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ANSWER BOOK

Forced vibrations and resonance

Periodic motion · Year 13

AQA 3.6.1.4 · CIE 17.3 · OCR A 5.3.3

10 questions · 30 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Free vibrations occur when a system is displaced and released, oscillating at its own natural frequency with no driving force. Forced vibrations occur when a periodic external driving force makes the system oscillate at the driving frequency. [2]

A2 Resonance is the large-amplitude response of a system when it is driven at (or very close to) its natural frequency, so that energy is transferred to it most efficiently. [2]

A3 The driving frequency must equal (or be very close to) the natural frequency of the system. [2]

SECTION B · Standard

B1 $f = (1/2\pi)\sqrt{(k/m)} = (1/2\pi)\sqrt{(100/0.25)} = 3.18$ Hz. Resonance occurs when the driving frequency equals this, about 3.18 Hz. [3]

B2 The graph rises to a sharp peak at the natural frequency and falls away on either side. At low frequencies the amplitude is small; it grows to a maximum at resonance, then decreases again at higher frequencies. [3]

B3 $T = 2\pi\sqrt{(l/g)} = 2\pi\sqrt{(0.50/9.81)} = 1.42$ s. $f = 1/T = 0.70$ Hz. Resonance occurs when driven at about 0.70 Hz. [4]

B4 More damping lowers and broadens the resonance peak (a smaller maximum amplitude over a wider range of frequencies) and shifts the peak to a slightly lower frequency. [3]

SECTION C · Stretch

C1 Well below 50 Hz the amplitude is small. As the driving frequency approaches 50 Hz the amplitude grows rapidly, reaching a maximum at resonance (50 Hz). As the frequency rises further above 50 Hz the amplitude falls again, becoming small at high frequencies. [4]

C2 If a periodic force (such as wind or marching feet) matches the structure's natural frequency, resonance builds up large-amplitude oscillations that can cause damage or collapse. Engineers add damping (for example tuned mass dampers) to absorb energy and limit the amplitude, or design the structure so its natural frequency avoids likely driving frequencies. [4]

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C3 Useful: the tuning circuit of a radio resonating at the chosen station's frequency (or MRI, or a pushed swing). Problematic: a bridge or building oscillating in the wind, or a washing machine vibrating badly at certain spin speeds. [1]

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