# Resonance

1. A car has a mass of 1000kg. Every time a person of mass 75kg sits in the car it is depressed by 15mm.

   (a) What is the spring constant of the suspension? *($4.9\times10^{4}Nm^{-1}$)*

   (b) Estimate the natural frequency of the car body if the wheels stay firmly on the ground. *(1.1Hz)*

   (c) If the car is driven at a steady $20ms^{-1}$ over a road with bumps in it, how far apart do the bumps have to be to set the car body oscillating vertically? *(18m)*

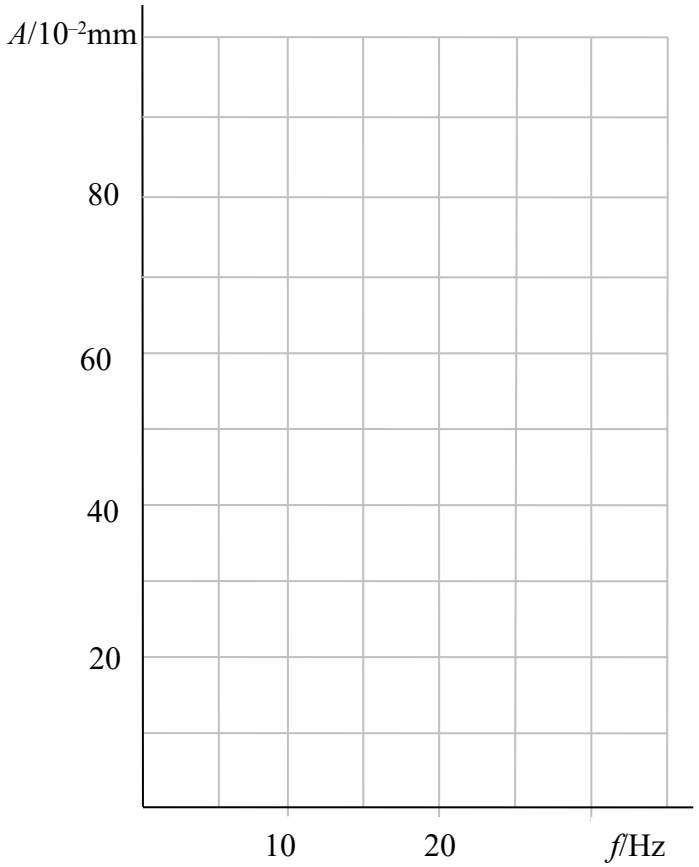
   (d) The mass of each car wheel is about 10kg.
   (i) Estimate the spring constant for the spring on each wheel. *($1.25\times10^{4}Nm^{-1}$)*
   (ii) Estimate the natural frequency of the car wheels if the car body remains fixed. *(6Hz)*
   (iii) How far apart do the bumps have to be to make the wheels oscillate when the car speed is $20ms^{-1}$? *(3.6m)*

2. Leaf springs (shown in the photo) have an advantage over coil springs for vehicle suspension. Each leaf can move relative the others clamped next to it. What advantage does that give?

3. Explain how it is possible to tell whether a moving lorry is full or empty by studying the way it oscillates when it goes over bumps in the road.

4. A drilling machine was found to vibrate so much that accurate work could not be done at certain frequencies. An investigation of its behaviour showed that the amplitude of the vibration of the drill $A$ was related to the frequency of rotation as follows:

| $f$/Hz | $A/10^{-2}$mm |
|---|---|
| 0 | 0 |
| 5 | 14 |
| 8 | 30 |
| 9 | 44 |
| 10 | 80 |
| 11 | 96 |
| 12 | 24 |
| 13 | 8 |
| 15 | 2 |
| 20 | 3 |
| 25 | 9 |
| 30 | 7 |
| 35 | 4 |




(a) Draw a graph of $A$ against $f$ and explain its shape.

(b) Why is it advisable to start to drill a hole with the drill rotating at a frequency of between 15Hz and 20Hz?

5. A bumble bee could not fly if its wing muscles had to oscillate at the same rate as its wing beat. Biochemistry makes it impossible for muscles to contract and relax as fast as this. However, the bee avoids the problem by having its wing roots embedded in a special block of elastic material.

Thinking of the wing as a mass and the block of material as a spring, explain how the bee's muscle can beat at a frequency less than the wing beat.