Work Done by a Constant Torque

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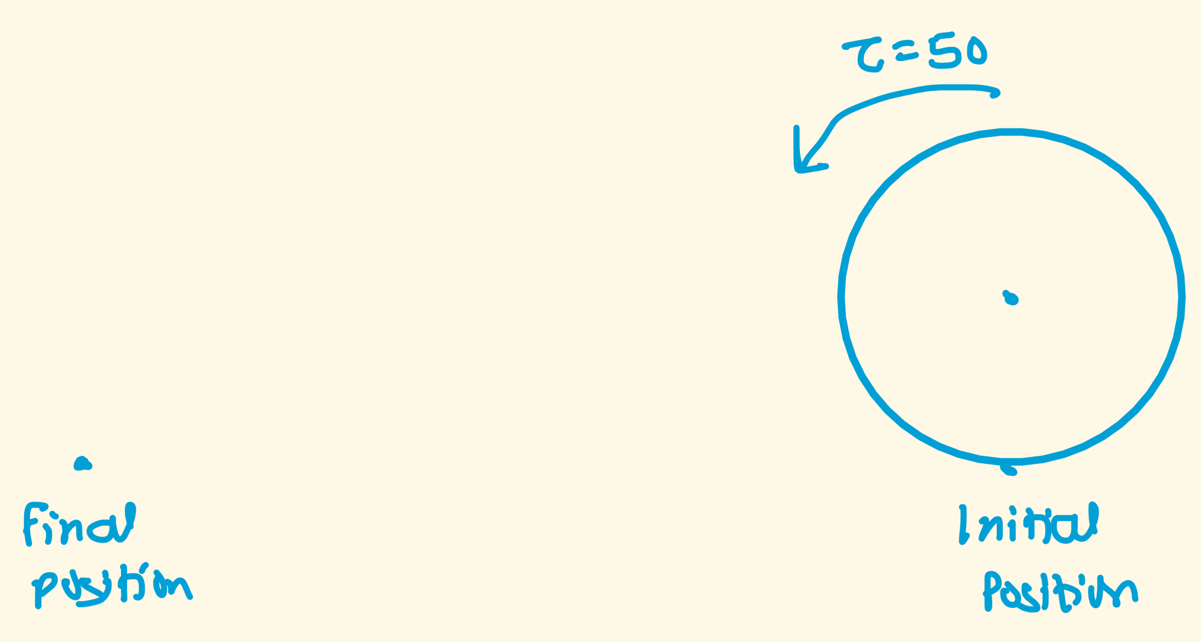
1. Problem 01:

A constant torque of 50 Nm is applied to a wheel causing it to make 40 rotations in a time period of 8 seconds.
(a) Calculate the work done by a torque.
(b) What is the average power exerted by the torque during this time period?

Solution:



a) Since it is given that, torque → constant
which means ⇒ α = constant

$\frac{d\omega}{dt} = 0$

ω → constant

In Translational Motion, when velocity is constant, we can apply:

distance = speed × time

Similarly, in Rotational motion, when angular velocity (ω) is constant, we can apply:

$$\boxed{\theta = \omega . t}$$

Converting 40 rotations into radians:

1 revolution = 1 radian × 2π
or 1 rotation = 1 radian × 2π

θ = 40 rotations
= $40 \cdot (2\pi)$ radians
= 80π radians

$$\theta = \omega t$$
$$\Rightarrow \omega = \frac{\theta}{t} = \frac{80\pi}{8}$$
$$\boxed{\omega = 10\pi \text{ rad/s}^2}$$

$W = f \cdot d$ (Translational from)
$W = \tau \cdot \theta$ (Rotational form)
$= 50 \cdot [80\pi]$
$= 4000\pi$
$= 4\pi$ kJ
$= 4(3.14)$ kJ
$\boxed{W = 12.56 \text{ kJ}}$

b) Average Power, $P = \frac{W}{t}$

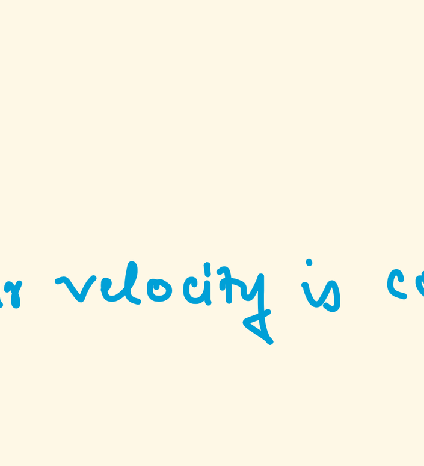
$= \frac{12.56}{8}$

$\boxed{P = 1.57 \text{ kW}}$

2. Problem 02:

A torque of 15Nm is needed to keep a wheel at a constant angular speed of 20 rad/s.
(a) Calculate the average power exerted by this torque?
(b) Calculate the amount of work performed by this torque in 5 minutes?

Solution:



a) $P = \frac{W}{t}$

$\boxed{P = \frac{\tau \cdot \theta}{t}}$ ---- (1)

We know that, when angular velocity is constant then we can apply:

$\theta = \omega t$ .... (2)

from (1) and (2)

$P = \frac{\tau \cdot (\omega t)}{t}$
$= \tau \cdot \omega$
$= (15)(20)$
$\boxed{P = 300 \text{ Watt}}$

b) $W = F \cdot d$
$W = \tau \cdot \theta$
$W = \tau \cdot (\omega t)$ [∵ from (2)]
$= 15 \cdot (20)(5 \times 60)$
$= 300 (300)$
$\boxed{W = 90 \text{ kJ}}$

3. Problem 03:

A 10kg solid disc with a radius of 0.5m accelerates from rest to 25 rad/s in 5 seconds.
(a) How much work was done on the disc?
(b) What was the average power exerted on the disc?

Solution:

a) Given: $\omega_0 = 0$ rad/s
$\omega_f = 25$ rad/s
$t = 5$ seconds

$\omega_f = \omega_0 + \alpha t$
$25 = 0 + \alpha(5)$
$\boxed{\alpha = 5 \text{ rad/sec}^2}$

∴ Work done, $W = F \cdot d$
$= \tau \cdot \theta$
$= I \cdot \alpha \cdot \left(\omega_0 t + \frac{1}{2}\alpha t^2\right)$
$= \left(\frac{1}{2}MR^2\right) \cdot (5)\left(0 + \frac{1}{2}(5)(5)^2\right)$ (disc Inertia)
$= \frac{1}{2}(10)(0.5)^2(5)\left(\frac{125}{2}\right)$
$= \frac{5}{100} \cdot 125 \left(\frac{125}{2}\right)$
$\boxed{W = 390.625 \text{ J}}$

b) $P = \frac{W}{t}$
$= \frac{390.625}{5}$
$\boxed{P = 78.125 \text{ Watts}}$

4. References:

1. The Organic Chemistry Tutor

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