TAP 307- 8: Resonance in car suspension systems

The background

At a simple level a car suspension system can be thought of as a mass-spring system. This means that there will be a 'natural frequency' at which the system will oscillate.


The spring constant

In order to work out the natural frequency of the car we need to know the spring constant of the suspension system and the mass of the car.

The frequency can then be calculated using:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}.$$

1. By looking at the following sequence of photos of a car, estimate the spring constant, k, of the front spring on this car. The weight applied to one side of the bonnet of the car is around 750 N. Below: Front wheel arch of car with no extra weight on the bonnet:
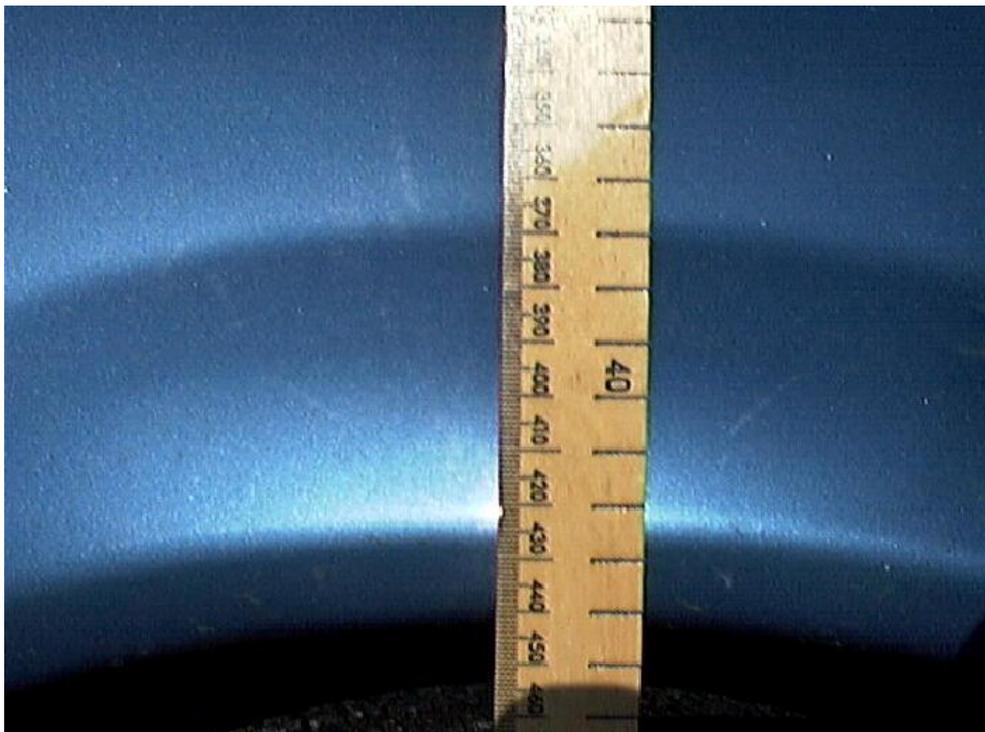
Front wheel arch of car with author sitting on the wing of the bonnet:

The natural frequency

2.   The mass of the car is listed in the handbook as 1120 kg. Calculate the natural frequency of the car suspension. (Remember that a car has four springs in the suspension system and therefore we can assume that the car's mass of 1120 kg is shared equally between the four springs.)

3.   If the car was 'boxed in' by other parked cars, describe how this information could be used to allow the car's owner (and a few friends) to extract the car from its tight location.

Some consequences

4.   Whilst driving along a particularly undulating stretch of road the driver noticed that at a speed of 70 km h^{-1} the car bounced up and down dramatically as it went over the humps.

Calculate how far apart the undulations in the road are likely to have been, if the effect noticed was due to resonance of the car suspension system.

You might like to try a similar calculation for your own car and then try setting it into oscillation and see if the resonant frequency coincides with the calculated value.

Practical advice

This set of questions provides a very tangible and interesting context in which to talk about resonance. But be careful not to encourage follow-up experimentation with your car, unless you are insured!

Alternative approaches

Watch a large-mass, high-amplitude, low-frequency oscillator between springs, and engage the imagination. (A dynamics trolley with 2 or 3 m of mending elastic on either side does well.

Sketch graphs of E_k against x and t, and E_p against x and t.)

Answers and worked solutions

1. The spring is compressed about 3 cm. This gives

   $$k = \frac{F}{x} = \frac{750 \text{ N}}{0.03 \text{ m}} = 25\,000 \text{ Nm}^{-1}.$$

2.
   $$f = \frac{1}{2\pi} \sqrt{\frac{25\,000 \text{ Nm}^{-1}}{280 \text{ kg}}} = 1.5 \text{ Hz}$$

3. Bounce the car at a frequency of 1.5 Hz to get maximum amplitude bounce and gradually bounce it sideways out of the gap!

   4.
   $$70 \text{ km h}^{-1} = \frac{70\,000 \text{ m}}{3600 \text{ s}} = 19 \text{ m s}^{-1}$$

   and

   $$v = \frac{s}{t} = sf$$

   so

   $$s = \frac{v}{f} = \frac{19 \text{ m s}^{-1}}{1.5 \text{ Hz}} \approx 13 \text{ m}.$$

External reference

This activity is taken from Advancing Physics chapter 10, 250S