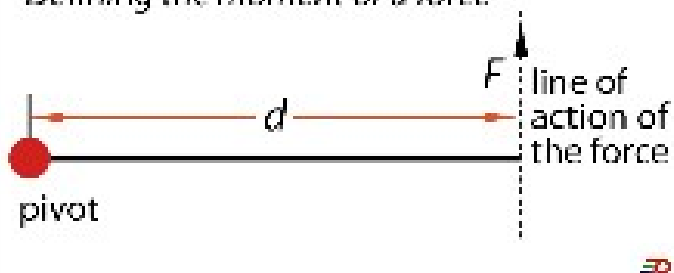


FORCES CAUSE TURNING

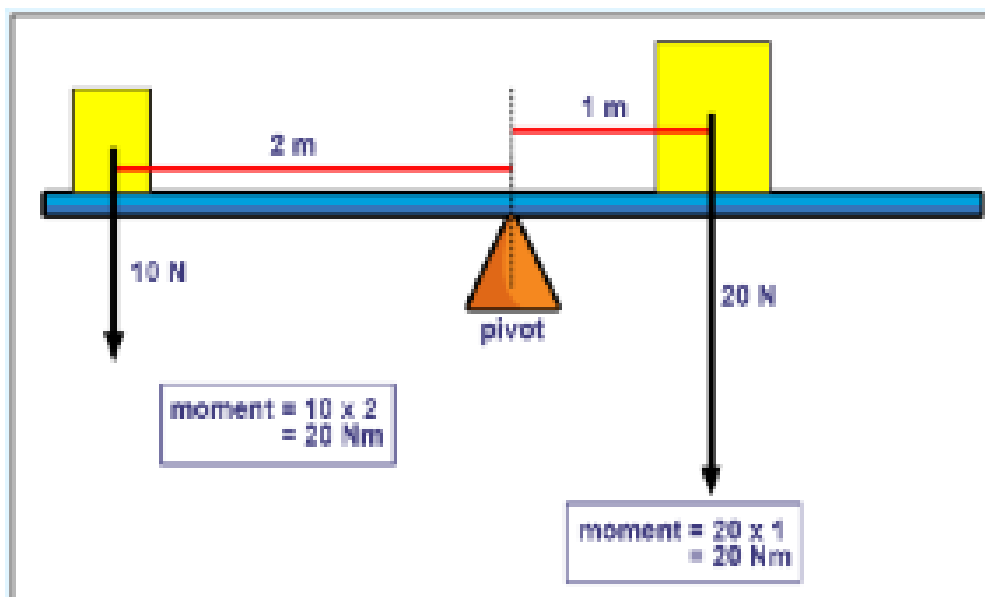
The relationship between the moment of a force and its distance from the pivot:

$$\text{moment} = \text{force} \times \text{perpendicular distance from the pivot}$$

Defining the moment of a force

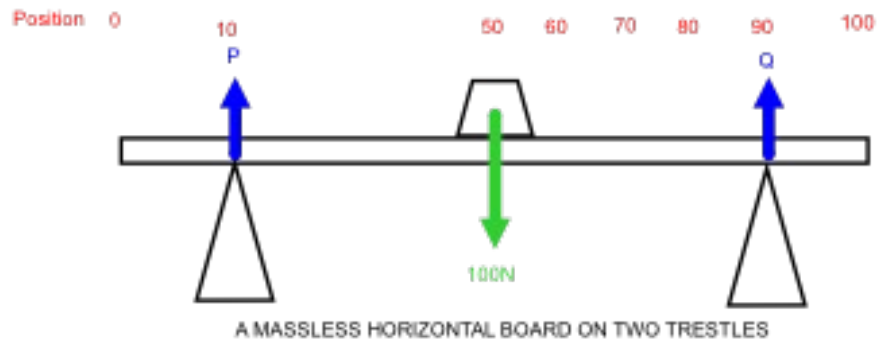


The principle of moments for a simple system of parallel forces acting in one plane



Understand that the upward forces on a light beam, supported at its ends, vary with the position of a heavy object placed on the beam

Use the principle of moments to calculate the forces P and Q at the trestles. (They add up to 100N).



FORCE COUPLE

A system of two equal and unlike parallel forces, whose lines of action are not the same, is called a couple or a torque.

