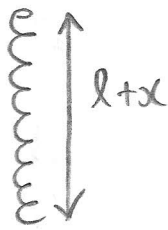
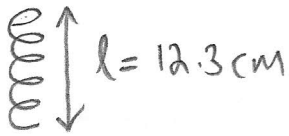


PHYSICAL PROPERTIES OF MATERIALS

1/ (i)

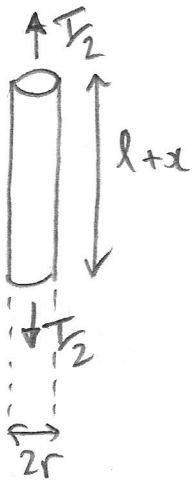


a) $x = 0.45 l$
 $x = 0.45 \times 12.3 \text{ cm}$
 $x = 5.535 \text{ cm}$ (5.535 cm)

b) $F = kx \therefore k = F/x \therefore k = \frac{6.7 \text{ N}}{5.535 \times 10^{-2} \text{ m}} = 121 \text{ N/m}$

c) $E = \frac{1}{2} kx^2 = \frac{1}{2} \left(\frac{6.7}{5.535 \times 10^{-2}} \right) (5.535 \times 10^{-2})^2$ (J)
 $= 0.19 \text{ J}$

(ii)



$Y = 200 \text{ GPa}$
 $l = 10.000 \text{ m}$
 $x = 2 \times 10^{-3} \text{ m}$
 $r = 42 \times 10^{-3} \text{ m}$

Stress $\sigma = \frac{T}{\pi r^2}$

$\frac{\sigma}{E} = \frac{\epsilon}{l}$ and $\epsilon = \frac{x}{l}$

so $\frac{T}{\pi r^2} = \frac{Yx}{l}$

$T = \frac{Yx \pi r^2}{l}$

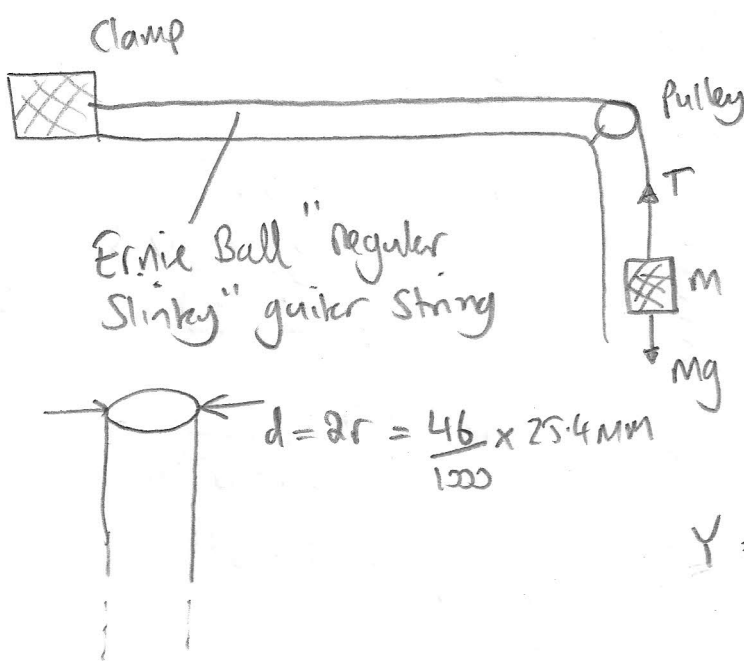
$\therefore T = \frac{200 \times 10^9 \times 2 \times 10^{-3} \times \pi \times (42 \times 10^{-3})^2}{10.00} = 2.22 \times 10^5 \text{ N}$

(ie a mass equivalent of 22.6 tonnes).

$\uparrow 22.6 \times 10^3 + 981 = 2.22 \times 10^5$

if the **Poisson ratio** (transverse axial strain ratio) was not zero, the rod would probably 'neck' (ie $r \downarrow$) as it is stretched. Since $T = \frac{Yx \pi r^2}{l}$, for the same extension, this means a slightly lower tension T .

