1

A cylindrical specimen of a titanium alloy having an elastic modulus of 107 GPa (15.5 x 106 psi) and an original diameter of 3.8 mm (0.15 in.) experiences only elastic deformation when a tensile load of 2000 N (450 lbf) is applied. Compute the maximum length of the specimen before deformation if the maximum allowable elongation is 0.42 mm (0.0165 in.).

Answer

$$E = 107\ GPa$$
$$A_0 = 3.61\pi\ mm^2$$
$$F_y = 2\ kN$$
$$\Delta L_y = 0.42\ mm$$

$$\sigma_y = \frac{F_y}{A_0} = \frac{2}{3.61\pi}\ GPa$$
$$\epsilon_y = \frac{\Delta L_y}{L_0} = \frac{0.42}{L_0}$$

$$E = \frac{\sigma_y}{\epsilon_y} = \frac{2L_0}{(0.42)3.61\pi} = 107\ GPa$$
$$L_0 = \frac{107(0.42)3.61\pi}{2}\ mm = 254.84\ mm$$

$$L_0 = 254.84\ mm$$
$\square$

2

A cylindrical specimen of aluminum having a diameter of 0.505 in. (12.8 mm) and a gauge length of 2.000 in. (50.800 mm) is pulled in tension. Use the load–elongation characteristics shown in the following table to complete parts (a) through (f).

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Load		Length	
N	lbf	mm	in.
0	0	50.800	2.000
7330	1650	50.851	2.002
15100	3400	50.902	2.004
23100	5200	50.952	2.006
30400	6850	51.003	2.008
34400	7750	51.054	2.010

38400	8650	51.308	2.020
41300	9300	51.816	2.040
44800	10100	52.832	2.080
46200	10400	53.848	2.120
47300	10650	54.864	2.160
47500	10700	55.880	2.200
46100	10400	56.896	2.240
44800	10100	57.658	2.270
42600	9600	58.420	2.300
36400	8200	59.182	2.330
Fracture			

a

Plot the data as engineering stress versus engineering strain.

✓ **Answer**

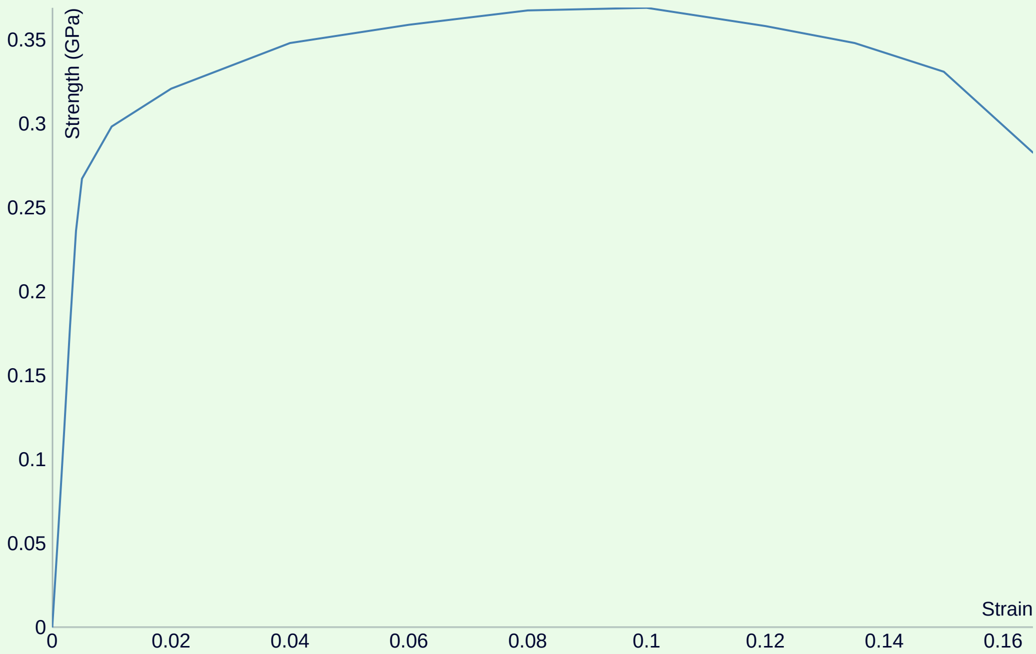
```
let d = 12.8
let l = 50.8
let data = [
        [0, 50.8],
        [7330, 50.851],
        [15100, 50.902],
        [23100, 50.952],
        [30400, 51.003],
        [34400, 51.054],
        [38400, 51.308],
        [41300, 51.816],
        [44800, 52.832],
        [46200, 53.848],
        [47300, 54.864],
        [47500, 55.880],
        [46100, 56.896],
        [44800, 57.658],
        [42600, 58.420],
        [36400, 59.182]
]

let a = Math.pow(d/2,2) * Math.PI
let epsi = data.map(i => [(i[1]-l)/l, i[0]/a/1000])

let renderObj = {
        data: [
                {
                        points: epsi,
```

```
                        fnType: 'points',
                        graphType: 'polyline',
                }
        ],
        xAxis: {
                label: "Strain",
                domain: [
                        Math.min( ... epsi.map(a ⇒ a[0])),
                        Math.max( ... epsi.map(a ⇒ a[0])),
                ]
        },
        yAxis: {
                label: "Strength (GPa)",
                domain: [
                        Math.min( ... epsi.map(a ⇒ a[1])),
                        Math.max( ... epsi.map(a ⇒ a[1])),
                ]
        }
}

console.log(JSON.stringify(renderObj))
```



