Force: Rate of change of momentum

Force can cause object to:

Shear , Bend , Stretch , compress etc.

Extention: Change in length due to application of force.

x = Streched length − orignal length.

x = −ve length decreases x = +ve length increases.

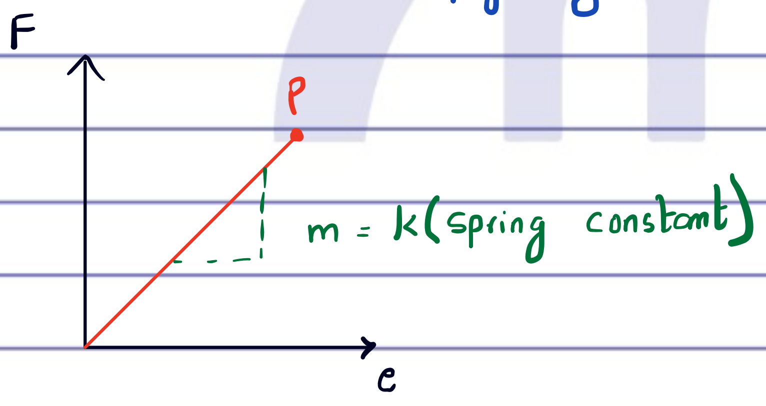
Hooks law: Force is directly propotional to extention until limit of propotionality is reached.

$F \propto x$ $\boxed{F = kx}$ k = spring constant

∴ Nm^{-1}

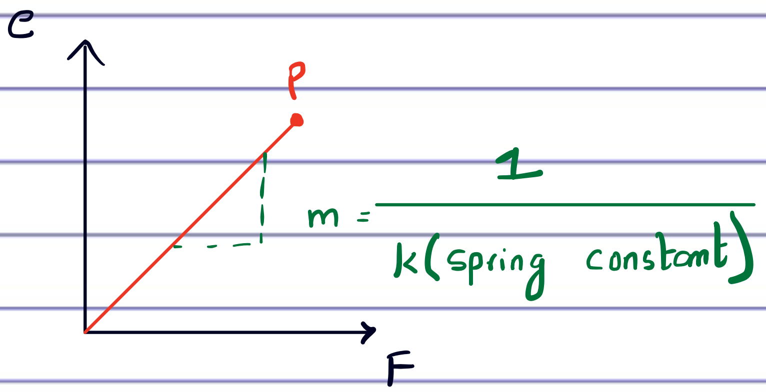
How to convert Ncm^{-1} to Nm^{-1}

multiply by 100 [to Convert Ncm^{-1} into Nm^{-1}]



Spring constant tells us about the stiffness of the body

Value of k depends upon design of object and material.

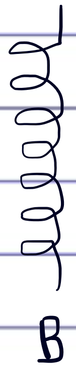


Spring A (Rigid / Stiff spring)

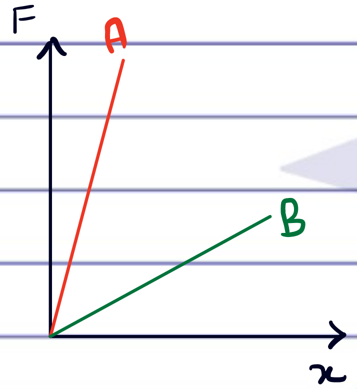
$k_A = 1020 Nmm^{-1}$ [means 1020 N force required for 1mm extention]

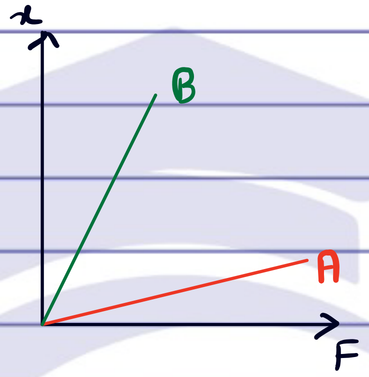
More value of spring constant means more stiffness.

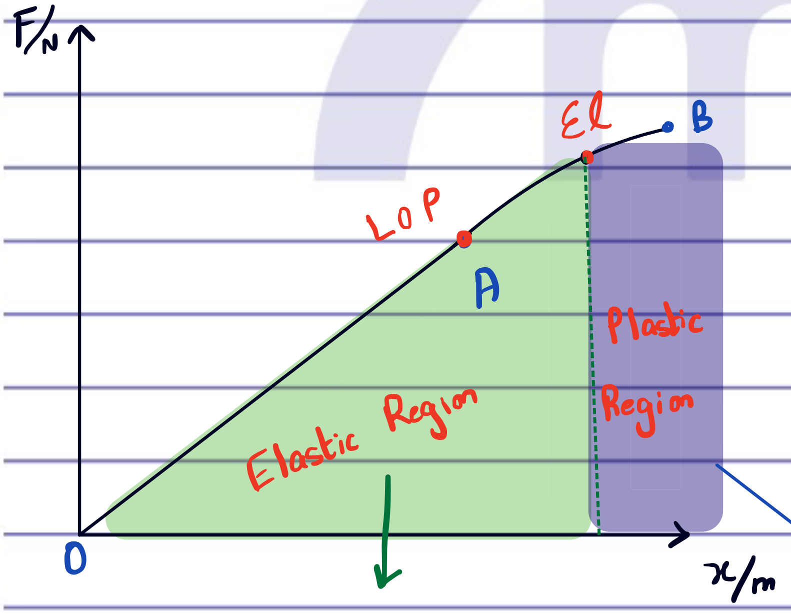
Spring B (Flexible)



$k_B = 300 Nmm^{-1}$





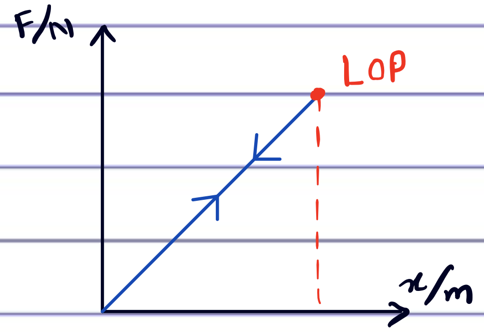


LoP (Limit of Propotionality)
Point till which $F \propto x$
F–x graph is a straight line.

