

**Calibre ?mm - seconde ? - balancier annulaire / bimétallique / à vis****Oscillateur**

## Fréquence, période, amplitude stationnaire

$$f := \blacksquare \cdot h^{-1} \quad f = \blacksquare \text{ Hz} \quad T_0 := \frac{1}{f} \quad T_0 = \blacksquare \quad \omega_0 := 2 \cdot \pi \cdot f \quad \theta_0 := 270 \cdot \text{deg} \quad (\text{choix})$$

Balancier annulaire Angle de levée  $\lambda_b := \blacksquare \cdot \text{deg}$ 

$$\text{serge} \quad D_{s\_int} := \blacksquare \cdot \text{mm} \quad D_{s\_ext} := \blacksquare \cdot \text{mm} \quad h_s := \blacksquare \cdot \text{mm}$$

$$\rho_b := \blacksquare \cdot \text{kg} \cdot \text{m}^{-3} \quad M_b := \blacksquare \cdot \text{mg} \quad (\text{valeur mesurée})$$

$$M_{\text{serge}} := \frac{\pi \cdot \rho_b}{4} \cdot (D_{s\_ext}^2 - D_{s\_int}^2) \cdot h_s \quad M_{\text{serge}} = \blacksquare \text{ mg}$$

$$J_{\text{serge}} := \frac{1}{8} \cdot M_{\text{serge}} \cdot (D_{s\_ext}^2 + D_{s\_int}^2) \quad J_{\text{serge}} = \blacksquare \text{ mg} \cdot \text{cm}^2$$

$$J_b := 1.1 \cdot J_{\text{serge}} \quad J_b = \blacksquare \text{ mg} \cdot \text{cm}^2$$

$$\text{Autre approche en partant de } M_b \quad M_{\text{serge}} := \frac{M_b}{1.2} \quad M_{\text{serge}} = \blacksquare \text{ mg}$$

$$J_{\text{serge}} := \frac{1}{8} \cdot M_{\text{serge}} \cdot (D_{s\_ext}^2 + D_{s\_int}^2) \quad J_{\text{serge}} = \blacksquare \text{ mg} \cdot \text{cm}^2$$

$$J_b := J_{\text{serge}} \quad J_b = \blacksquare \text{ mg} \cdot \text{cm}^2 \quad \text{Valeur NIHS} \quad J_b := \blacksquare \cdot \text{mg} \cdot \text{cm}^2$$

$$\text{Pivotage} \quad D_{\text{pivot}_b} := \blacksquare \cdot \text{mm} \quad D_{\text{appui}} := \blacksquare \cdot \text{mm} \quad (\text{voir relevé de calibre})$$

$$\text{Pare-choc} \quad D_{\text{trou\_pierre\_bal}} := \blacksquare \cdot \text{mm} \quad L_{\text{palier\_sup}_b} := \blacksquare \cdot \text{mm} \quad L_{\text{palier\_inf}_b} := \blacksquare \cdot \text{mm}$$

## Paramètres de frottements

## Mesures des courbes d'amortissement en positions HH, HB, 4 positions V

## Equilibrage du balancier

## Mesures d'amplitudes et de marche aux positions HH, HB, 4 positions V

$$\text{Spiral} \quad C := \omega_0^2 \cdot J_b \quad e_{sp} := \blacksquare \cdot \text{mm}$$

$$e_{sp} := \blacksquare \cdot \text{mm} \quad h_{sp} := \blacksquare \cdot \text{mm} \quad d_{\text{piton}} := \blacksquare \cdot \text{mm} \quad d2_{sp} := \blacksquare \cdot \text{mm} \quad d1_{sp} := \blacksquare \cdot \text{mm}$$

$$p_{sp} := \blacksquare \cdot \text{mm} \quad n_{sp} := \frac{d2_{sp} - d1_{sp}}{2 \cdot p_{sp}} \quad n_{sp} = \blacksquare$$

$$L_{sp} := \pi \cdot \frac{n_{sp}}{2} \cdot (d2_{sp} + d1_{sp}) \quad L_{sp} = \blacksquare \text{ cm}$$

$$\text{Numéro du spiral} \quad K := C \cdot (d2_{sp}^2 - d1_{sp}^2) \quad N := \blacksquare$$

## Goupilles de raquette

$$\text{position:} \quad R_{\text{goupille}} := \blacksquare \cdot \text{mm} \quad \text{diamètre:} \quad d_{\text{goupille}} := \blacksquare \cdot \text{mm}$$

