Torques and Moments:

M = Fr

What does the r stand for?

The Basic steps to doing a moment/torque questions is:

1. Find the pivot point
2. Draw a basic diagram with all forces
3. Macw = Mcw
4. Solve

For Torques it is important to understand one main concept. The r in M = Fr stands for lever arm not radius. This is defined as the perpendicular distance from the force to the pivot point.

In practice:

I. Find your force. Draw a dotted line along its force of action (i.e. extend the line of force off the page)
II. Find the pivot point
III. Draw a line perpendicular to your extended force line that touches the pivot.
IV. This is your level arm or the "r" of M=Fr.

Many students find this concept annoying to use in prac tice and prefer to use a length given in the question. This is usually fine AS LONG AS you use a component of the force **perpendicular** to the length you have used.

In short you can generally use any length or force you like but the r and F you use must be perpendicular to each other. Any other part of the force will simply stretch or squash the pole which is not a factor covered in the Physics course and was moved to the engineering course.

The Basic steps to doing a moment/torque questions are:

5. Find the pivot point
6. Draw a basic diagram with all forces
7. Macw = Mcw
8. Solve

There is really only one main idea in Moments.

Strategy 1:

1. Find all the forces. (F)
2. Draw a line perpendicular to the line of action of the force that goes to the pivot.(r)
3. Multiply these 2 values. (M=Fr)

Strategy 2:

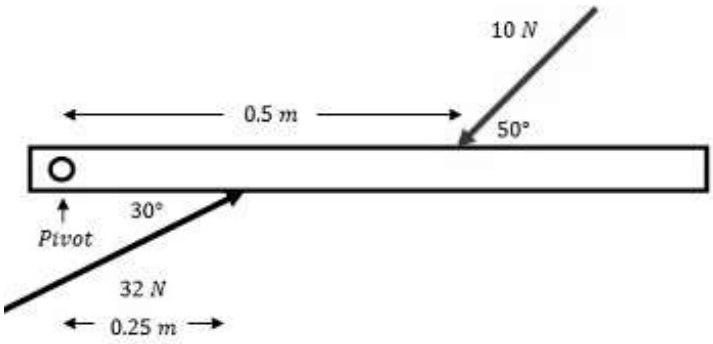
1. Find all the forces.
2. Find the distance from the pivot to the forces.(r)
3. Calculate the component of the force perpendicular to these distances. (F)
4. Multiply these 2 values. (M=Fr)

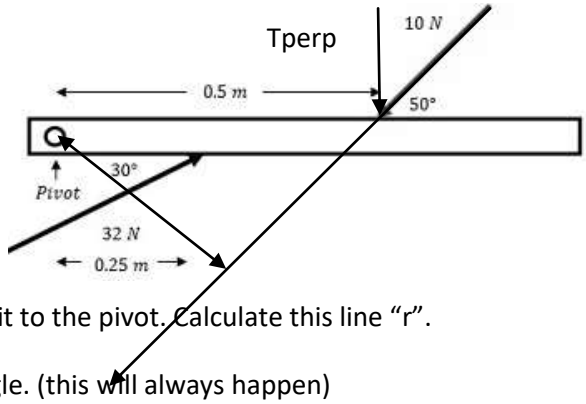
If you understand this, you can do ALL Moment questions. The only possible further obstacle being your ability/memory of right angle trigonometry. Year 12 students have not practiced right angle trigonometry for a while. Make sure you trigonometric skills are sufficient.

Examples:

a) Find the moment due to the 10 N force.

b) Find the moment due to the 32 N force.





a) Find the moment due to the 10 N force.

Force Method:

Extend the force. Then draw a line perpendicular to it to the pivot. Calculate this line "r".

Note that the force and "r" make a right angle triangle. (this will always happen)

r=0.5cos40. then M=Fr = 10x0.5cos40 = 3.83 Nm.

Length Method:

Get the distance to the force (0.5 m). Calculate the component of the force perpendicular to that distance (Tperp). T perp = 10 cos40 (or 10sin50). then as before M=Fr = 10cos40x0.5 = 3.83 Nm.

b) Find the moment due to the 32 N force.

