# Basic of spring and common understanding

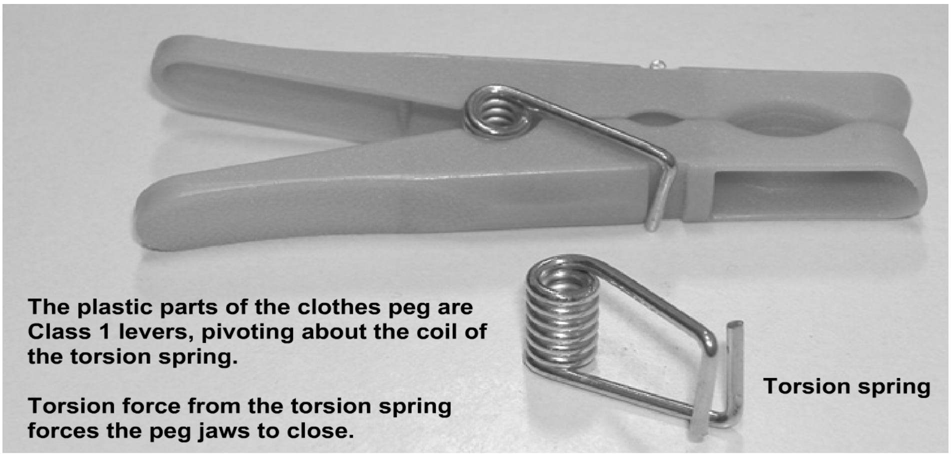
Commonly seen springs in day to day life.

Everyone of us had used at any time in life a spring, may it be in toy or in a ball point pen of a cloth hanger or in the exam pad. The spring is a very common component in day to day life. The basic function of spring we often see is to provide the restoring force. Further our sofas also have springs which function as cushioning device. Our two wheelers have springs in shock absorbers which act as an absorbers. Springs are also used for measuring force.

In the forthcoming chapter we will discuss in details about what is a spring, its functions and applications, also we will study the materials used for spring and then we will learn about designing a helical spring.

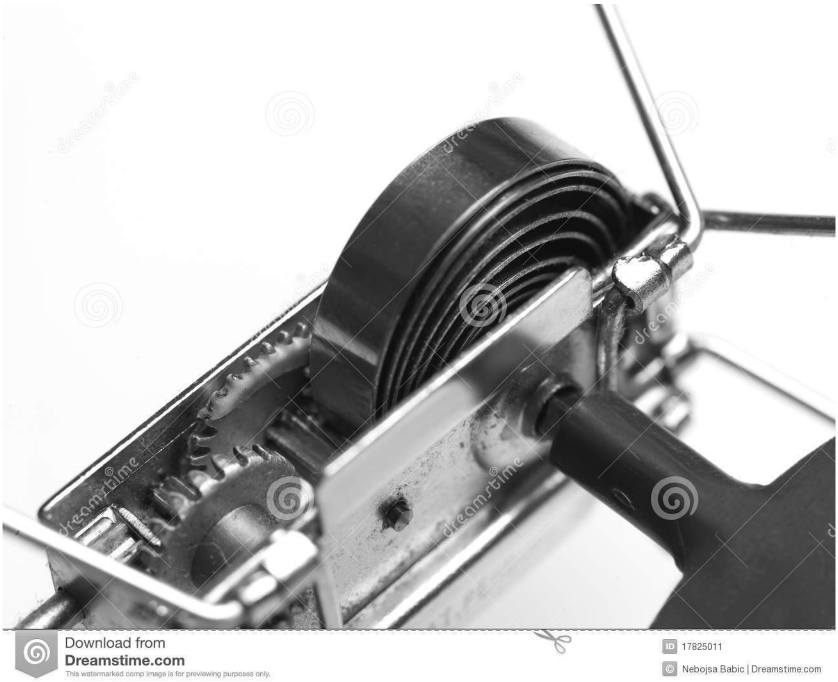
## Real Life examples of uses of springs

Cloth peg uses a torsion spring




Clutch pencil uses a compression spring.