- **Moment of Couple:** The moment of a couple is the product of one of the forces forming the couple and the arm of the couple. The perpendicular distance between the forces is called the arm of the couple.
- The moment of the couple is regarded as positive or negative according as it has a tendency to turn the body in the anti-clockwise or clockwise direction.
- The algebraic sum of the moments of the two forces forming a couple about any point in their plane is constant, and equal to the moment of the couple.
- Two couples, acting in one plane upon a rigid body, whose moments are equal and opposite balance one another.

Physics IX –Torque & Moment

- Any number of couples in the same plane acting on a rigid body are equivalent to a single couple, whose moment is equal to the algebraic sum of the moments of the couples.
- If three forces, acting upon a rigid body, are represented in magnitude, direction, and line of action by the sides of a triangle taken in order, they are equivalent to a couple whose moment is represented by twice the area of the triangle.

Solved Example:

Two unlike parallel forces each of magnitude $20\sqrt{3}$ units acting on a rigid body form an anti-clock couple. If these forces lie in the x y-plane and act at the points A $(-1, 0)$, B $(3, 0)$ and are inclined at 60° to the x-axis, find the moment of the couple.

Solution:

From B, draw BM perpendicular to the line of action of the force passing through A.

Since, $AB = 4$ units and $\angle MAB = 60^\circ$

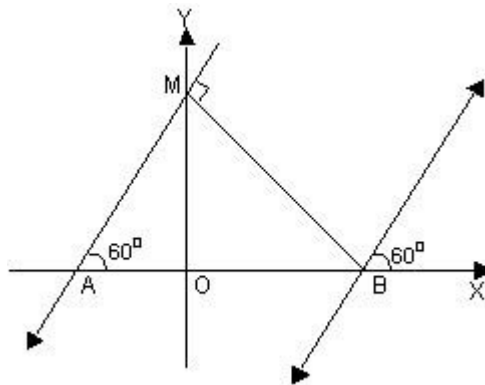
From right angled triangle AMB

$$MB = AB \sin 60^\circ = 2\sqrt{3} \text{ units}$$

Therefore, the moment of the couple

$$= 20\sqrt{3} \times MB = 20 \times 2\sqrt{3} \text{ units}$$

$$= 120 \text{ units}$$



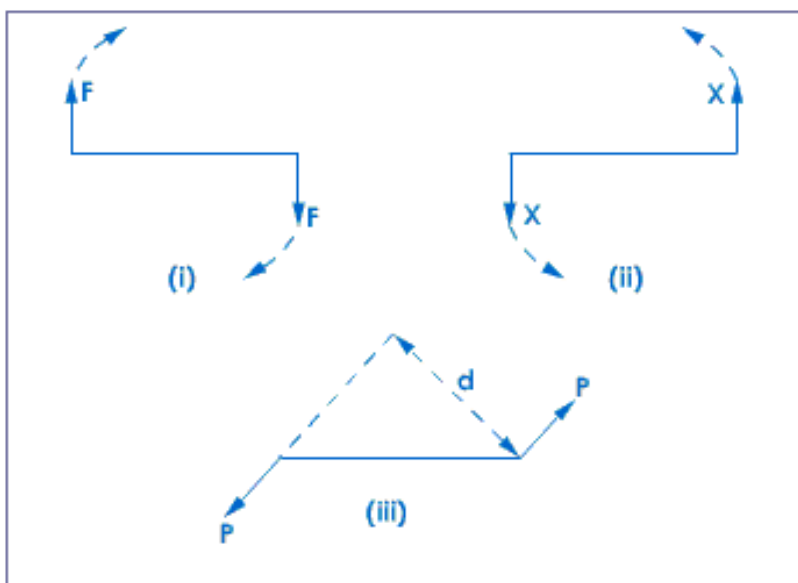
Couple:

Two equal and opposite parallel forces acting along different lines on a body constitute a couple.

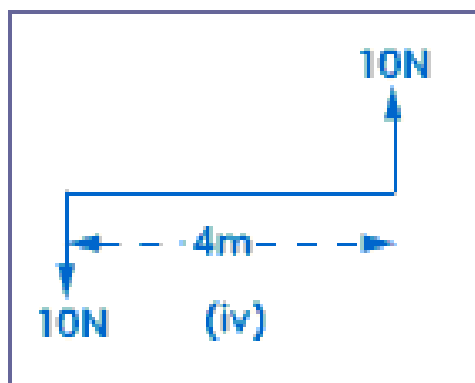
The turning effect of the couple is called its moment and is calculated by the product of either of the forces and the perpendicular distance between them (i.e., between their lines of action).

