4 **(a)** A metal wire has spring constant k. ⟨for⟩ces are applied to the ends of the wire to extend it within the limit of Hooke's law.
Show that, for an extension x, the strain energy E stored in the wire is given by

$$E = \tfrac{1}{2}kx^2.$$

[4]

(b) The wire in **(a)** is now extended beyond its elastic limit. The forces causing the extension are then removed.
The variation with extension x of the tension F in the wire is shown in Fig. 4.1.
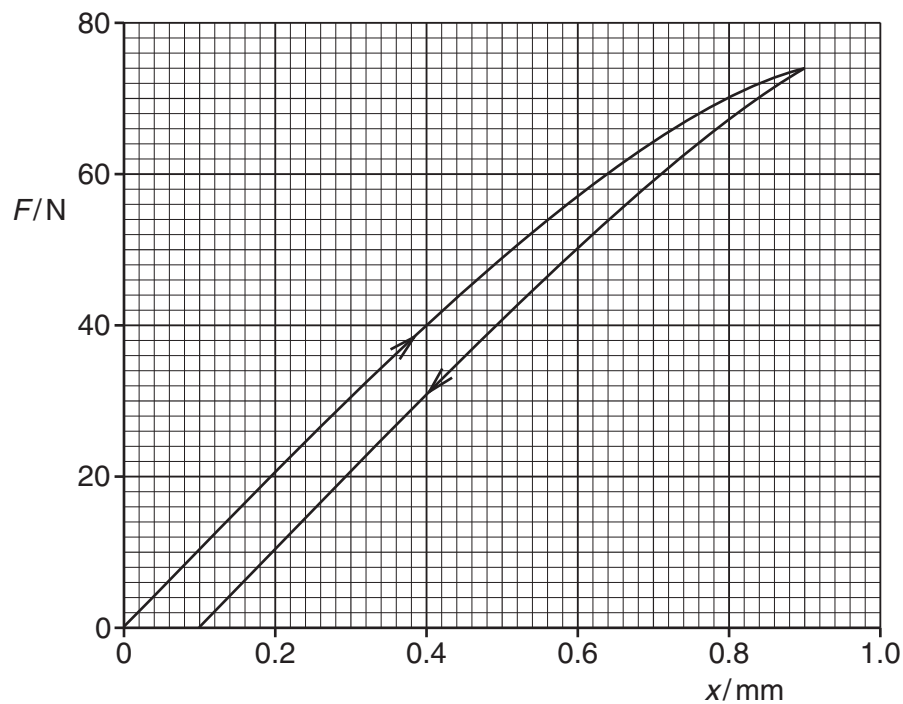
Fig. 4.1

Energy E_S is expended to cause a permanent extension of the wire.

(i) On Fig. 4.1, shade the area that represents the energy E_S. [1]

(ii)   Fig. 4.1 to calculate the energy E_S.

$E_S =$ .... mJ [3]

(iii) Suggest the change in the structure of the wire that is caused by the energy E_S.

....

....[1]