Spring used in Toys operated with key.



# 5.1.Classification and applications of springs

## 1) What is Spring ? What are its functions/objectives?

***"A spring is an elastic object used to store mechanical energy. Spring acts as a flexible joint in between two parts or bodies."***

Objectives/functions of Spring:

A spring can is used for multiple purposes and functions in different devices, Some of them are listed below. Following are the objectives of a spring when used as a machine member:

*1. Cushioning , absorbing , or controlling of energy due to shock and vibration.*
*Car springs or railway buffers acts as cushions.*
*2.Control of motion*
*Maintaining contact between two elements (cam and its follower)*
*Creation of the necessary pressure in a friction device (a brake or a clutch)*
*Restoration of a machine part to its normal position when force is withdrawn (a governor )*
*3.Measuring forces*
*Spring is used for measuring forces in Spring balances, gauges.*
*4. Storing of energy*
*In clocks,starters and toys spring is used to store energy and release it over time.*

## 2) Give Classification of Springs?

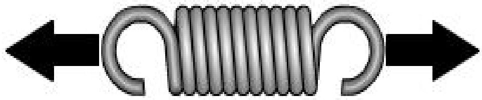
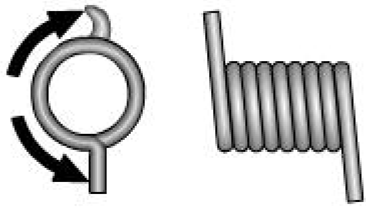
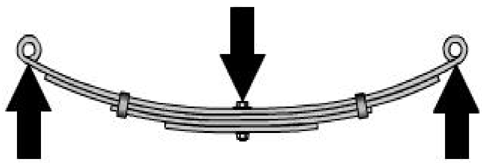
Springs can be classified depending on how the load force is applied to them:

1. Tension/Extension spring – the spring is designed to operate with a tension load, so the spring stretches as the load is applied to it. examples helical tension spring,rubber spring.
2. Compression spring – is designed to operate with a compression load, so the spring gets shorter as the load is applied to it. Examples compression helical spring, Belleville spring
3. Torsion spring – unlike the above types in which the load is an axial force, the load applied to a torsion spring is a torque or twisting force, and the end of the spring rotates through an angle as the load is applied. examples torsion bars, clock spring etc.
4. Constant spring - supported load will remain the same throughout deflection cycle.
5. Variable spring - resistance of the coil to load varies during compression.

They can also be classified based on their shape:

- Coil spring – this type is made of a coil or helix of wire
- Flat spring – this type is made of a flat or conical shaped piece of metal.
- Machined spring – this type of spring is manufactured by machining bar stock with a lathe and/or milling operation rather than coiling wire. example clip springs

## Common Classification with applications of springs

| | |
|---|---|
| ***Compression Spring*** This is a coil spring that has an open helical form and resists compressive forces. When it is compressed it reacts by pushing back until it has returned to its original form. |  |
| ***Tension Spring*** This is a coil spring that has a closed helical form and resists tension forces. When it is stretched it reacts by pulling back until it has returned to its original form. |  |
| ***Torsion Spring*** This is a coil spring that has a closed helical form and has a straight or hooked bar at its ends. It resists torsion forces. When it is twisted, i.e. when torsion force is applied and it is deformed, it reacts with an opposite torsion force until it has returned to its original form. |  |
| ***Clock Spring*** This is spiral spring that resists torsion forces. One end of a clock spring is fixed and the other is wound to make a tighter spiral. The spring resists this torsion force and the energy used to wind the spring is stored in the spring as potential energy. This spring is used to power mechanical clocks and clockwork toys. |  |
| ***Leaf Springs*** Leaf springs are composed of one or more curved metal beams clamped and bolted together. Leaf springs are mostly used with road vehicles to absorb vibration and shocks caused by the vehicle moving over uneven road surfaces. |  |

## 3) What are commonly used materials used for springs?

Following are the commonly used material for the springs

**Hard-drawn wire:** This is cold drawn, cheapest spring steel. Normally used for low stress and static load. The material is not suitable at subzero temperatures or at temperatures above 120 $^0$C.