A body acted upon by a couple will rotate in a clockwise direction or anticlockwise direction as shown [Figure (i), (ii) and (iii) shown below].

If the two forces acting on the body have the same line of action, then the moment becomes zero.



Two equal, unlike and parallel forces acting along different lines form a couple.
 Moment of a couple = Force (N) x Perp. Distance (m)
 [Figure (iv) shown below].

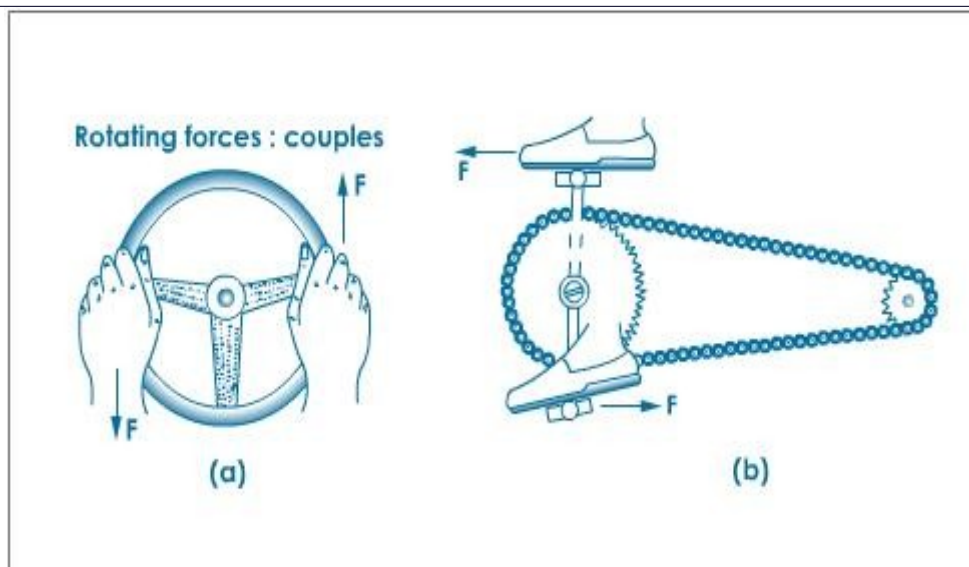


$$\text{Moment of the couple} = 10 \text{ N} \times 4 \text{ m} = 40 \text{ N m}$$

Steering Wheel and Pedals of a Bicycle:

Two examples of the turning effect of two equal and opposite forces not acting in the same straight line are the steering wheel and the pedals of a bicycle. In the figure (a) below, the left hand is pulling with force F on the steering wheel while the right hand is pushing with the same force F. The two forces make the wheel turn in an anticlockwise direction.

Physics IX –Torque & Moment



In figure (b) shown above, one pedal is being pushed forward while the other is being pushed back. This rotates the sprocket wheel and the attached chain anticlockwise.

Can you think of other everyday examples in which a turning effect or rotation takes place?

Examples of Couple:

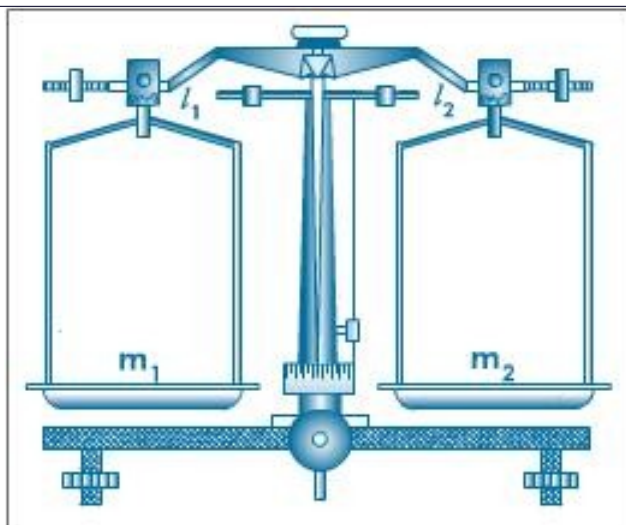
In our day-to-day life, we come across many objects which work on the principle of couple. Winding up the spring of a toy car, opening and closing the cap of a bottle, turning of a water tap, cork screws, door key etc. are some of the common examples of couples.