**Assortiment**

Relevés détaillés de la roue d'échappement, de l'ancre, du plateau et sa cheville, du balancier, en plan et en coupe

Distance des centres balancier - ancre

$$b := \blacksquare \cdot mm$$

Distance des centres ancre - roue d'échappement

$$a := \blacksquare \cdot mm$$

Diamètre de la cheville

$$d_{cheville} := \blacksquare \cdot mm$$

Distance axe de balancier - centre de courbure de la cheville

$$\rho_3 := \blacksquare \cdot mm$$

Ancre Moment d'inertie de l'ancre complet

$$J_a := \blacksquare$$

$$J_a = \blacksquare mg \cdot cm^2$$

Angle de repos

$$\varepsilon := \blacksquare \cdot deg$$

Angles d'impulsion partagée

entrée

palette

$$\Delta\psi_{ep} := \blacksquare \cdot deg$$

roue

$$\Delta\psi_{ed} := \blacksquare \cdot deg$$

$$\Delta\psi_{ie} := \Delta\psi_{ep} + \Delta\psi_{ed}$$

$$\Delta\psi_{ie} = \blacksquare deg$$

sortie

palette

$$\Delta\psi_{sp} := \blacksquare \cdot deg$$

roue

$$\Delta\psi_{sd} := \blacksquare \cdot deg$$

$$\Delta\psi_{is} := \Delta\psi_{sp} + \Delta\psi_{sd}$$

$$\Delta\psi_{is} = \blacksquare deg$$

Angles de tirage

entrée

$$\beta_{te} := \blacksquare \cdot deg$$

$$\beta_e := \beta_{te} - \varepsilon$$

$$\beta_e = \blacksquare deg$$

sortie

$$\beta_{ts} := \blacksquare \cdot deg$$

$$\beta_s := \beta_{ts} + \varepsilon$$

$$\beta_s = \blacksquare deg$$

Chemin perdu

$$\Delta\psi_{cp} := \blacksquare \cdot deg$$

Angle de levée de l'ancre

$$\lambda_a := \varepsilon + \Delta\psi_{ie} + \Delta\psi_{cp} \quad \lambda_a = \blacksquare deg$$

Distance axe de l'ancre - centre de courbure de la cheville en position de repos

$$\rho_2 := \sin\left(\frac{\lambda_b}{2}\right) \cdot \sin\left(\frac{\lambda_a}{2}\right)^{-1} \cdot \rho_3 \quad \rho_2 = \blacksquare mm \quad \rho_2 \cdot \cos\left(\frac{\lambda_a}{2}\right) + \rho_3 \cdot \cos\left(\frac{\lambda_b}{2}\right) = \blacksquare mm$$

Tige d'ancre

$$d_{pivots\_a} := \blacksquare$$

$$l_{pivots\_a} := \blacksquare$$

$$jeu_{pivots\_a} := \blacksquare$$

**Mesures des coefficients de frottement sur l'ancre**

Roue d'échappement

Moment d'inertie de la roue complète

$$J_r := \blacksquare$$

$$J_r = \blacksquare mg \cdot cm^2$$

Masse de la roue complète

$$M_{re} := \blacksquare$$

$$z_e := \blacksquare$$

$$\alpha_0 := \blacksquare$$

$$\alpha'_0 := \blacksquare$$

$$R_d := \blacksquare \cdot mm$$

$$R_d = \blacksquare mm$$

Angles d'impulsion partagée

palette

$$\Delta\alpha_p := \blacksquare \cdot deg$$

dent

$$\Delta\alpha_d := \blacksquare \cdot deg$$

Chute

$$\Delta\alpha_{ch} := \blacksquare \cdot deg$$

$$\alpha_{recul} := \blacksquare \cdot deg$$

mesuré:

$$R_{re\_ext} = \blacksquare mm$$

$$R_{fond\_dent} := \blacksquare \cdot mm$$

$$R_{re\_m} := \frac{R_{re\_ext} + R_{fond\_dent}}{2}$$

$$R_{re\_ext} := \blacksquare \cdot mm$$

$$R_{re\_m} = \blacksquare mm$$

$$R_{re\_int} := \blacksquare \cdot mm$$

$$\text{épaisseur}_{re} := \blacksquare \cdot mm$$

Angle parcouru par la roue

$$\Delta\alpha_p + \Delta\alpha_d + \Delta\alpha_{ch} = \blacksquare deg$$

vérification

$$\frac{360 \cdot deg}{2 \cdot z_e} = \blacksquare deg$$

Pignon d'échappement

$$z_6 := \blacksquare \quad \text{mod} := \blacksquare \cdot mm$$

$$D_{pe\_p} := z_6 \cdot \text{mod}$$

$$D_{pe\_p} = \blacksquare mm$$

$$h_{pe} := \blacksquare \cdot mm$$

$$M_{pe} := \frac{\pi \cdot \rho_a}{4} \cdot D_{pe\_p}^2 \cdot h_{pe} \quad M_{pe} = \blacksquare mg$$

$$J_{pe} := \frac{1}{8} \cdot M_{pe} \cdot D_{pe\_p}^2$$

$$J_{pe} = \blacksquare mg \cdot cm^2$$

Mesures des coefficients de frottement du rouage : accélération de la roue d'échappement

