STAEDTLER® No. 937 811E Engineer's Computation Pad

••48 Figure 12-58 shows an approximate plot of stress versus strain for a spider-web thread, out to the point of breaking at a strain of 2.00. The vertical axis scale is set by $a = 0.12$ GN/m^2, $b = 0.30$ GN/m^2, and $c = 0.80$ GN/m^2. Assume that the thread has an initial length of 0.80 cm, an initial cross-sectional area of 8.0×10^{-12} m^2, and (during stretching) a constant volume. Assume also that when the single thread snares a flying insect, the insect's kinetic energy is transferred to the stretching of the thread. (a) How much kinetic energy would put the thread on the verge of breaking? What is the kinetic energy of (b) a fruit fly of mass 6.00 mg and speed 1.70 m/s and (c) a bumble bee of mass 0.388 g and speed 0.420 m/s? Would (d) the fruit fly and (e) the bumble bee break the thread?

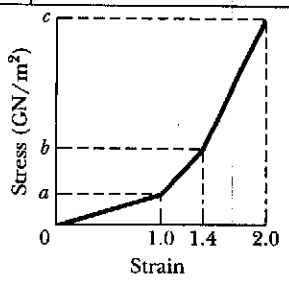


FIG. 12-58 Problem 48.

FOR TENSION AND COMPRESSION:
STRESS & STRAIN
STRESS $\equiv F/A$ (A is $\perp$ to $\vec{F}$)
STRAIN $\equiv \Delta L/L$ (the DEFORMATION)
$(F/A) = E(\Delta L/L)$; THE PROPORTIONALITY CONSTANT $= E =$ YOUNG'S MODULUS

$E = \frac{2-0}{1-0} = 0.12 \frac{GN}{m^2}$ REGION #1
$= \frac{b-a}{1.4-1} = \frac{0.3-0.12}{0.4} = 0.456 \frac{GN}{m^2}$ #2
$= \frac{c-b}{2-1.4} = \frac{0.8-0.3}{0.6} = 0.83 \frac{GN}{m^2}$ #3

} PER UNIT DEFORMATION

$W^{net} = \Delta K$ & $W^{net} = -\Delta U$ if... ELASTIC LIMIT IS NOT EXCEEDED

W to stretch to a STRAIN OF 2 $\Rightarrow \Delta L/L_0 = 2 \Rightarrow L = L_0 + \Delta L$
$L = L_0(1 + \Delta L/L_0) = L_0(1+2) = 3L_0$

$W_{net} = \int \vec{F} \cdot d\vec{r} = -\int F\,dx = -\int [(\text{STRESS})A]\,[(\text{DIFFERENTIAL STRAIN})L]$
$= (AL = V = \text{CONSTANT}) \left\{ \int \text{STRESS}\,[\text{DIFFERENTIAL STRAIN}] = \text{AREA UNDER STRESS VS STRAIN CURVE} \right\}$
$= [(0.0080\text{m})(8.0\times10^{-12}\text{m}^2)] \left\{ \frac{1}{2}(1)a + \left[\frac{1}{2}(0.4)(b-a) + (0.4)a\right] + \left[\frac{1}{2}(0.6)(c-b) + (0.6)b\right] \right\}$
$= (6.4\times10^{-14}\text{m}^3)\{0.474\,(\text{GN/m}^2 = 10^9\,\text{N/m}^2)\} = 3.0\times10^{-5}\,(\text{Nm} = \text{Joule})$

NOTE EXTRA: $\pi r^2 = A = 8.0\times10^{-12}\text{m}^2 \Rightarrow 1.6\times10^{-6}\text{m} = r \Rightarrow \text{diam} = 3.2\,\mu\text{m}$

a) $W^{\text{net}}_{\text{to break}} = \Delta K = 3.0\times10^{-5}$ (JOULES = Nm) $\quad \Delta K = K_f - K_i = -K_i$ if $K_f = 0$

b) FRUIT FLY: $\frac{1}{2}mv^2 = \frac{1}{2}\left[6\text{ mg} = 6\times10^{-3}\text{ g}\ \frac{\text{kg}}{10^3\text{ g}}\right](1.7\,\frac{\text{m}}{\text{s}})^2$
$= 8.67\times10^{-6}$ Joules $= 86.7$ ergs

c) BUMBLE BEE: $\frac{1}{2}Mv^2 = \frac{1}{2}\left[0.388\text{ g}\ \frac{10^{-3}\text{kg}}{\text{g}}\right](0.420\,\frac{\text{m}}{\text{s}})^2$
$= 3.42\times10^{-5}$ Joules $= 342$ ergs

d) THE BUMBLE BEE BREAKS THE WEB AND GETS AWAY
THE FRUIT FLY IS STUCK AND GETS EATEN
THAT'S PHYSICS AND NATURAL SELECTION