**Oil-tempered wire:** It is a cold drawn, quenched, tempered, and general purpose spring steel. However, it is not suitable for fatigue or sudden loads, at subzero temperatures and at temperatures above 180 $^0$C.

**Chrome Vanadium:** This alloy spring steel is used for high stress conditions and at high temperature up to 220 $^0$C. It is good for fatigue resistance and long endurance for shock and impact loads. When we go for highly stressed conditions then alloy steels are useful.

**Music wire:** This spring material is most widely used for small springs. It is the toughest and has highest tensile strength and can withstand repeated loading at high stresses. However, it can not be used at subzero temperatures or at temperatures above 120 $^0$C.

## 4) What is the curvature effect in a helical spring? How does it vary with spring index?

Ans: For springs where the wire diameter is comparable with the coil diameter, the inside length of the spring segment is relatively shorter than the outside length. Hence shearing strain is more in the inner segment than the outer segment. This unequal shearing strain is called the curvature effect. Curvature effect decreases with the increase in spring index.

The combined effect of direct shear and curvature correction is accounted by Wahl's correction factor and is given as: $K=\frac{4C-1}{4C-4}+\frac{0.615}{C}$

## 5) State the significance of Wahl's correction factor in springs?

Ans :

The shear stress developed in the spring is given by,

$$\tau=\frac{8WD}{\pi d^3}\times K_s$$

Where ks is shear stress factor..

It is given by,

$$K_s=1+\frac{1}{2C}$$

The curvature of the wire increases the shear stress on the inner surface of the spring and decreases it slightly on the outer surface. This curvature effect stress is localized and is significant only when fatigue load is present. In order to consider the effects of both direct shear stress as well as curvature effect, the shear stress correction factor Ks is replaced by another factor Kw known as Wahl's factor.

$$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$ ..

Maximum shear stress produced is given by ,

$$\tau = \frac{8WD}{\pi d^3} \times K_w$$

The Wahl factor increases very rapidly as the spring index decreases. It signifies that the curvature stress also increases with increase in spring index.

## 6) What are the different stresses a helical spring is subjected to?

A helical spring is subjected to ,

**1) Direct shear stress :** This is the stress induced in the wire as direct effect of load on spring.

$$\tau_d = \frac{W}{\frac{\pi}{4} d^2}$$

**2) Torsional shear stress :** This stress is induced due to the torsional effect of load on coil.

From equation of torsion , this stress can be written as

$$\tau_t = \frac{8WD}{\pi d^3}$$

**3) Shear stress due to curvature:** The curvature of the wire increases the shear stress on the inner surface of the spring and decreases it slightly on the outer surface. This is taken into account through Wahl's correction factor.

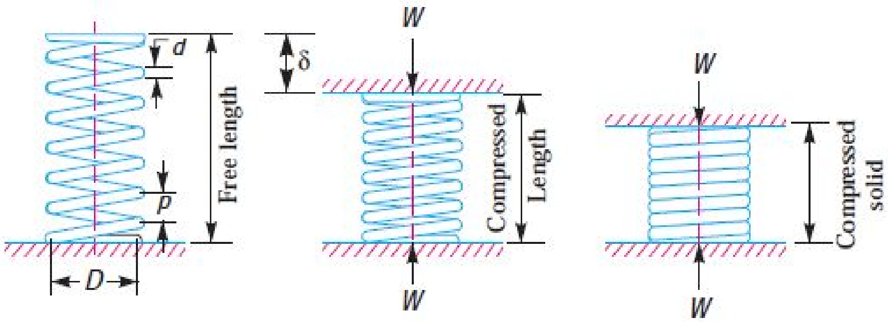
## 7) Explain the following terms related to the spring with diagram, Spring index,solid length,free length,compressed length,pitch,stiffness

**The spring index** is defined as the ratio of mean coil diameter to wire diameter. Or C = D/d

The spring index indicates the relative sharpness of the curvature of the coil.