b

Compute the modulus of elasticity.

✓ **Answer**

```
let d = 12.8
let l = 50.8
let data = [
        [0, 50.8],
        [7330, 50.851],
        [15100, 50.902],
        [23100, 50.952],
        [30400, 51.003],
        [34400, 51.054],
        [38400, 51.308],
        [41300, 51.816],
        [44800, 52.832],
        [46200, 53.848],
        [47300, 54.864],
        [47500, 55.880],
        [46100, 56.896],
        [44800, 57.658],
        [42600, 58.420],
        [36400, 59.182]
]

let a = Math.pow(d/2,2) * Math.PI
let epsi = data.map(i => [(i[1]-l)/l, i[0]/a/1000])
let e = Math.max( ... epsi.slice(1).map(i => i[1]/i[0]))

console.log(e)
```

```
59.995998220175025
```

$E = 59.995998220175025\,GPa$

c

Determine the yield strength at a strain offset of 0.002.

✓ **Answer**

```
let d = 12.8
let l = 50.8
let data = [
        [0, 50.8],
        [7330, 50.851],
```

```
        [15100, 50.902],
        [23100, 50.952],
        [30400, 51.003],
        [34400, 51.054],
        [38400, 51.308],
        [41300, 51.816],
        [44800, 52.832],
        [46200, 53.848],
        [47300, 54.864],
        [47500, 55.880],
        [46100, 56.896],
        [44800, 57.658],
        [42600, 58.420],
        [36400, 59.182]
]

let a = Math.pow(d/2,2) * Math.PI
let epsi = data.map(i => [(i[1]-l)/l, i[0]/a/1000])
let e = 59.995998220175025
let x = 0.002

let mapped = epsi.map(i => [i[0]-(i[1]/e), i[1]])
let bounds = mapped.reduce((i, j) => i.length === 0 || j[0] < x ? [j] : i.length < 2 && j[0] >= x ? [...i, j] : i, [] as number[][])

let pos = (x - bounds[0][0]) / (bounds[1][0] - bounds[0][0]) * (bounds[1][1] - bounds[0][1]) + bounds[0][1]

console.log(pos)
```

```
0.27742759187638605
```

$Y_u = 0.27742759187638605\,GPa$

d

Determine the tensile strength of this alloy.

✓ **Answer**

```
let d = 12.8
let l = 50.8
let data = [
```

```
        [0, 50.8],
        [7330, 50.851],
        [15100, 50.902],
        [23100, 50.952],
        [30400, 51.003],
        [34400, 51.054],
        [38400, 51.308],
        [41300, 51.816],
        [44800, 52.832],
        [46200, 53.848],
        [47300, 54.864],
        [47500, 55.880],
        [46100, 56.896],
        [44800, 57.658],
        [42600, 58.420],
        [36400, 59.182]
]

let a = Math.pow(d/2,2) * Math.PI
let epsi = data.map(i => [(i[1]-l)/l, i[0]/a/1000])

let max = Math.max( ... epsi.map(i => i[1]))

console.log(max)
```

```
0.3691337791438002
```

$\sigma_U = 0.3691337791438002\, GPa$

e

What is the approximate ductility, in percent elongation?

✓ **Answer**

```
let e = 59.995998220175025
let y = 0.27742759187638605

console.log(Math.pow(y,2) / (2*e))
```

16.50%

f

Compute the modulus of resilience.