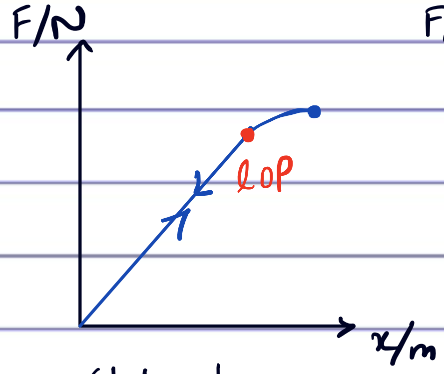
El (Elastic limit): Point beyond which permenent deformation occurs.

Elastic Deformation

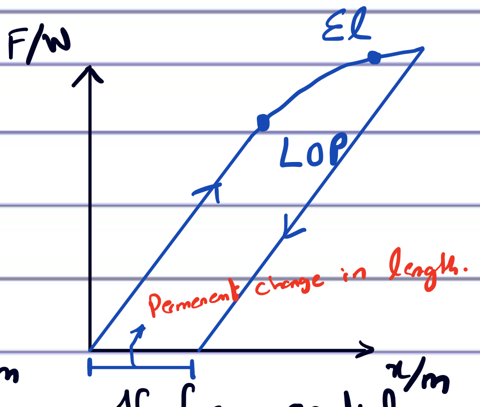
Plastic Deformation.



If force is applied till LOP object returns to its orignal length



Still returns as Elastic limit is not reached.



If force applied beyond elastic limit permement deformation occurs.

Concept of Energy stored by a spring:

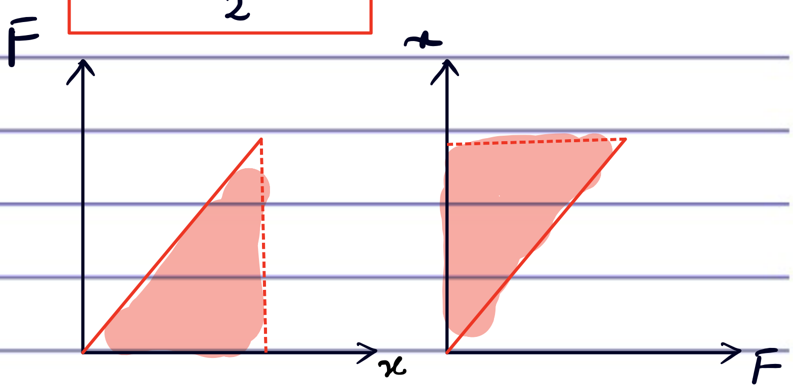
Whenever spring is either streached or compressed, it stores energy.

* This energy is called Elastic Potential Energy, strain energy or workdone by the spring.

This energy can be obtained by area of F−x graph

Energy stored in an object due to deformation.

$$\boxed{EPE = \frac{1}{2} Fx}$$

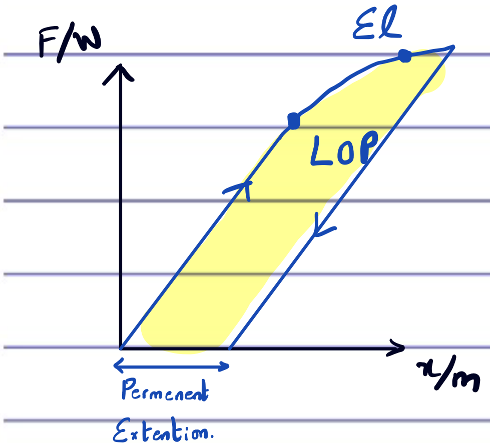


$$EPE = \frac{1}{2} Fx$$

$\therefore F = kx$

$$EPE = \frac{1}{2} (kx)(x)$$

$$\Rightarrow \boxed{\frac{1}{2} kx^2 = EPE}$$

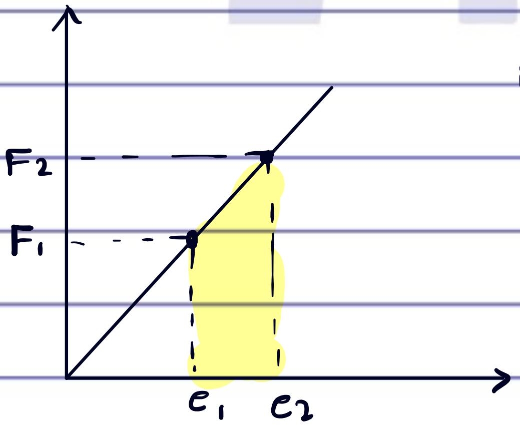


Non Recoverable Energy:

EPE stored due to Permenent deformation. (lost in heat)

"Concept of Additional Strain Energy."

Concider the material which has undergone an initial extention e_1 when a force of F_1 has been applied when force is increased to F_2 and corresponding extention is represented by e2 then energy stored in second stage is given the name of additional strain Energy.