**Solid length:**solid length is defined as the axial length of the spring which is so compressed, that the adjacent coils touch each other. In this case, the spring is completely compressed and no further compression is possible. The solid length is given by.

Solid length = $N_t \times d$...mm {$N_t$=total no of turns, d= diameter of wire}




**Compressed length**: Compressed length is defined as the axial length of the spring that is subjected to maximum compressive force. In this case, the spring is subjected to maximum deflection. When the spring is subjected to maximum force, there should be some gap or clearance between the adjacent coils. The gap is essential to prevent clashing of the coils.

The clashing allowance or the total axial gap is usually taken 15% of the maximum deflection.

**Free length:** Free length is defined as the axial length of an unloaded helical compression spring. In this case, no external force acts on the spring. Free length is an important dimension in spring design and manufacture. It is the length of the spring in free condition prior to assembly.

Free length is given by,    Free length = solid length + $\delta + 0.15 \times \delta$……mm

**The pitch** of the coil is defined as the axial distance between adjacent coils in uncompressed state of spring. It is denoted by p. It is given by,

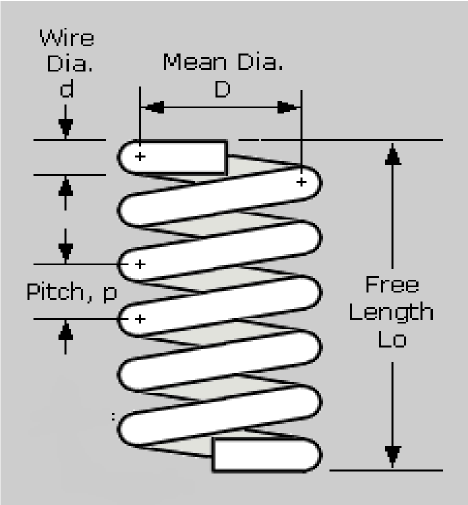
$$Pitch = \frac{Free\,length}{N_t - 1}$$

**Stiffness:** It is defined as the load required to produce the unit deflection of the spring.

$$Stiffness = \frac{Load}{Deflection} N/mm$$

# 5.2 Design of Helical Spring

## Formula's and Steps




d=Diameter of spring wire,
D=Mean coil diameter,
C=Spring index= D/d,
W=Load acting on spring,
$\tau = Shear\ stress$ ,
$\delta = deflection\ of\ spring$ ,
K= Wahl's correction factor,

**1) To find d and D of spring**

$$\tau = \frac{8WC}{\pi d^2} \times K \qquad K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

**2) To find number of turns**

$$\delta = \frac{8WC^3}{G.d} \times n \quad .......When\ only\ one\ W\ is\ given$$

$$\delta = \frac{8(W - Wmin)C^3}{G.d} \times n \quad ......When\ W\ and\ Wmin\ is\ given$$

{This equation is used to find number of turns}

**3) Total Number of Turns**

$$n' = n + 2..........for\ square\ and\ ground\ ends$$

$$n' = n..........for\ plain\ ground\ ends$$

**3) Solid Length**

$$L_s = d \times n'$$

**4) Max deflection**

$$\delta_{max} = \delta$$

When only one load is given

$$\delta_{max} = \frac{\delta \times W}{(W - W_{min})}........When\ W\ and\ Wmin\ is\ given$$

**5) Free length**

$$L_F = L_s + \delta_{max} + 0.15.\delta_{max}$$

**6) Pitch of the spring**

$$pitch = \frac{Free\,length}{n' - 1}$$

**7) Outside and inside coil diameters**

$$D_0 = D + d$$

$$D_i = D - d$$

{When asked to design the spring find all 7 parameters otherwise find only what is asked }

## Numerical Problems on Spring

## 5.2 Problems with One load given

***1.A spring for a spring balance is required to have deflection of 60mm for a load of 1500 N. Design the spring assuming spring index 6. Take shear stress as 360 Mpa and modulus of rigidity as 84 GPa. find free length of spring.***