Force Method:

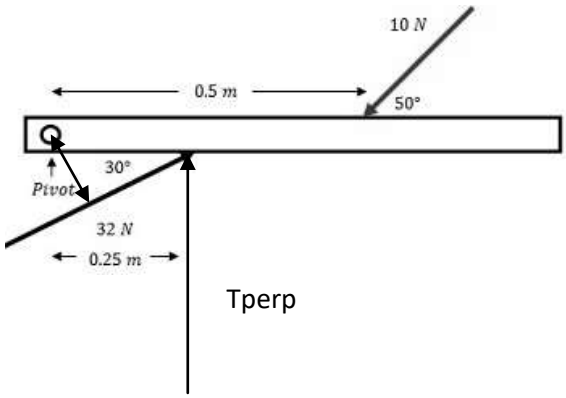
In this example the force does not need to be extended. Draw a line perpendicular to it to the pivot. Calculate this line "r".

Note that the force and "r" make a right angle triangle. (this will always happen)

r=0.25sin30. then M=Fr = 32x0.25sin30 = 4.00 Nm.

Length Method:

Get the distance to the force (0.25 m). Calculate the component of the force perpendicular to that distance (Tperp). T perp = 32 sin30 (or 32cos60). then as before M=Fr = 32x0.25sin30 = 4.00 Nm



Torque can be thought of as a “turning force”. It tries to cause things to rotate. Any object that is not moving is in what we call static equilibrium. To be in static equilibrium there are 3 things that must be true.

1. All up forces must equal all down forces
2. All right forces equal all _____ forces.
3. All clockwise moments must equal all anti-clockwise moments.

The formula on your data sheet is M=Fr.

F is the force in newtons.
r is the perpendicular distance from the force to the pivot.
M is the moment in Newton metres

In moments we only care about the force perpendicular to the pivot. Any other component of the force will simply try and squash or stretch the metal bar and we do not care about this. (this has been moved to the engineering course – let THEM worry about it!)

Let’s try an easy example.

1. A 450 N child sits 2 metres from the centre of a see saw.
    a. What torque will he apply?

    b. If a parent is 900 N in weight where should they sit to keep the see-saw still?

In other words the further a force is from a pivot is the stronger that force becomes. The closer to the pivot the weaker it becomes.

No one carries the shop groceries with their arms straight out in front of them, every one brings a heavy weight close to their body for this reason.

The most confusing part of moments and torques is the idea of a lever arm. The r in the formula is NOT always radius. It is “the distance perpendicular to the force to the pivot”.

When drawing diagrams draw a dotted line for the forces involved. Then draw a line perpendicular to this line that will just touch your pivot. This distance is your “r” or lever arm for your formula.

If you cannot understand this idea then use whatever r you like. But make sure you only use the component of the force perpendicular to the r you have chosen.

Simple Torque Question 1: Usually made up of a bridge or a plank supported by 2 supports. Everything is vertical or horizontal making finding r (the moment arm) very simple.

A 20metre long bridge has a total weight of 10 tonnes. A toll booth weighing half a tonne is built 4 metres from one end. Usually trucks will wait at the booth providing a 8 tonne point load between the toll booth and the end of the bridge.

What forces must the supports be built to take?

Step 1: Decide what kind of question this is.

Step 2: Draw a free body diagram of the situation making sure you have taken into account all information given.

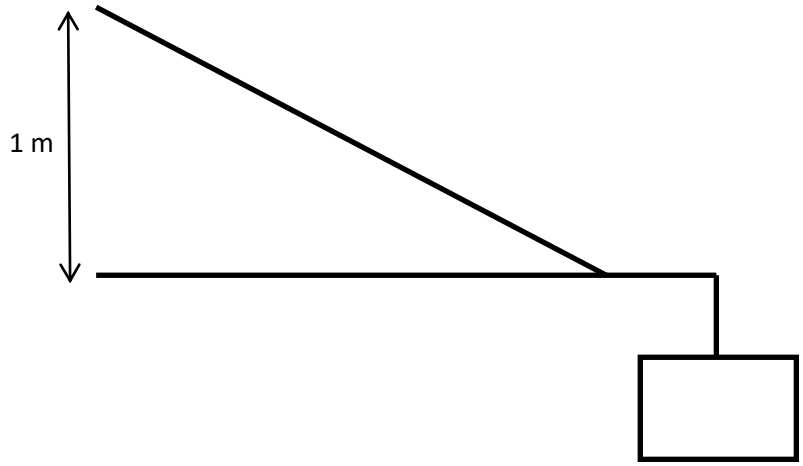
Step 3: Choose a pivot point.