Show that Additional strain energy is given by $\frac{1}{2}k(e_2^2-e_1^2)$

$$\frac{1}{2}(F_1+F_2)\times(e_2-e_1)$$

$F = ke$

$$\frac{1}{2}(ke_1+ke_2)(e_2-e_1)$$

$$\frac{1}{2}k(e_2+e_1)(e_2-e_1)$$

$$\boxed{E = \frac{1}{2}k(e_2^2-e_1^2)}$$

Topic: ______________ Date: ______________

Example no 1 : $k = 30 N cm^{-1}$

$e_1 = 5cm$ $e_2 = 7cm$

Calculate Additional Strain Energy.

$$\frac{1}{2} k (e_2^2 - e_1^2)$$

$$\frac{1}{2}(3000)(0.07^2 - 0.05^2)$$

$= +3.6 J$ (energy gained)

Example no 2 $k = 40 N cm^{-1}$

$e_1 = 6 Cm$ to $e_2 = 4cm$

Can we still use the term additional strain energy.

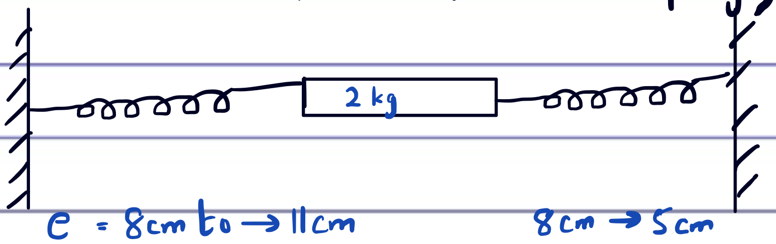
Yes ! Although you whould get your answer in negative.

What is the significance of -ve answer?

Additional Strain Energy $= \frac{1}{2}(4000)(0.04^2 - 0.06^2)$

$-4J$ (Energy released)

Q $k = 60\ Ncm^{-1}$ (Identical springs)



e = 8cm to → 11cm   8cm → 5cm

$\frac{1}{2}k(e_2^2 - e_1^2)$ $\frac{1}{2}(6000)(0.05^2 - 0.08^2)$

$\frac{1}{2}(6000)(0.11^2 - 0.08^2)$ -11.7 $17.1 + (-11.7)$

17.1J   5.4J

Given that all this energy is converted to KE of the block calculate initial speed of the block.

$5.4 = \frac{1}{2}mv^2$

$v = 2.3\ m/s$

$5.4 \times 2 = 2(v^2)$

Describe the motion of this spring.

Oscillatory motion. about a mean position.

$F = kx$

$\frac{F}{k} = x$

Q)

Spring P	Spring Q
→ F	→ F
→ k	→ $3k$
$e = \frac{F}{k}$	→ $\frac{F}{3k}$

$$= \frac{\cancel{\frac{1}{2}} F_p x_p}{\cancel{\frac{1}{2}} F_q x_q} = \frac{\cancel{F}\ \frac{\cancel{F}}{\cancel{k}}}{\cancel{F}\ \frac{\cancel{F}}{3k}} \quad 1 \div \frac{1}{3}$$

$3 : 1$

Find ratio of $\frac{\text{strain Energy in P}}{\text{Strain Energy in Q}}$

Q)

Spring P	Spring Q
$5F$	$7F$
$3k$	$8k$
$e = \frac{5F}{3k}$	$e = \frac{7F}{8k}$

$$\Rightarrow \frac{\cancel{\frac{1}{2}}(5\cancel{F})\left(\frac{5\cancel{F}}{3\cancel{k}}\right)}{\cancel{\frac{1}{2}}(7\cancel{F})\left(\frac{7\cancel{F}}{8\cancel{k}}\right)}$$

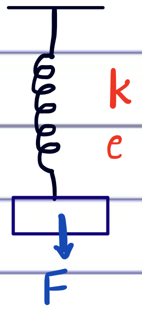
$$\frac{25}{3} \div \frac{49}{8}$$

$$\frac{25}{3} \times \frac{8}{49} =$$

Find ratio of $\frac{\text{Strain Energy in P}}{\text{Strain Energy in Q}}$

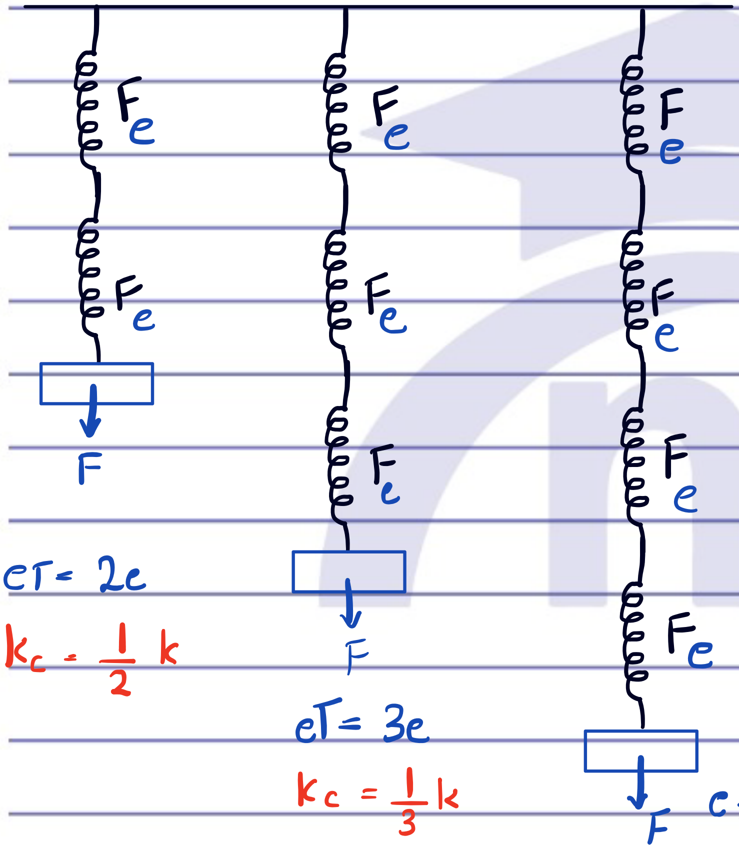
Arrangment of Springs (identical) in Series & Parallel combination