Mesures des coefficients de restitutions de chocs roue - ancre et cheville - fourchette

**Rouage****Roue de seconde**

$z_5 := \blacksquare$

$\text{mod} := \blacksquare \cdot \text{mm}$

$D_{rs\_p} := z_5 \cdot \text{mod}$

$D_{rs\_p} = \blacksquare \text{ mm}$

$\rho_l := \blacksquare \cdot \text{kg} \cdot \text{m}^{-3}$

$\text{ép}_{rs} := \blacksquare \cdot \text{mm}$

$D_{rs\_int} := \blacksquare \cdot \text{mm}$

$M_{rs} := \frac{\pi \cdot \rho_l}{4} \cdot (D_{rs\_p}^2 - D_{rs\_int}^2) \cdot \text{ép}_{rs} \quad M_{rs} = \blacksquare \text{ mg}$

$J_{rs} := \frac{1}{8} \cdot M_{rs} \cdot (D_{rs\_p}^2 + D_{rs\_int}^2) \quad J_{rs} = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Pignon de seconde**

$z_4 := \blacksquare$

$\text{mod} := \blacksquare \cdot \text{mm}$

$D_{ps\_p} := z_4 \cdot \text{mod}$

$D_{ps\_p} = \blacksquare \text{ mm}$

$h_{ps} := \blacksquare \cdot \text{mm}$

$M_{ps} := \frac{\pi \cdot \rho_a}{4} \cdot D_{ps\_p}^2 \cdot h_{ps} \quad M_{ps} = \blacksquare \text{ mg}$

$J_{ps} := \frac{1}{8} \cdot M_{ps} \cdot D_{ps\_p}^2 \quad J_{ps} = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Moment d'inertie sur l'axe de la roue de seconde:**

$J_3 := (J_{rs} + J_{ps}) \cdot 1.1$

$J_3 = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Roue de moyenne**

$z_3 := \blacksquare$

$\text{mod} := \blacksquare \cdot \text{mm}$

$D_{rm\_p} := z_3 \cdot \text{mod}$

$D_{rm\_p} = \blacksquare \text{ mm}$

$\text{ép}_{rm} := \blacksquare \cdot \text{mm}$

$D_{rm\_int} := \blacksquare \cdot \text{mm}$

$M_{rm} := \frac{\pi \cdot \rho_l}{4} \cdot (D_{rm\_p}^2 - D_{rm\_int}^2) \cdot \text{ép}_{rm} \quad M_{rm} = \blacksquare \text{ mg}$

$J_{rm} := \frac{M_{rm}}{8} \cdot (D_{rm\_p}^2 + D_{rm\_int}^2) \quad J_{rm} = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Pignon de moyenne**

$z_2 := \blacksquare$

$\text{mod} := \blacksquare \cdot \text{mm}$

$D_{pm\_p} := z_2 \cdot \text{mod}$

$D_{pm\_p} = \blacksquare \text{ mm}$

$h_{pm} := \blacksquare \cdot \text{mm}$

$M_{pm} := \frac{\pi \cdot \rho_a}{4} \cdot D_{pm\_p}^2 \cdot h_{pm} \quad M_{pm} = \blacksquare \text{ mg}$

$J_{pm} := \frac{1}{8} \cdot M_{pm} \cdot D_{pm\_p}^2 \quad J_{pm} = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Moment d'inertie sur l'axe de la roue de moyenne:**

$J_2 := (J_{rm} + J_{pm}) \cdot 1.1$

$J_2 = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Roue de centre**

$z_1 := \blacksquare$

$\text{mod} := \blacksquare \cdot \text{mm}$

$D_{rc\_p} := z_1 \cdot \text{mod}$

$D_{rc\_p} = \blacksquare \text{ mm}$

$\text{ép}_{rc} := \blacksquare \cdot \text{mm}$

$D_{rc\_int} := \blacksquare \cdot \text{mm}$

$M_{rc} := \frac{\pi \cdot \rho_l}{4} \cdot (D_{rc\_p}^2 - D_{rc\_int}^2) \cdot \text{ép}_{rc} \quad M_{rc} = \blacksquare \text{ mg}$