Applications of principle of moment:

The principle of moment is applied in simple machines like the lever. A beam balance also works on the principle of moments.

A beam balance:

The physical balance used in the school laboratory is pivoted in the middle with equal arms. The two scale pans of equal weights are hung from the upper edge of wedge shaped supports at either end of the beam. When the beam is raised for weighing, it swings freely about the lower edge of a wedge shaped support in the center. In this position the balance is in equilibrium.



Beam balance

Because $l_1 = l_2$ and $m_1 = m_2$, according to the principle of moments,
 $m_1 \times l_1 = m_2 \times l_2$

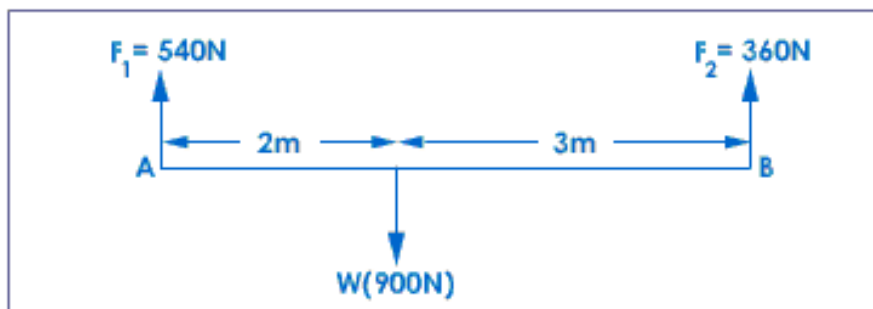
Now if you place a mass of 1 kg in one pan and an unknown mass 'x' on the other pan so that the balance is in equilibrium.

then, $(m_1 + x) l_1 = (m_2 + 1) l_2$

As $m_1 = m_2$ and $l_1 = l_2$

$\therefore x = 1 \text{ kg}$

Let us take another example of two boys carrying a load on a stick between them as shown in figure below.



Let us calculate what part of the load each boy carries.

To find the upward force exerted by the boy at A, we shall consider the hand of the boy at B as the pivot.

Now, the clockwise moment = $F_1 \times 5 \text{ m}$ and the anticlockwise moment due to the load $900 \text{ N} = 900 \times 3$.

If the bar is in equilibrium, then

$$F_1 \times 5 = 900 \times 3$$

$$F_1 = 900 \times \frac{3}{5} = 540 \text{ N}$$

Physics IX –Torque & Moment

Hence, the force exerted by the boy = 540 N.

But $F_1 + F_2 = 900$ N (sum of the downward forces equal to the sum of upward forces).

$$\begin{aligned}\text{Therefore, } F_2 &= 900 - F_1 \\ &= 900 - 540 \\ &= 360 \text{ N}\end{aligned}$$

The force exerted by the boy at B can also be calculated by using A as a pivot.

Therefore, $F_2 \times 5 = 900 \times 2$

$$\begin{aligned}F_1 &= 900 \times \frac{2}{5} \\ &= 360 \text{ N}\end{aligned}$$

Moment, couple and torque:

The moment of a force F about a point is its turning effect about the point.

It is quantified as the product of the force and the perpendicular distance from the point to the line of action of the force.

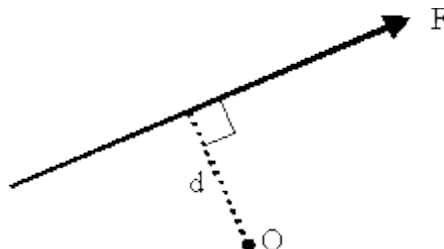


Figure: Moment of a force

In Figure 3.5 the moment of F about point O is

$$\text{moment} = Fd$$

A **couple** is a pair of equal and parallel but opposite forces as shown in Figure

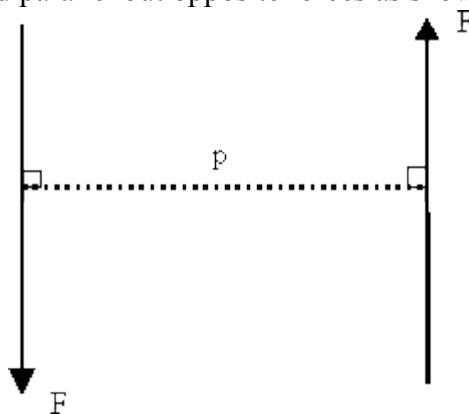


Figure: A couple

The moment of a couple about any point in its plane is the product of one force and the perpendicular distance between them:

$$\text{Moment of couple} = Fp$$

Example of a couple includes turning on/off a tap, or winding a clock.