Refercmce



$e \propto \frac{1}{k}$

Series



$e_T = 2e$

$k_c = \frac{1}{2}k$

$e_T = 3e$

$k_c = \frac{1}{3}k$

$e_T = 4e$

$k_c = \frac{1}{4}k$

For identical springs

$x_T = x_1 + x_2 + x_3$

(Similar Spring) $x_T = x_1 + x_2 + x_3$

$\boxed{x_T = nx}$ → extension of 1 spring. → no of springs

Total Spring constant

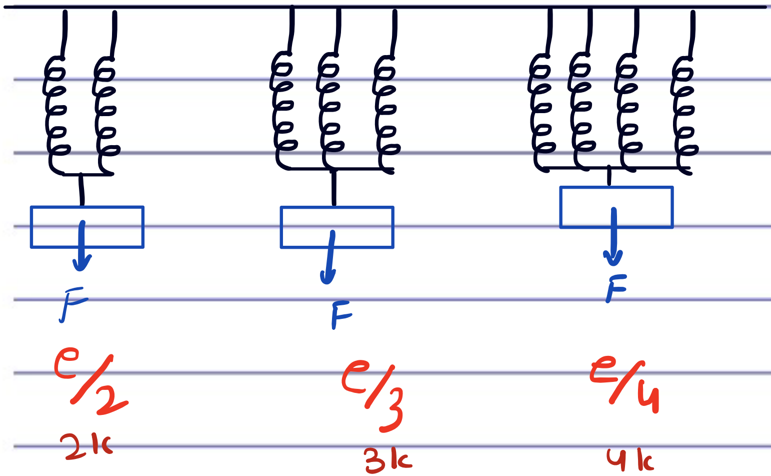
$$\frac{1}{k_T} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} \dots$$

$$\boxed{k_T = \frac{k}{n}}$$

Each Spring Experience the same Force

The Total Extention is always the sum of individual Extention

Parallel.



$$\boxed{F_{springs} = \frac{F_T}{n}}$$

Force in each spring!

applied force

no of Springs

- Force in Parallel gets divided equally

$$\boxed{x_n = \frac{x}{n}}$$

extention of one spring

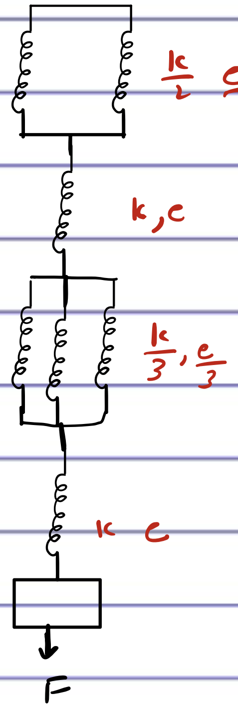
no of spring.

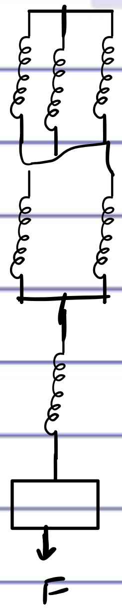
$$\boxed{k_n = nk}$$

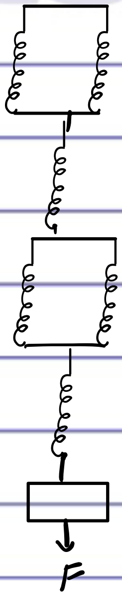
- Total extension is the same as the extension of any one spring

Find the total Extention and combine spring constant. (Identical)

①







→ Find spring constant and extention for these arrangment?

$F = kx$

$$\frac{17}{6}x$$

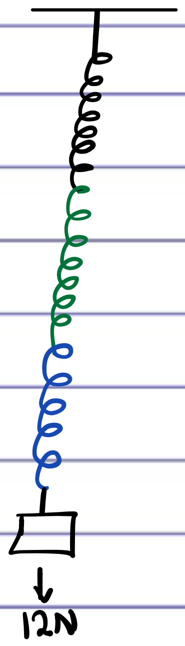
$$\frac{6}{17}k$$

Topic:

Non Identical Springs

Date:

a)



$K = 2 N m^{-1}$

$k = 3 N m^{-1}$

$k = 6 N m^{-1}$

→ Calculate Total Extention and Combine spring constant.