(iii)



$$g = 9.81 \text{ N/kg}$$

$$l = 3.14 \text{ m}$$

$$d = 2.7 \text{ mm}$$

$$Y = 200 \text{ GPa}$$

$$Y = \frac{T/\pi r^2}{d/l}$$

$$T = mg$$

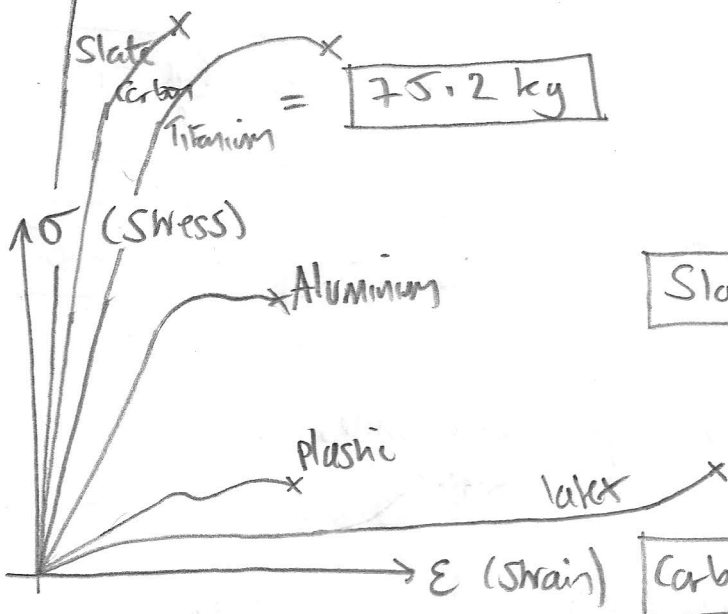
$$\frac{d}{e} Y \pi r^2 / g = m$$

$$m = \frac{2.7 \times 10^{-3} \times 200 \times 10^9 \times \pi \times \left(\frac{46}{1000} \times 25.4 \times 10^{-3}\right)^2}{9.81}$$

$$= 75.2 \text{ kg}$$

{ About the mass of Dr F! }

(iv)



Slate

ceramic. High Y. Brittle, i.e. fractures before it yields. (at small strain)

Carbon Fiber

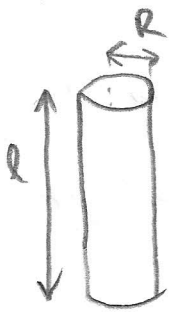
High Y

(230 GPa is larger than steel), so very stiff. Weave and epoxy composite fabrication probably allows for some degree of yield, but expect to be less tough than titanium or aluminium.

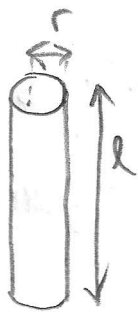
Plastic should yield before fracture, (i.e. undergo plastic deformation first), and expect latex do do this in a more extreme way. i.e. lowest ϵ and largest strain.

2

v)



Steel



Carbon
fiber

Let tension T applied to steel rod be such that it is under maximum stress.

$$\frac{T}{\pi R^2} = 3 \text{ GPa}$$

$$\therefore T = 3 \text{ GPa} \times \pi R^2$$

If T is the same for the carbon fiber:

$$\frac{T}{\pi r^2} = Y_{cf} \alpha / l \quad (1)$$

Now extension α is the same as steel

$$\text{So: } \frac{T}{\pi r^2} = Y_s \alpha / l \quad (2)$$

$$\Rightarrow \left(\frac{r}{R}\right)^2 = \frac{Y_s}{Y_{cf}} \quad (2)/(1)$$

$$\Rightarrow r = \sqrt{\frac{Y_s}{Y_{cf}}} \times 3.5 \text{ mm}$$

$$r = \sqrt{\frac{200}{230}} \times 3.5 \text{ mm}$$

$$\boxed{r = 3.26 \text{ mm}}$$

If T_{max} for steel is $3 \text{ GPa} \times \pi R^2$

and T_{max} for carbon fiber is $3 \text{ GPa} \times \pi r^2$

$$\Rightarrow \text{max force is } 3 \times 10^9 \text{ N/m}^2 \times \pi \times (3.26 \times 10^{-3})^2 = \boxed{1.00 \times 10^5 \text{ N}}$$

(10.2 tone equivalent).

$$\text{Fractional weight saving is } \frac{\pi R^2 \rho_s l - \pi r^2 \rho_{cf} l}{\pi R^2 \rho_s l} = 1 - \left(\frac{r}{R}\right)^2 \frac{\rho_{cf}}{\rho_s}$$

(3)