$J_{rc} := \frac{1}{8} \cdot M_{rc} \cdot (D_{rc\_p}^2 + D_{rc\_int}^2) \quad J_{rc} = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Pignon de centre**

$z_0 := \blacksquare$

$\text{mod} := \blacksquare \cdot \text{mm}$

$D_{pc\_p} := z_0 \cdot \text{mod}$

$D_{pc\_p} = \blacksquare \text{ mm}$

$h_{pc} := \blacksquare \cdot \text{mm}$

$M_{pc} := \frac{\pi \cdot \rho_a}{4} \cdot D_{pc\_p}^2 \cdot h_{pc} \quad M_{pc} = \blacksquare \text{ mg}$

$J_{pc} := \frac{1}{8} \cdot M_{pc} \cdot D_{pc\_p}^2 \quad J_{pc} = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Moment d'inertie sur l'axe de la roue de moyenne:**

$J_1 := (J_{rc} + J_{pc}) \cdot 1.1$

$J_1 = \blacksquare \text{ mg} \cdot \text{cm}^2$

**Rapports d'engrenages**

$\rho_1 := \frac{z_1 \cdot z_3 \cdot z_5}{z_2 \cdot z_4 \cdot z_6} \quad \rho_1 = \blacksquare$

$\rho_2 := \frac{z_3 \cdot z_5}{z_4 \cdot z_6} \quad \rho_2 = \blacksquare$

$\rho_3 := \frac{z_5}{z_6} \quad \rho_3 = \blacksquare$

**Inertie du rouage**

$J_r = \blacksquare \text{ mg} \cdot \text{cm}^2$

$J_{rouage} := J_r + \sum_{i=1}^3 [J_i \cdot (\rho_i)^{-2}] \quad J_{rouage} = \blacksquare \text{ mg} \cdot \text{cm}^2$

## Organe moteur

### Barillet

$$z_b := \blacksquare \quad \text{mod} := \blacksquare \cdot \text{mm} \quad D_{\text{bar}_p} := z_b \cdot \text{mod} \quad D_{\text{bar}_p} = \blacksquare \cdot \text{mm}$$

$$D_{t\_ext} := \blacksquare \cdot \text{mm} \quad D_{t\_int} := \blacksquare \cdot \text{mm} \quad h_{t\_int} := \blacksquare \cdot \text{mm}$$

$$D_{\text{bonde}} := \blacksquare \cdot \text{mm} \quad r_{\text{bonde}} := \blacksquare \cdot D_{\text{bonde}}$$

### Ressort

$$e_{rb} := \blacksquare \cdot \text{mm} \quad h_r := \blacksquare \cdot \text{mm} \quad L_{rb} := \blacksquare \cdot \text{mm} \quad \sigma_{\text{max}} := \blacksquare \cdot \text{N} \cdot \text{mm}^{-2}$$

$$N_b := \frac{1}{e_{rb}} \cdot \left[ \sqrt{r_{\text{bonde}}^2 + \frac{L_{rb} \cdot e_{rb}}{\pi}} + \sqrt{\left(\frac{D_{t\_int}}{2}\right)^2 - \frac{L_{rb} \cdot e_{rb}}{\pi}} - \frac{D_{t\_int}}{2} - r_{\text{bonde}} \right] \quad N_b = \blacksquare$$

$$C_B := \frac{e_{rb}^2 \cdot h_r \cdot \sigma_{\text{max}}}{6} \quad C_B = \blacksquare \cdot \text{N} \cdot \text{mm}$$

### Valeurs mesurées:

$$M_{025} := \blacksquare \cdot \text{kgf} \cdot \text{mm} \quad M_{025} = \blacksquare \cdot \text{N} \cdot \text{mm}$$

$$M_{\text{max}} := \blacksquare \cdot \text{kgf} \cdot \text{mm} \quad M_{\text{max}} = \blacksquare \cdot \text{N} \cdot \text{mm}$$

### Vitesse de rotation du barillet

$$\rho_0 := \frac{z_b \cdot z_1 \cdot z_3 \cdot z_5}{z_0 \cdot z_2 \cdot z_4 \cdot z_6} \quad \rho_0 = \blacksquare \quad \omega_b := 2 \cdot \pi \cdot \frac{f}{z_e \cdot \rho_0} \quad \omega_b = \blacksquare$$