$F = ke$	$F = ke$	$F = ke$
$\frac{12}{6} = e$	$\frac{12}{3} = e$	$\frac{12}{2} = e$
$2 = e$	$4 = e$	$6 = e$

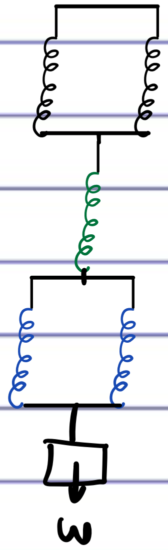
12 m

$F = ke,$

$\frac{12}{12} = k$

$1 N m^{-1}$

b)



$2K, \frac{W}{4}k$

$3k \quad \frac{W}{3k}$

$5K, \frac{W}{10}k$

Find in terms of K and W

i) total extention

ii) Combine spring constant

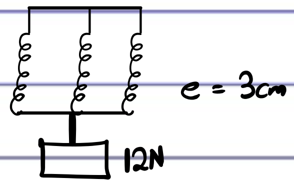
$F = ke$

$$W = k_e\left(\frac{W}{4}k + \frac{W}{3k} + \frac{W}{10}k\right)$$

$\frac{W}{2} = (5k)(e)$ $\quad$ $\frac{W}{2} = (2k)(e)$

$\frac{W}{10}k$ $\quad$ $\frac{W}{4k}$

Example 3



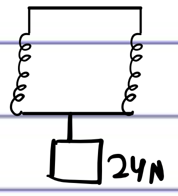
In the diagram each spring extends by 3cm.

$k = ?$

$F = ke$

$4 = k(3)$

$\frac{4}{3} = k$



The middle spring is removed and weight is changed to 24N. Calculate New extension.

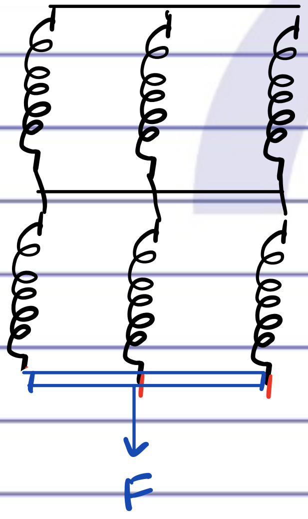
9cm = e

$12 = \left(\frac{4}{3}\right)(e)$

$\frac{36}{4}$ $9 = e$

Example 4

The Diagram shows a spring arrangment state what happens to the total extention if following changes are made independently.



1) Increase Number of springs per unit area.
   extention ↓ F will be distribute

2) Use more layers of springs.
   extention will increase.

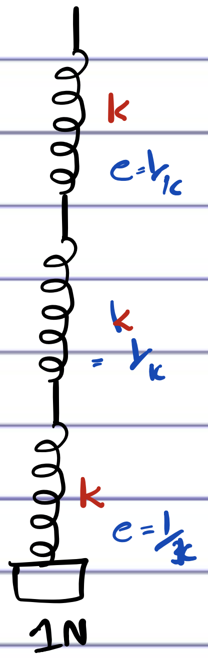
3) Replace spring with new with higher spring constant
   ext reduce.

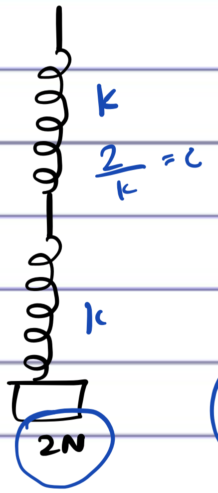
$F = \uparrow k e \downarrow$

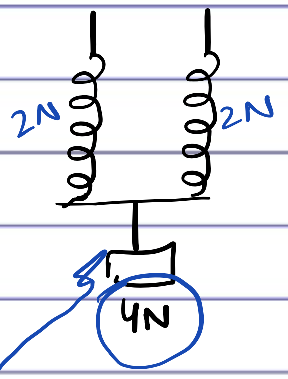
$\uparrow k \propto \frac{1}{e\downarrow}$

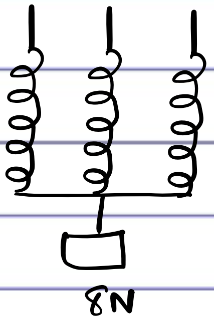
Which option gives greatest extention.

