PHYSICS OF MATERIALS

Physics School Autumn 2025

Series 9 Solution **21 November 2025**

Exercise 1: Creep

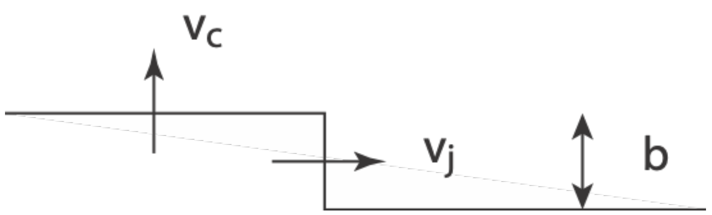
a) When a Frank-Read source is activated:

$$\sigma = \frac{\mu b}{\ell}$$

with ℓ the distance between strong pinning points. If we have a Frank network of dislocations: $\Lambda = \ell^{-2}$ and, therefore:

$$\sigma = \mu b\sqrt{\Lambda} \qquad \text{and} \qquad \Lambda = \left(\frac{\sigma}{\mu b}\right)^2$$

b) Climb occurs by lateral movement of jogs :



$\mathbf{v}_c = \frac{n_j}{n}\mathbf{v}_j$. n_j is the number of jogs, and $n = \frac{\ell}{b}$ is the number of atoms on the dislocation length, i.e., the number of atoms that is required for the jog to move to the dislocation anchoring point.

In the course, we have defined $C_j = \frac{n_j}{n}$ and therefore.

$$\mathbf{v}_c = C_j \mathbf{v}_j \, .$$

But $\mathbf{v}_j$ is controlled by the diffusion velocity of vacancies, and the Einstein equation tells us that:

$$\mathbf{v}_j = \frac{DF}{kT}$$

Since a jog is a dislocation having a length of its Burgers vector (b), we can say that $F = \sigma b \cdot b = \sigma b^2$. So:

$$\mathbf{v}_c = C_j \frac{\sigma b^2}{kT} D$$

c) The Orowan equation determines the creep occurring due to dislocations:

$$\dot{\varepsilon} = \Lambda b \cdot \mathbf{v}$$

In this case, the dislocation velocity is the climb velocity. Therefore :

$$\dot{\varepsilon} = \Lambda(\sigma) b \cdot \mathrm{v}_c(\sigma) = \left(\frac{\sigma}{\mu b}\right)^2 \cdot b \cdot C_j \frac{\sigma b^2}{kT} D = \frac{C_j D b}{\mu^2 kT} \sigma^3$$

This illustrates the formula (9.56) of the text. Remember that the diffusion of interstitials or vacancies to the dislocation core at critical temperatures facilitates dislocation climb, and diffusion rates are key parameters in creep mechanisms and the creep rate.