✓ **Answer**

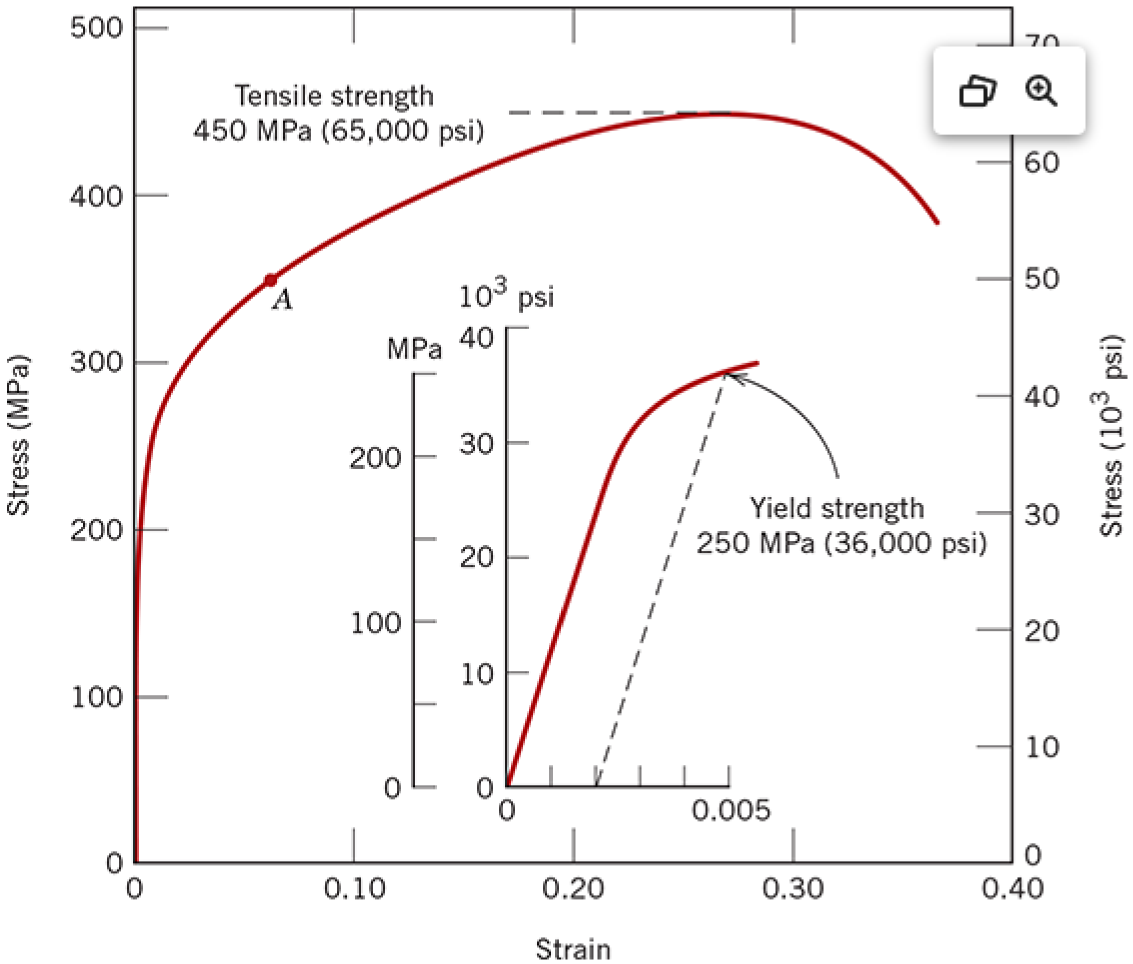
```
let e = 59.995998220175025
let y = 0.27742759187638605

console.log(Math.pow(y,2) / (2*e))
```

$U_r = 0.6414266869256708 \; MPa$

3

A cylindrical specimen of a brass alloy 7.5 mm (0.30 in.) in diameter and 90.0 mm (3.54 in.) long is pulled in tension with a force of 6000 N (1350 lbf); the force is subsequently released.



a

Compute the final length of the specimen at this time. The tensile stress–strain behavior for this alloy is shown in the Figure.

✓ **Answer**

$$\frac{6\,kN}{(\frac{7.5}{2})^2\pi\,mm^2} = 0.136\,GPa$$

The force remains within the elastic limit.

$$L_f = 90.0\,mm$$

b

Compute the final specimen length when the load is increased to 16,500 N (3700 lbf) and then released.