Spring constant = k









$2 = k e$

$\frac{2}{k} = e$

$F = k c$

$\frac{2}{k} = c$

$\frac{4}{k}$

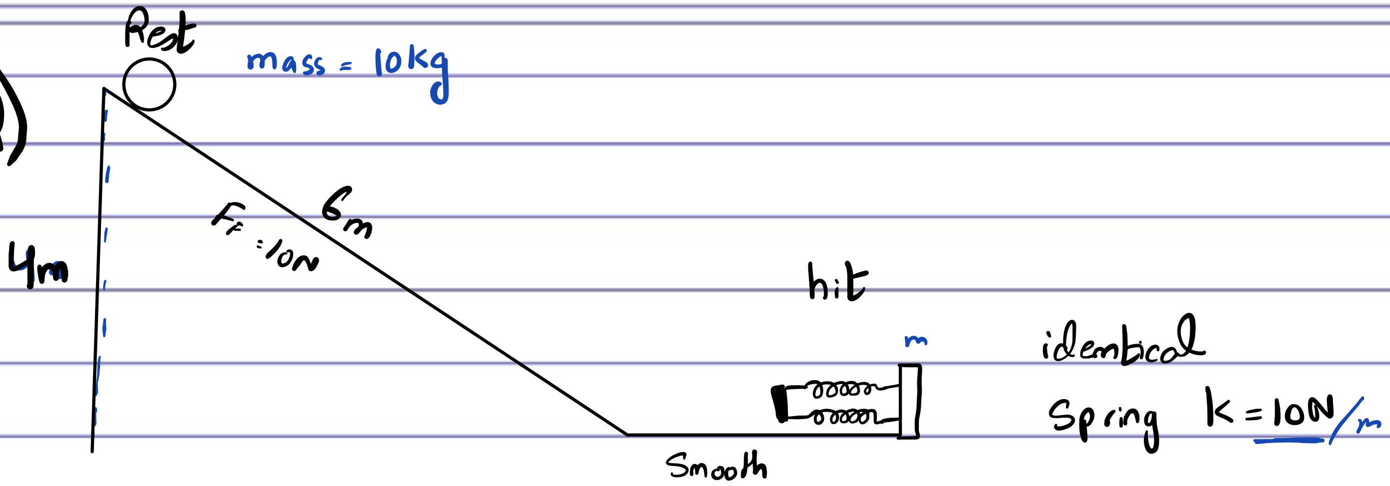
$F = k e$

$\frac{1}{k} = c$

$\frac{1}{k} + \frac{1}{k} + \frac{1}{k}$

$= \frac{3}{k}$

Q)



All KE → EPE calculate compression of Each spring

$$\text{Loss in GPE} - (\text{WD againt Friction}) = \frac{1}{2}Kx^2$$

$$mgh - F \times d = \frac{1}{2}k(x^2)$$

$$(10)(9.81)(4) - (10 \times 6) = \frac{1}{2}k(x^2)$$

$$392.4 - 60 = \frac{1}{2}(10 \times 2)(x^2)$$

$$\boxed{\text{extension } (x) = 5.8\text{ m}}$$

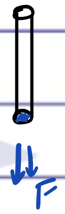
Topic: Concept of stress, strain and Young's and Modulus. Date:

Spring	Wire/Rod.
Force →	Stress
extention →	Strain
Spring constant →	Young's and modulus.

① **Stress:** Stress is just alternate name of pressure (σ)

units = Pa / N/m²

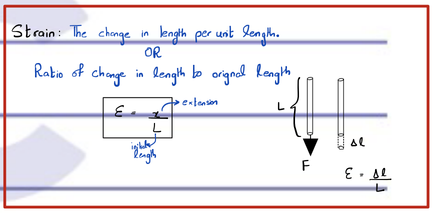
Formula => $\boxed{\text{Stress} = \frac{\text{Force}}{\text{Area.}}}$



$$\frac{\frac{F}{A}}{\frac{e}{L}} = \frac{FL}{Ae}$$

② **Strain.** Change in length upon orignal length

$$\boxed{\text{Strain} = \frac{\text{change in length}}{\text{orignal length}} = \frac{\Delta L}{L}}$$



Strain: The change in length per unit length.

OR

Ratio of change in length to orignal length

$$\boxed{\varepsilon = \frac{x}{L}}$$

$\varepsilon = \frac{\Delta l}{L}$

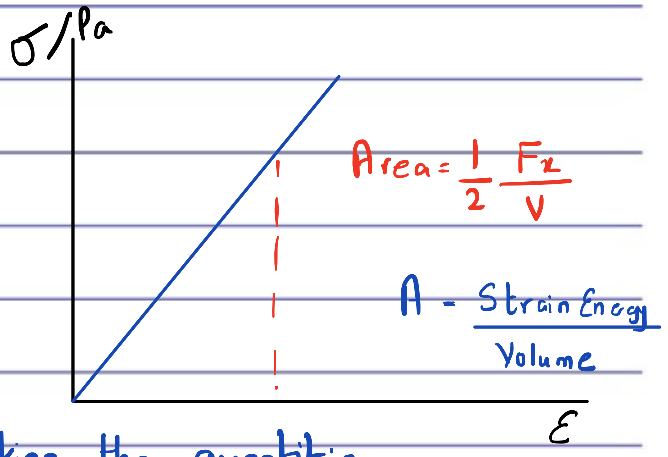
extention upon orignal length.

$$\boxed{\text{Strain} = \frac{\text{ext}}{\text{OL}} \Rightarrow \frac{e}{L}}$$

Youngs Modulus (E) The ratio of stress to Strain

$$E = \frac{\sigma}{\varepsilon} = \frac{\text{Stress}}{\text{Strain}}$$

$$\boxed{E = \frac{FL}{Ax}}$$ ⇒ Pascals



* Stress and strain helps in making the quantities independent of design.

Area under σ - ε graph tells strain energy density i.e energy stored per unit volume

Stress ∝ strain (limit of Propotionality)

Stress = E (Strain)

$$E = \frac{\text{Stress}}{\text{Strain}}$$

The more the E the more Elastic the material (Property of material)

$$E = \frac{FL}{Ae}$$

$$E = \frac{kL}{A}$$

$$F = ke$$

$$\frac{F}{e} = k.$$

$$E \propto k$$

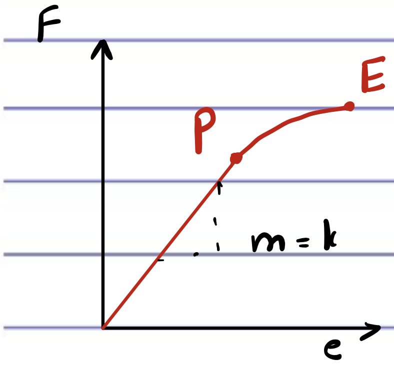
↓

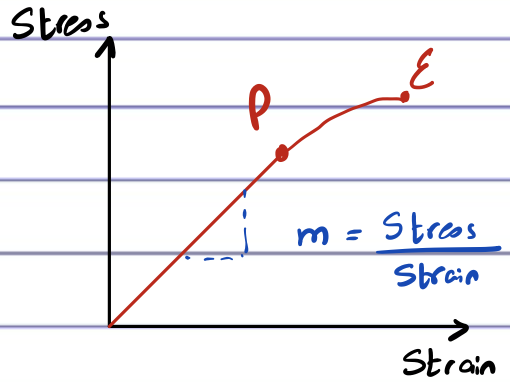
Rigid material have high value of Young's Modulus.