The SI units for a moment or a couple are Newton meters, Nm .

In engineering the moment of a force or couple is known as **torque**. A spanner tightening a nut is said to exert a torque on the nut, similarly a belt turning a pulley exerts a torque on the pulley.

Work done by a constant torque:

Let a force F turn a light rod OA with length r through an angle of θ to position OB , as shown in Figure 3.7.

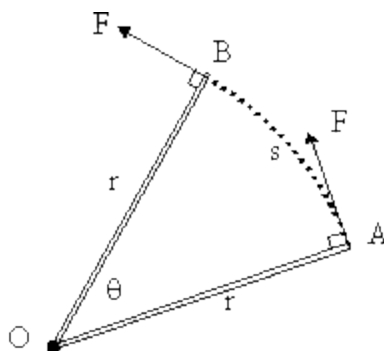


Figure 3.7: Work done by a constant torque

The torque T_O exerted about O is force times perpendicular distance from O .

$$T_O = Fr$$

Now work done by F is

$$\text{work done} = Fs$$

s is the arc of the circle, when θ is measure in radians

$$s = r\theta$$

$$\text{work done} = Fr\theta$$

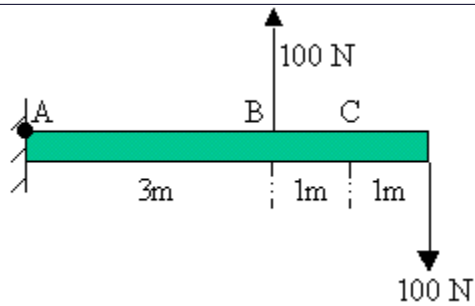
$$\text{work done} = T_O\theta$$

The work done by a constant torque T_O is thus the product of the torque and the angle through which it turns (where the angle is measured in radians.)

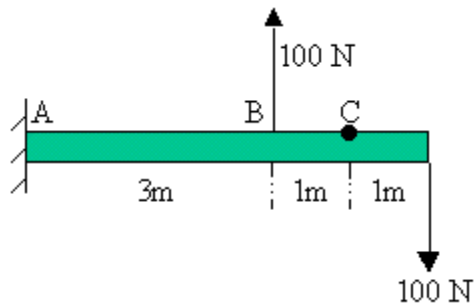
As the SI units for work is Joules, T_O must be in Nm

Q.1) Determine the couple moment by computing the moment of the couple's two forces about point A.

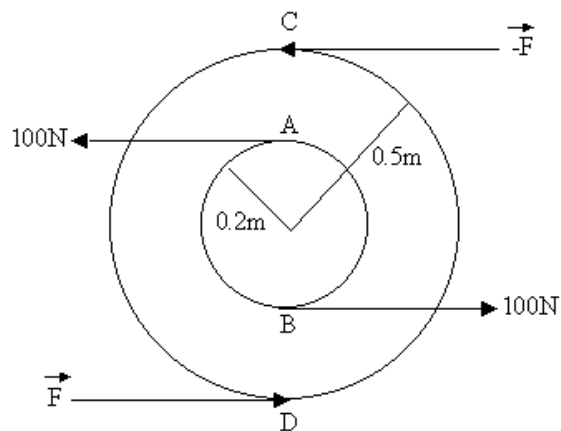
Physics IX –Torque & Moment



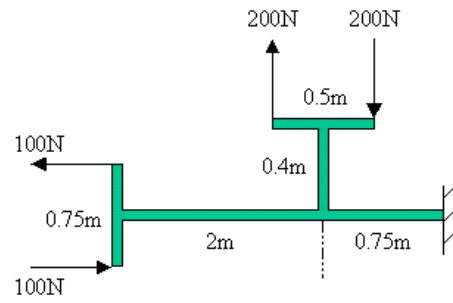
Q.2) Determine the couple moment by computing the moment of the couple's two forces about point A



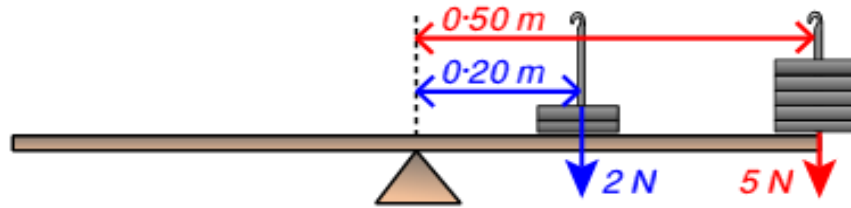
Q.3) Compute the magnitude F for each of the two forces acting on the outer circle, so that they create the same couple moment as that created by the 100-N forces acting on the inner circle.



