Apparatus

1 Torsion pendulum 346 00
1 DC power supply 0…16V/0…5 A...................... 521 545
1 Plug-in power supply for torsion pendulum........ 562 793
1 Ammeter, DC, I ≤ 2 A, e.g. LDanalog 20 .... 531 120
1 Voltmeter, DC, U ≤ 24 V, e.g. LDanalog 20 .... 531 120
1 Connecting lead, 100 cm, blue 500 442
2 Pair cables, red and blue, 100 cm 501 46
1 Stop clock 313 07

For the specific solution the following relationship can be used:

$$\varphi(t) = \varphi_0(\omega_{ex}) \cdot \sin(\omega_{ex} \cdot t - \phi) \qquad \text{(III)}$$

Substituting equation (III) in equation (II) gives after several trigonometric transformations the amplitude of the forced oscillation:

$$\varphi_0(\omega_{ex}) = \frac{M_0 / J}{\sqrt{(\omega_0 - \omega_{ex})^2 + \left(\frac{k}{J}\,\omega_{ex}\right)^2}} \qquad \text{(IV)}$$

The frequency at which the amplitude of the oscillation is maximal is called the resonance frequency ω_R (amplitude resonance). This is the case when the radicand in the denominator is minimal. By equating the derivative of the radicand with respect to ω to zero the following relationship for the resonance frequency is found:

$$\omega_R = \sqrt{\omega_0^2 - \frac{k^2}{2\,J^2}} = \sqrt{\omega_0^2 - 2\,\delta^2} \qquad \text{(VI)}$$

with

$$\omega_0 = \sqrt{\frac{D}{J}} \qquad \text{(natural frequency)} \qquad \text{(VII)}$$

$$\delta = \frac{k}{2 \cdot J} \qquad \text{(damping constant)} \qquad \text{(VIII)}$$

The lower the damping the less the resonance frequency differs from the natural frequency ω_0 and the larger is the amplitude. In the limit of disappearing damping ($k \to 0$) the amplitude at the resonance frequency ($\omega_{ex} = \omega_0$) would tend towards infinity (so called resonance catastrophe).

From equation (IV) follows that amplitude of the forced oscillation tends towards zero for very high frequencies. For very low frequencies ($\omega \to 0$) the amplitude tends towards the value M_0/J (which is not equal zero). The resonance curve is not symmetrical with respect to the resonance frequency ω_R.

Fig. 2: Schematic representation (wiring diagram) of the experimental setup: (A) exciter, (B) eddy current brake.