$\frac{F}{A} \times \frac{e}{L}$

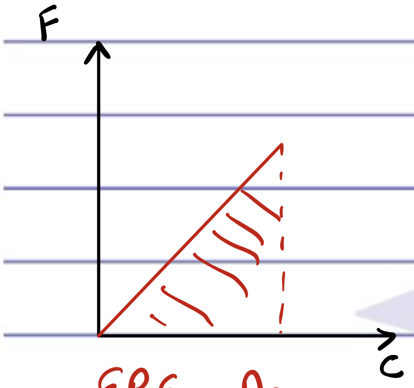
$\frac{F \times e}{\text{Volume}}$

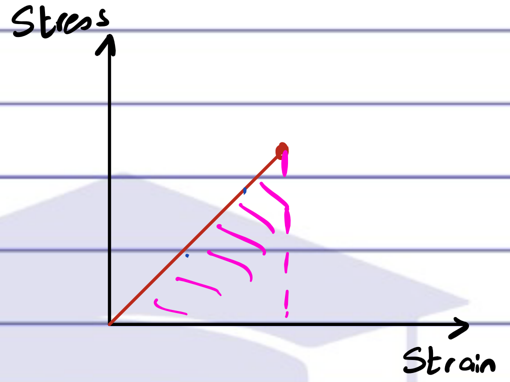
Topic: ______ Date: ______





$m = \frac{\text{Stress}}{\text{Strain}} = E$





EPE = Area

$\frac{1}{2} \times F \times e$

$\text{Area} = \frac{1}{2} \times \text{Stress} \times \text{Strain}$

$= \boxed{\frac{1}{2} \times \frac{F}{A} \times \frac{e}{L}}$

Strain energy/EPE

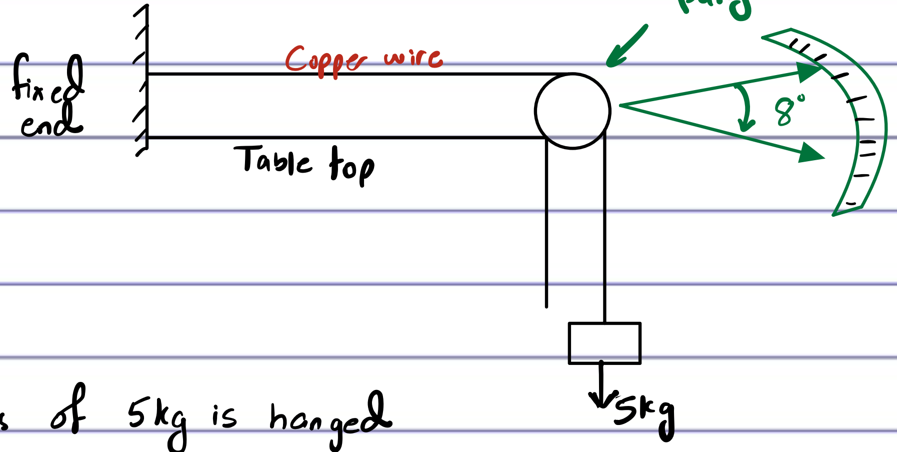
Volume.

$\text{Area} = \frac{\text{Strain Energy}}{\text{Volume}}$.

Area under stress strain graph gives strain Energy per unit Volume.

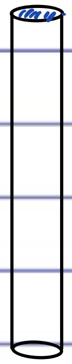
Experiment to determine Young's Modulus

Pully radius = 2cm => 0.02 m



$\mathcal{E} = \frac{FL}{Ae}$

⇒ As mass of 5kg is hanged the pointer deflects (due to extension of the wire) by 8° as shown above.



⇒ What measurements are to be taken:

$L = 0.85 m$

$A = \frac{\pi d^2}{4} = \pi r^2$

$F = W = mg. \qquad 5(9.81) = 49N$ ✓

To find extention, Lets assume if pully rotates by 360° than

extention = Circumference of the pully i.e $2\pi r$

$360° \longrightarrow 2\pi r$

$8° \longrightarrow x$

OR $\frac{\theta}{360} \times 2\pi r \Rightarrow$ Arc length.

$e = \frac{8}{360} \times 2\pi(0.02) = 2.8 \times 10^{-3} m$

$\boxed{\mathcal{E} = \frac{FL}{Ae}}$

$\frac{49 \times 0.85}{A\ (2.8 \times 10^{-3}}$

What instruments are needed.

