6. A ball of mass *M* is dropped from a height h_0 above sea level and it falls under gravity experiencing an air resistance force proportional to the square of its velocity, i.e. $f = -\alpha_{air} v^2$, where α_{air} is the coefficient of resistance with the air. Derive and plot the velocity of the ball as a function of height *h*. When the ball hits the surface of the sea, it is observed that the ball continues to travel under water at a constant velocity, where $\alpha_{water} \neq \alpha_{air}$. How does this velocity compare with i) the terminal velocity in water, and ii) the terminal velocity in air? Plot the acceleration on the ball as a function of height *h* (take the sea level to be zero and under water to be negative height) after it hits the water at the terminal velocity in air.

7. Estimate the number of atoms in a glass of water.

8. Write down the structures for all possible isomers of $C_2H_4O_2$.

9. An exothermic reaction A + B ➔ C occurs in aqueous solution at a rate given by the formula:

$$\frac{d[C]}{dt} = k[A][B]$$

a) Sketch a graph of reaction temperature, T, versus time, t for this reaction.

b) Sketch a graph of rate of change of temperature versus time.

c) Very briefly describe what affects the form of the curves you have drawn.