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***2.Design a spring to take a load of 300 N with spring index 8 and shear stress 400 MPa...The spring should deflect by 15 mm under this load..Take G= 84 GPa.***

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***Model QP 3] Design a helical compression spring for a maximum load of 1000 N for a deflection of 25mm using the value of spring index as 5 and Wahl's correction factor as 1.3. The maximum permissible shear stress for the spring wire is 400 Mpa and modulus of rigidity 84 KN/mm2.***

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***W-2013-8 marks 4] The spring of spring balance, elongates by 15 mm, when subjected to a load of 400 N. the spring index is 6. Take permissible shear stress for the wire material 540 MPa and G=84 Gpa..Determine***
***1) the wire diameter 2) the diameter of Coil 3) No of turns.***

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***{W-2010} 5] A helical spring is made from a wire of diameter 6mm diameter and has outside diameter of 75 mm. If the permissible shear stress is 350 MPa and modulus of rigidity is 84 kN/mm2. find the axial load which the spring can carry and the deflection per active turn.***

***{W=383.4 N,*** $\frac{\delta}{n} = 9.26\,mm$}

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***{S-2009} 6] A closed coil helical spring is used for an automobile suspension system. The spring has stiffness 85 N/mm with square and ground ends. The load on the spring causes a total deflection of 9 mm. Taking permissible shear stress 400 MPa spring index 6 and G=80 GPa.Find***
***1) Wire diameter of spring***
***2) Length of spring.***

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***7} Design a helical compression spring for a maximum load of 1000 N for a deflection of 23mm using spring index 5. The maximum permissible shear stress is 420 MPa and modulus of rigidity is 84 GPa.Find the pitch of spring assuming square and ground ends.***

***{d=6.3 mm***$\approx 7mm$***,D=35 mm,n=13.44***$\approx 14$***turns, Lf=138.45, p=9.23 mm}***

## 5.3 Problems with range of loads {W and Wmin}

*S-2012 8 marks Important*

***8] Design a close coiled helical compression spring for a service load ranging from 2250 to 2750. The axial deflection of the spring for the load range is 6mm. Assume a spring index of 5. $\tau = 420\,MPa\ and\ G = 84\,GPa$ , Neglect the effect of stress concentration . Draw fully dimensioned sketch of the spring showing the details of the finish of the end coils. Assume squared and ground ends.***

***{$d = 9.15\,mm \approx 10mm,\ D = 50mm, n = 9.5 \approx 10\,turns, L_f = 152mm$ pitch =13.80mm}***

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***9] Design a helical spring with square and ground ends for a load ranging from 80 N to 145 N when required deflection is 6.5 mm. Take spring index as 8 ,permissible shear stress for the wire material 475 MPa and G=84 Gpa.***

***{$d = 2.70\,mm \approx 3mm,\ D = 24mm, n = 6.15 \approx 7\,turns, L_f = 49.5\,mm$***

***pitch =6.19mm}***

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***10) Design and draw a valve spring of a petrol engine for the following operating conditions :***

***Spring load when the valve is open = 400 N***
***Spring load when the valve is closed = 250 N***
***Maximum inside diameter of spring = 25 mm***
***Length of the spring when the valve is open = 40 mm***
***Length of the spring when the valve is closed = 50 mm***
***Maximum permissible shear stress = 400 MPa***

## 5.4 Problems on Railway Buffers and other special applications

***11) A rail wagon of mass 20 tonnes is moving with a velocity of 2 m/s. It is brought to rest by two buffers with springs of 300 mm diameter. The maximum deflection of springs is 250 mm. The allowable shear stress in the spring material is 600 MPa. Design the spring for the buffers.***