✓ **Answer**

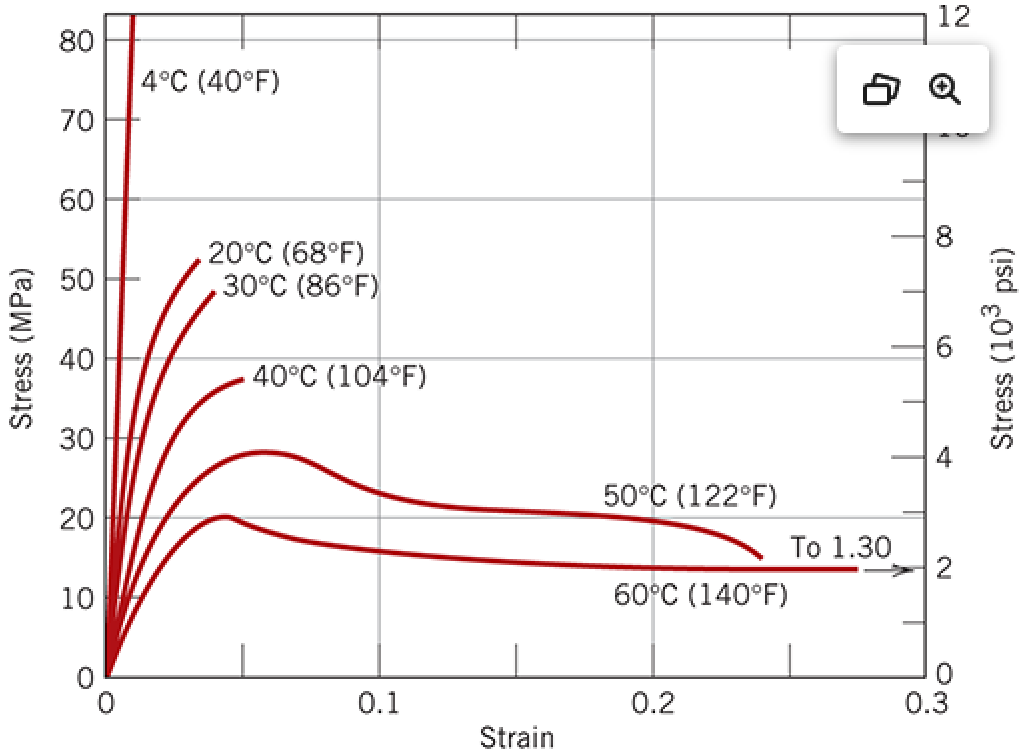
$$\frac{16.5\,kN}{(\frac{7.5}{2})^2\pi\,mm^2} = 0.373\,GPa$$

The force does not remain within the elastic limit.

$$L_f = 90.0 * (1 + 0.08)\,mm = 97.2\,mm$$

4

From the stress–strain data for poly(methyl methacrylate) shown in the Figure, determine the modulus of elasticity and tensile strength at room temperature [20°C (68°F)], and compare these values with those given in Tables below



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	Modulus of Elasticity		
Material	GPa	10^6 psi	Poisson's Ratio
Phenol-formaldehyde	2.76-4.83	0.40-0.70	—
Poly(vinyl chloride) (PVC)	2.41-4.14	0.35-0.60	0.38
Poly(ethylene terephthalate) (PET)	2.76-4.14	0.40-0.60	0.33
Polystyrene (PS)	2.28-3.28	0.33-0.48	0.33
Poly(methyl methacrylate) (PMMA)	2.24-3.24	0.33-0.47	0.37-0.44

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	Yield Strength		Tensile Strength		
Material	MPa	ksi	MPa	ksi	Ductility, %EL [in 50mm (2 in.)]
Nylon 6,6	44.8-82.8	6.5-12	75.9-94.5	11.0-13.7	15-300
Polycarbonate (PC)	62.1	9.0	62.8-72.4	9.1-10.5	110-150
Poly(ethylene terephthalate) (PET)	59.3	8.6	48.3-72.4	7.0-10.5	30-300
Poly(methyl methacrylate) (PMMA)	53.8-73.1	7.8-10.6	48.3-72.4	7.0-10.5	2.0-5.5

✓ **Answer**

$$E = \frac{40}{0.02} = 2\,GPa$$
$$\sigma_U = 53\,MPa$$

My estimated values line up very closely with the table values of $E = 2.24\ GPa$ and $\sigma_U = 53.8\ MPa$

5

Find a reference on the internet that gives a value for the tensile strength of optical glass fiber made from silica.

✓ **Answer**

https://www.sciencedirect.com/science/article/pii/S0022309313004171
"estimated strengths of $\sim 7 - 8\ GPa$"