Rotational Work

Unit: Energy, Work & Power

NGSS Standards/MA Curriculum Frameworks (2016): N/A

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): 6.2.A, 6.2.A.1, 6.2.A.2, 6.2.A.3

Mastery Objective(s): (Students will be able to…)

- Solve problems that involve work on a rotating object.

Success Criteria:

- Correct equations are chosen for the situation.
- Variables are correctly identified and substituted correctly into equations.
- Algebra is correct and rounding to appropriate number of significant figures is reasonable.

Language Objectives:

- Describe how an object can have both rotational and translational work.

Tier 2 Vocabulary: work, energy, translational

Notes:

Just as work is done when a force causes an object to translate (move in a straight line), work is also done when a torque causes an object to rotate.

As with other equations for rotational motion, the rotational equation for work looks just like the linear (translational) equation, with each variable from the linear equation replaced by its analogue from the rotational equation.

In the equation for work, force is replaced by torque, and (translational) distance is replaced by rotational distance (angle):

$W = F_{\parallel} d$	$W = \tau \Delta\theta$
translational	**rotational**

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Sample Problem

Q: How much work is done on a bolt when it is turned 30° by applying a perpendicular force of 100 N to the end of a 36 cm long wrench?

A: The equation for work is:

$$W = \tau \Delta\theta$$

The torque is:

$$\tau = rF_{\perp}$$
$$\tau = (0.36)(100) = 36\,\text{N}\cdot\text{m}$$

The angle, in radians, is:

$$\theta = 30° \times \frac{2\pi\,\text{rad}}{360°} = \frac{\pi}{6}\text{rad}$$

The work done on the bolt is therefore:

$$W = \tau \Delta\theta$$
$$W = (36)\left(\frac{\pi}{6}\right)$$
$$W = 6\pi = (6)(3.14) = 18.8\,\text{J} = 18.8\,\text{N}\cdot\text{m}$$

Note that torque and work are different, unrelated quantities that both happen to use the same unit (N·m). (We typically use joules for work, but a joule is equivalent to a newton-meter.) However, *torque and work are not interchangeable*! Notice that 36 N·m of *torque* produced 18.8 N·m of *work* because of the angle through which the torque was applied. If the angle had been different, the amount of work would have been different.

This is an example of why you cannot rely exclusively on dimensional analysis to set up and solve problems!