STAEDTLER® No. 937 811E Engineer's Computation Pad

••63 A 1000 kg car carrying four 82 kg people travels over a "washboard" dirt road with corrugations 4.0 m apart. The car bounces with maximum amplitude when its speed is 16 km/h. When the car stops, and the people get out, by how much does the car body rise on its suspension?

RESONANCE

OCCURS WHEN AN EXTERNAL FORCE ACTS ON A SYSTEM WITH A DRIVING FREQUENCY $\omega_d = 2\pi f_d$ THAT MATCHES A NATURAL FREQUENCY $\omega_0 = 2\pi f_0$ OF THE SYSTEM

ALL BODIES & SYSTEMS, DEPENDING ON THEIR GEOMETRICAL SHAPE, MASS, etc HAVE NATURAL FRENQUENCIES OF OSCILLATION. IF YOU PUMP A BODY AT ONE OF ITS NATURAL FREQUENCIES, THEN THE SYSTEM EFFICIENTLY ABSORBS ENERGY, OSCILLATING AT THE SAME FREQUENCY WITH THE AMPLITUDE OF THE MOTION GROWING TO THE POINT WHERE THE SYSTEM MAY SELF DESTRUCT – A SINGER CAN CREATE SOUND WAVES WITH FREQUENCIES THAT RESONATE WITH A GLASS CAUSING IT TO SHATTER.

AT A SPEED, v, THE TIRE OF A CAR WILL HIT BUMPS SPACED BY DISTANCE, d, EVERY $T = d/v$ SINCE $d = vT$

THIS CORRESPONDS TO AN EXTERNAL DRIVING FORCE OF ANGULAR FREQUENCY $\omega_d = 2\pi/T$ THAT ACTS ON THE SPRINGS IN THE SUSPENSION THAT HAVE NATURAL FREQUENCY $\omega_0^2 = k/m$ ie. WHICH DEPENDS ON THE MASS OF THE CAR & THE LOAD IT CARRIES.

RESONANCE $\Rightarrow \omega_d = \omega_0 \Rightarrow \frac{2\pi}{T} = d/v = \sqrt{\frac{k}{m = M + 4m_p}}$

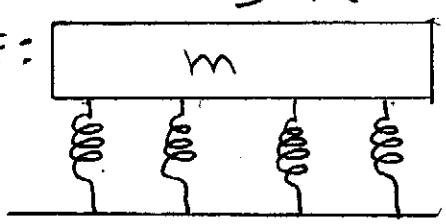
$$\Rightarrow k = 4\pi^2 (M + 4m_p) v^2/d^2 = 4\pi^2 (1328\,\text{kg}) \left(\frac{16000\,\text{m}}{3600\,\text{s}}\right)^2 / 4^2 = 64700\,\frac{\text{N}}{\text{m}}$$

EQUILIBRIUM COMPRESSION OF SPRINGS WITH & WITHOUT PEOPLE:

$mg = k|x| \Rightarrow |x_{CAR}| = Mg/k$ & $|x^{CAR}_{w/p}| = (M + 4m_p) g/k$

$$|x^{CAR}_{w/p}| - |x_{CAR}| = 4m_p g/k = 4(82)(9.8)/64700 = 0.0497\,\text{m} = 5\,\text{cm}$$

NOTE:



$F = k_{total} x$ EACH SPRING HAS THE SAME COMPRESSION

$= k^{single}_{spring} x + kx + kx + kx$

$= 4 k_{spring} x$

$\Rightarrow k_{total} = 4 k_s$

WE USED k_{total} & NOT k_{spring}

SPRINGS IN PARALLEL ADD