5.3 Forces and elasticity

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

KEY WORDS Elastic

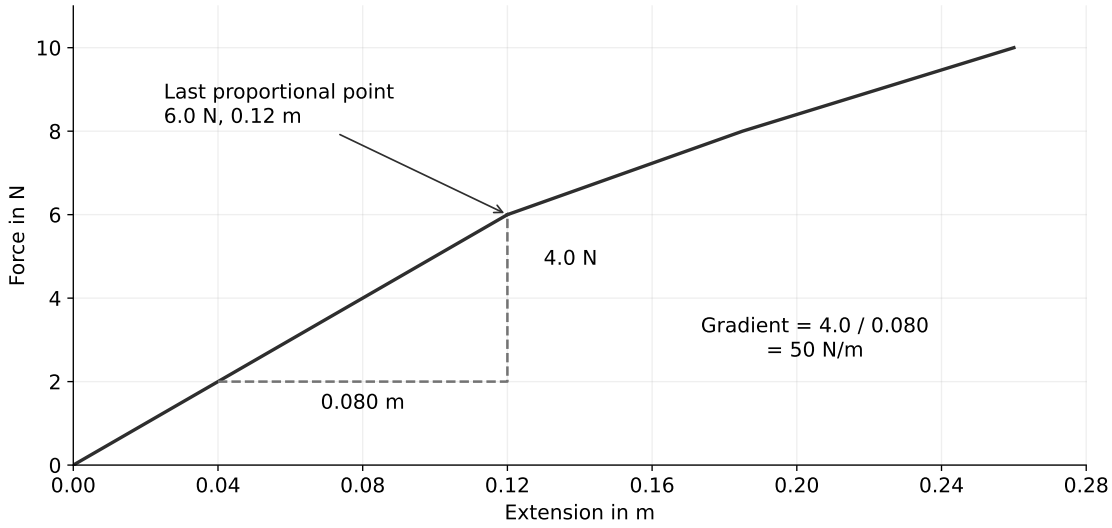
Objective

Use $F = ke$ and $E_e = \frac{1}{2}ke^2$, interpret force–extension graphs, and describe RP6 with the limit of proportionality. Original questions for spec statement 4.5.3 and required practical 6.

1 Key knowledge and worked examples

More than one force is needed to stretch, bend or compress a stationary object (one force alone would accelerate it).

- **Elastic deformation** : the object returns to its original shape when the forces are removed.
- **Inelastic deformation** : it does not fully recover.



Gradient of the straight section = k.

$$F = ke \qquad E_e = \frac{1}{2}ke^2$$

- e is the **extension** = stretched length − original length (or compression).
- The equations hold **below the limit of proportionality**.

RP6 method: hang a mass holder on a suspended spring; add equal masses; measure the total length each time with a ruler at eye level (pointer on the spring helps); compute extension; plot force against extension.

Credited analysis points:

- linear section through the origin: $F \propto e$, gradient $= k$;
- the line curves beyond the limit of proportionality;
- check for zero error (measure the unloaded length first);
- repeats and a mean reduce random error;
- same k = same stiffness; a stiffer spring has a larger k.

Worked example. A spring of original length 0.84 m stretches to 1.10 m under a child's weight of 340 N.

- Extension: $e = 1.10 - 0.84 = 0.26$ m.

$$k = \frac{F}{e} = \frac{340}{0.26} = 1310 \text{ N/m} \approx 1300 \text{ N/m (2 s.f.)}$$

Worked example. A spring with $k = 250$ N/m is stretched 4.0 cm.

- Convert: $e = 0.040$ m (its own mark).

$$E_e = \tfrac{1}{2}ke^2 = \tfrac{1}{2} \times 250 \times 0.040^2 = 0.20 \text{ J}$$

2 Practice

2.1 A spring stretches 3.0 cm under a 6.0 N load. Calculate k in N/m. [3]

2.2 A spring of $k = 200$ N/m is compressed 5.0 cm. Calculate the elastic energy stored. [3]

2.3 State the difference between elastic and inelastic deformation. [2]

3 Exam-style questions

3.1 A student hangs masses on a spring and measures its length.

Load in N	**0**	**2.0**	**4.0**	**6.0**	**8.0**	**10**
Length in cm	20.0	24.0	28.0	32.0	38.5	46.0

(a) Plot-ready: state the extension at each load. [1]

(b) Describe the shape of the force–extension graph and identify where the limit of proportionality lies. [2]

(c) Calculate k using data from the linear section. [2]

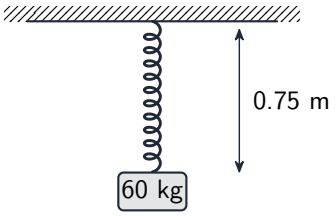
(d) Suggest why the graph curves at large loads. [1]

3.2 A bungee cord behaves like a spring of $k = 800$ N/m. A 60 kg person hangs at rest stretching it 0.75 m ($g = 10$ N/kg for this question).

(a) Show the cord obeys $F = ke$ at this stretch. [3]

(b) Calculate the elastic energy stored. [2]

(c) (Link) State where this energy came from, using energy stores. [2]



3.3 Two springs, X ($k = 100$ N/m) and Y ($k = 400$ N/m), are each stretched by the same 8.0 N force.

(a) Calculate each extension. [4]

(b) Calculate the ratio of stored energies $E_X : E_Y$. [3]

(c) Starting with both springs unstretched, state which needs more work to stretch it by 1.0 cm, with a reason. [2]