Q.4) Calculate the magnitude of the resultant couple moment of the two couples acting on the bar.

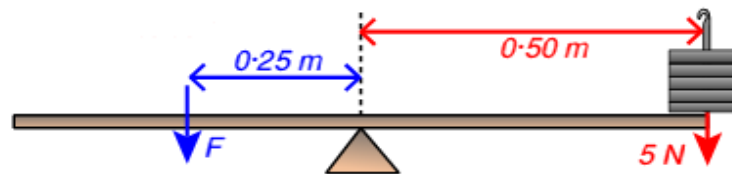


Q.5



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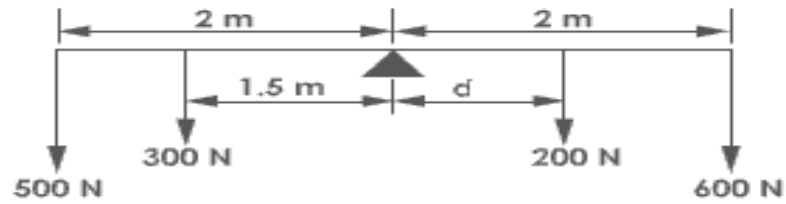
Q.6



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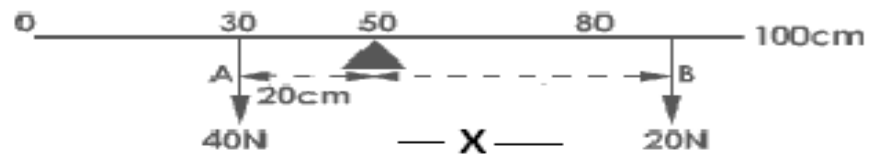
Physics IX -Torque & Moment

Q.7



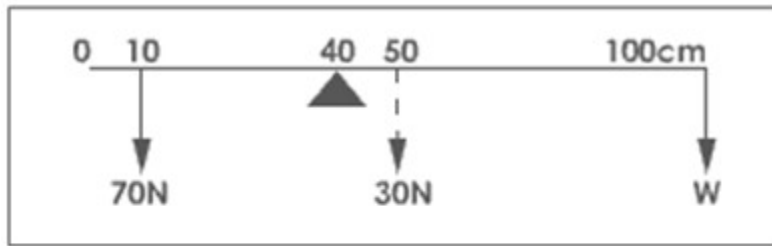
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Q.8



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Q.9



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Difference between torque and couple an moment:

Torque is simply a turning effect produced on a body by a force. Mathematically it is force X perpendicular distance. Torque is used to measure couple. Couple is nothing but two torques acting together its whole effect is to rotate a body.

Moment and torque are same physical quantities.

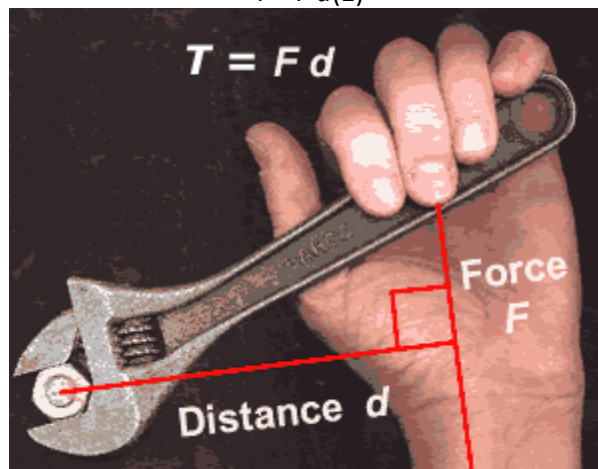
Moments and Couples:

The moment of a Force or Torque:

The moment of a force is the perpendicular force F acting at a distance, d and causes an object to rotate.

