3, cont'd graph coordinates : x, y (mm) . Scales are
$\$_x$ (eg. at synchronous) = $n/x$ = 25 Hz/118.2 mm
= 0.212 Hz/mm
$\$_y$ (eg. at breakdown) = $T/y$ = 348 Nm/67.7 mm
= 5.14 Nm/mm

Net torques measured on the diagram are of the order of 50 mm (scaled), so we prepare the reciprocal torque curve ($y'$) preparatory to integrating as

$y' = 10^3 \,(\text{mm}^2)/\, y\,(\text{mm})$ mm

giving workable ordinates of ~20mm

$= 10^3 \text{ mm}^2/(T/5.14)$ mm

i.e. $\$_{y'} = (1/T)/y' = \frac{1}{5140}$ (Nm)$^{-1}$ per mm.

With a pole distance $p$ = 66.5 mm as shown

$\$_z = p\,\$_x\,\$_{y'} = 66.5 \times 0.212/5140 = 1/365$

(units: mm × Hz/mm × 1/(Nm.mm) → Hz/Nm per mm)

$y'$ is integrated graphically, and is found to be 40.4 mm as shown. So

$\Delta t = 2\pi\, J \times$ integral

$= 2\pi\,(3.5 + 0.16) \times 40.4 \times \frac{1/365}{} \times 1$

(units: rad/rev, kg m², mm, rev/(s Nm mm), Ns²/kg m)

$= 2.5$ s

This tallies with figure of 2.7s from "Motors"

```
******                                                     version 3a
MOTORS                                                  by Doug Wright
******
TITLE - problem #3 - 180M motor
MOTOR - full load speed   1470 rpm    LOAD - reference speed   1450 rpm
        full load torque 120.0 Nm            constant torque   10.0 Nm
        starting torque  276.0 Nm            linear torque      0.0 Nm
        breakaway torque 348.0 Nm            quadratic torque  99.4 Nm
        inertia moment   0.160 kg.m**2       inertia moment    3.50 kg.m**2
        running speed     1472 rpm           running speed     1472 rpm
        running torque   112.5 Nm            running torque   112.5 Nm
        acceleration time  2.7 sec    REDUCER -   ratio        1.000 :1
```

4 Assume 5.75 gearbox in two stages, each 96% efficient. Then $\eta$ gearbox ≈ 92%, and motor power necessary = 6/0.92 = 6.5kW.
Need a motor 132 M or larger for this output.
Total torque necessary at 250 rpm is

$T = 6.5/(2\pi \times \frac{250}{60}) = 250$ Nm

Assuming $T_0$ (friction) and $T_2$ (windage) components contribute equally, the load torque-speed characteristic is

$T_L = [125 + 125\,(n/5.75 \times 250)^2]\,/\,5.75$ Nm

where $n$ is motor speed (eg see (1))