***[ans: d=60mm, n= 8 turns, Lf=887.5 mm]***

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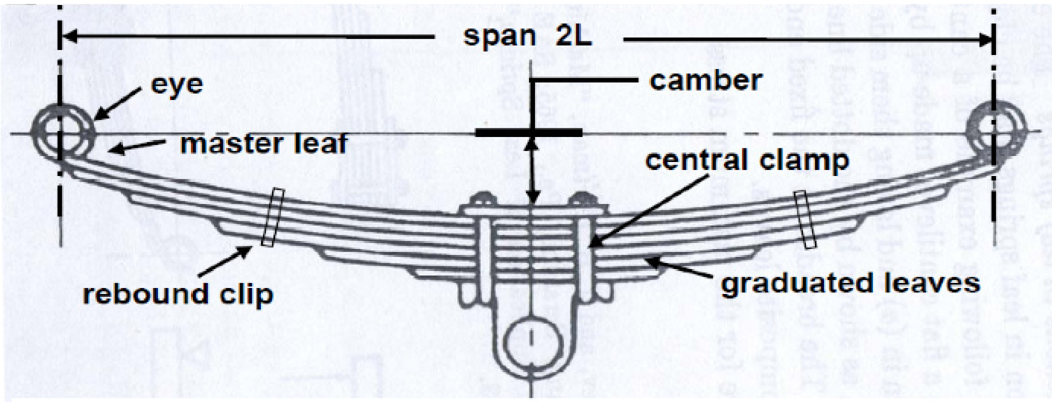
***12) A railway wagon weighing 50 kN and moving with a speed of 8 km per hour has to be stopped by four buffer springs in which the maximum compression allowed is 220 mm. Find the number of turns in each spring of mean diameter 150 mm. The diameter of spring wire is 25 mm. Take G= 84 kN/mm2***

***[Ans. 8 turns]***

# 5.3 Leaf springs

## 8) Explain with sketch the construction and application of leaf spring.




**Laminated semi-elliptic spring**

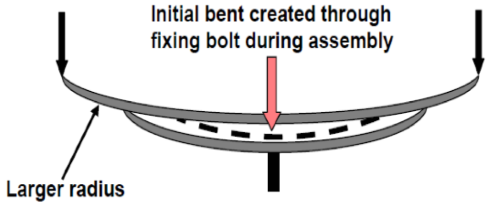
Leaf spring is built up of number of plates (known as leaves). The leaves are usually given as initial curvature or cambered so that they will tend to straighten under load. The leaves are held together by means of a band shrunk around them at the centre or by bolt passing through the centre. Since, the band exerts stiffening and straightening effect, therefore the effective length of the spring for bending will be overall length of spring minus width of band. In case of a centre bolt, two-third distance between centers of U-bolt should be subtracted from the overall length of spring in order to find effective length. The spring is clamped to the axle housing by means of U-bolt.

The longest leaf known as main leaf or master leaf has its ended formed in the shape of an eye through which the bolts are passed to secure the spring to its supports. Usually the eyes, through which the spring is attached to the hanger or shackle, are provided with bushings of some anti-friction material such as bronze or rubber. The other leaves of the spring are known as graduated leaves. In order to prevent digging in the adjacent leaves the ends of the graduated leaves are trimmed in various forms as shown in figure.

Applications:

1. It is used for mainly automobile suspension
2. For rail road spring

## 9) What do you mean by Nipping of leaf spring?




Nipping of leaf spring

Ans : In a leaf spring which have few full length leaves and other graduated leaves. It is observed that the stress in the full length leaves is 50% greater than the stress in the graduated leaves. To distribute this additional stress from the full length leaves, pre-stressing is done, which is called “Nipping “ of leaves.

Simply the nipping is stressing the material in reverse direction than that of it will be subjected during its use. Means is a bar is going to be subjected to tension, then initially compressing it and then subjecting to tension.

This is achieved by bending the leaves to different radii of curvature, before they are assembled with the centre bolt. The full length leaves are given in greater radii of curvature than the adjacent one. Due to the different radii of curvature, when the full length leaves are staked with the graduated leaves, without bolting, a gap is observed between them. This gap is called Nip The nip eliminated by tightening of the center bolt