The moment of a force, also known as the torque T is defined as the force F acting at a perpendicular distance d .

$$T = F d(1)$$



Physics IX –Torque & Moment

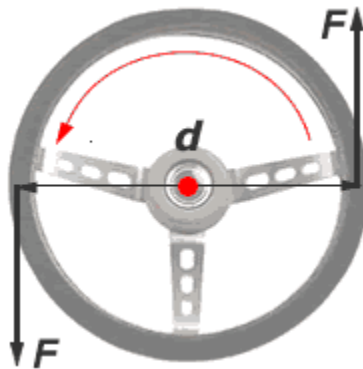
The moment of a force

The dimension of moment is $[M L^2 T^{-2}]$ which is the same as energy, however there is no direct relationship between the two. The SI unit of a moment is the Newton meter (Nm).

A special case of moments is where two anti-parallel forces separated by a distance d cause an object to rotate. This is known as a couple.

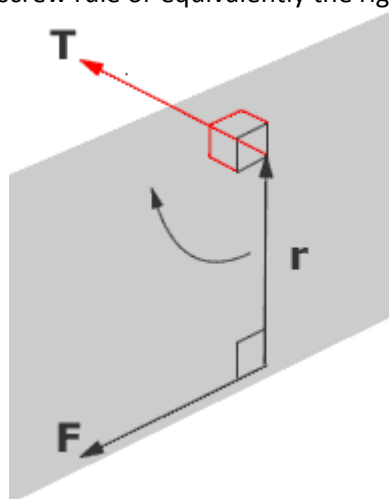
Couples:

If two opposite moments act to cause an object to rotate, such as when your two hand are at the 'quarter-past-three' position on a car steering wheel, it is called a couple. The moment of a couple is called the torque. It is quite often said of engines and applies to the ability of the engine to turn the wheels, or wrongly by Jeremy Clarkson from 'Top Gear' as in, "This engine has a lot of torques."



A couple

The torque is a vector quantity. That is, it has magnitude and it has a direction that is projected perpendicular to the plane of the vectors \mathbf{F} and \mathbf{r} . The direction of the vector from the plane follows a right-handed corkscrew rule or equivalently the right-hand screw rule.



Torque is a vector quantity with the direction given by the right-hand screw rule.

The magnitude of the torque of a couple can be found by finding the net torque from clockwise and anti clockwise moments acting on an arbitrary point of rotation.

$$T = F(x + d)$$

$$T = Fx$$

Equating, $Fx + Fd = Fx$.

Net Torque. $T = Fd$

Couples:

If you have two forces (for instance, a couple of forces) acting on an object and the forces are:

- parallel
- in opposite directions
- of equal size
- not along the same line of action

...you have got a couple.

Couples produce rotation only. So the object spins faster and faster but it remains on the spot. (In physics speak - no linear acceleration or translation.)

How can we calculate the moment (or torque) of a couple?

So to calculate the moment (or torque) due to a couple you can use:

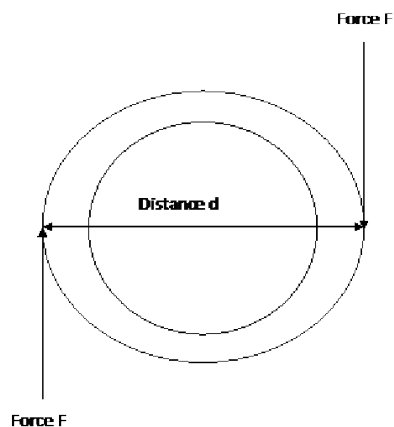
Moment = Magnitude of one force x perpendicular distance between the lines of action of the forces.

Couple

A couple is when two forces of equal magnitude but acting in opposite direction on an object causing a rotation.

The best example is the car steering wheel or the handle of a motorcycle. As the diagram below shows two forces that are equal to each other in magnitude but acting in opposite direction act on an object.

The points of applications of the two forces are separated by a distance d .



Hence the couple can be calculated using the equations below.

Couple = Magnitude of one of the two forces * the distance between the point of application of the two forces

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$$\text{Couple} = F \times d$$

Of course the same principle will apply to couple if the forces are not at right angle to the distance. Then the component of the force at right angle to the distance must be used. The couple will then be calculated using the equation

$$\text{Couple} = F d \cos\theta$$