1) L = mete rule
2) A = micrometer to measure diameter.
3) F = W = newton meter/ spring Balance.
e) Scale/protactor

Young's Modulus calculation

$$E = \frac{FL}{Ac} = \frac{(49)(0.85)}{(4.9\times10^{-6})(2.8\times10^{-3})}$$

$$\boxed{E = \quad\quad\quad}$$

⇒ Precausions:

- Do preliminary trials to ensure that weight attached does not cause the wire to reach its breaking point.
- After loading the wire the wire must be deloaded. so that it can be checked that the pointer returns back its orignal position this is done to ensure Elastic limit is not been exceeded.
- Pully should be oiled to reduce friction.
- Ensure that the wire is taut (i.e it is free from any bends or kinks)

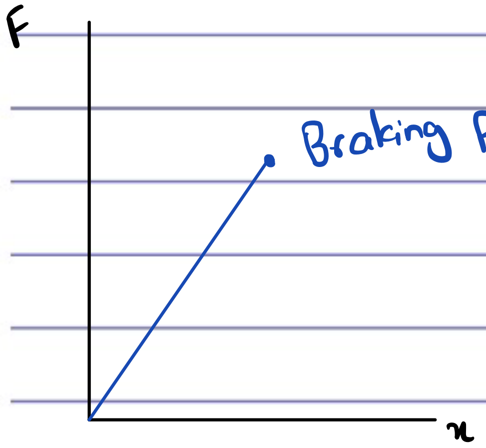
Topic: ____________ Date: ____________

Spring constant is also known as force constant

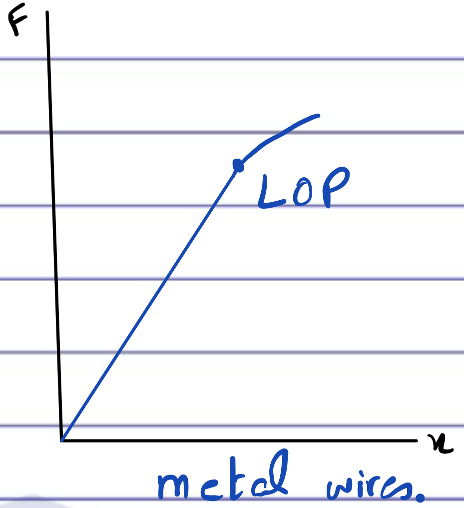
Concept of Percentage. Q19

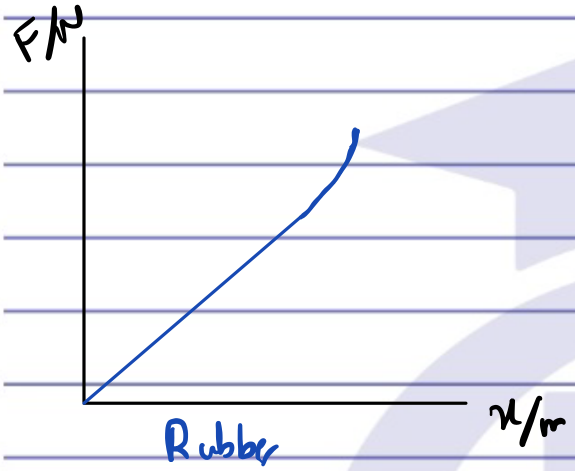
Topic: ____________________ Date: ____________________

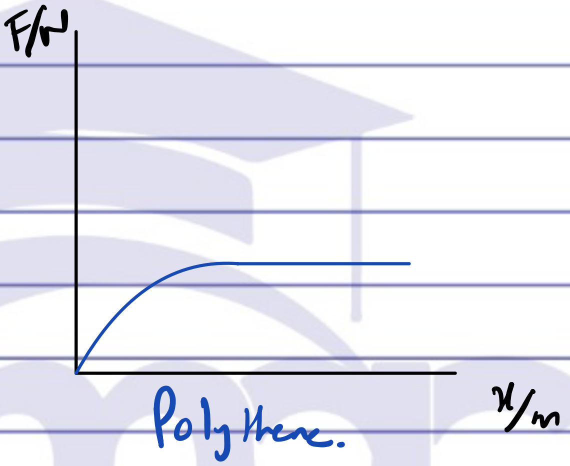
Brittle



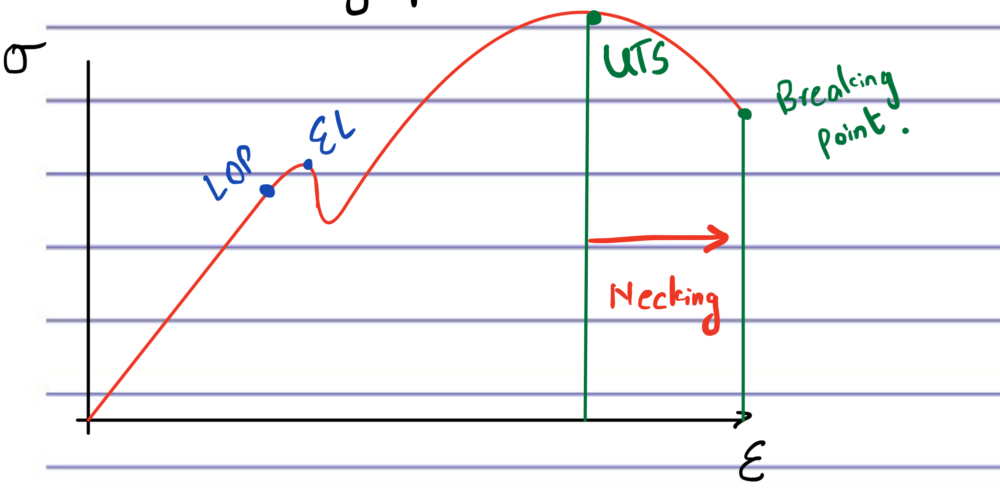
Ductile



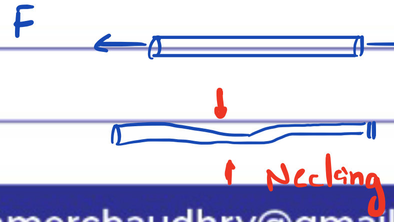




Stress - Strain graph of Ductile material.



UTS = (Ultimate Tensile Stress) : The maximum stress a material can endure before failure



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