Step 4: Do clockwise moments = anticlockwise moments and solve.

Step 5: Do Forces up = forces down & forces left = forces right to solve for any other forces required.

[123480N&57820N]

Classic Torque Question 2: A 100 kg sign is hung of the end of a 10 kg, 2 m long pole supported 20 cm from the end by a rope.



a)

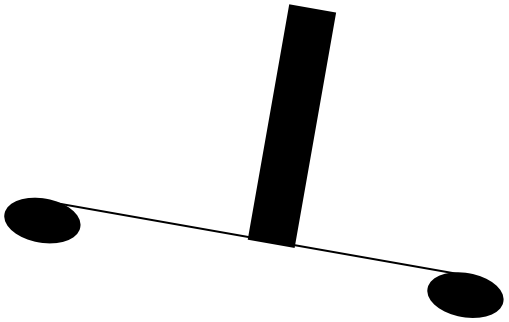
[2355N]

b) What is the reaction force of the wall?

[2059N]

Short Answer Moment Questions:

1. A boat has a width of 24 metres. Estimate the torque created by the wind acting on the boat in the circumstances shown. The main sail is 3250 kg, the hull is 1200 kg and each outrigger is 650 kg. [4 marks]



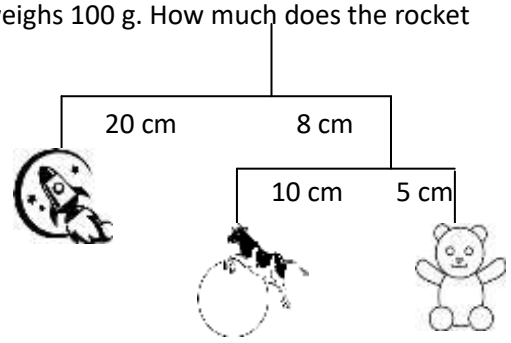
[6.5×10^5 Nm]

2. A 1 metre ruler weighing 100 grams is placed on a table with part of it hanging off the table. A 350 gram weight is placed at the rulers midpoint. When the end is lifted slightly by a spring balance it reads 2.30 N. When the ruler is lowered the pivot point changes and the spring balance now reads 1.70 N. What is the distance between the 2 pivot points? [4 marks]

[0.186]

3. You get a flat tyre. As you attempt to remove the wheel using the tyre iron from your boot you remember that the mechanic tightened the bolt using a machine rated for 290 Nm. Are you able to change the tyre?[4 marks]

4. A mobile is hung from a ceiling as shown. The bear weighs 100 g. How much does the rocket weigh? [4 marks]



[60g]

Long Answer Moment Questions:

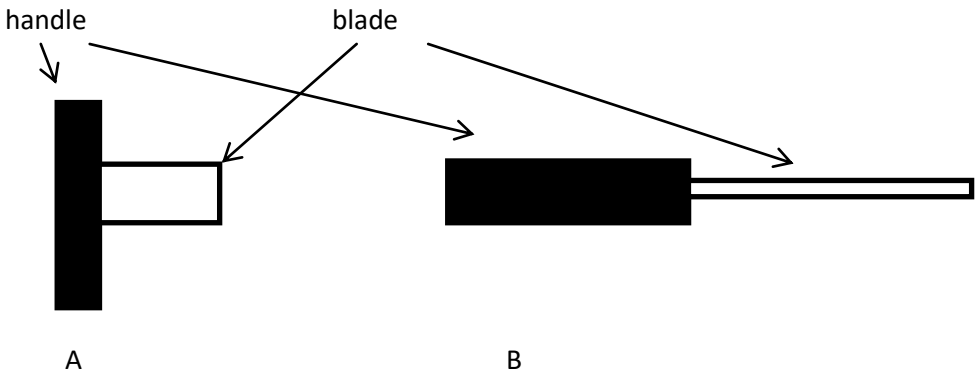
1. A 9 kg projector hangs from a 1 kg, 1 metre metal bar attached to the wall by a metal plate and 2 screws as shown.

   a. If the screen is 70 cm from the wall and the 2 bolts are each 5 cm from the metal bar calculate the horizontal force in each bolt. [6 marks]

[666]

   b. Explain quantitatively how moving the projector further from the wall will affect the force required by the top bolt. [3 marks]

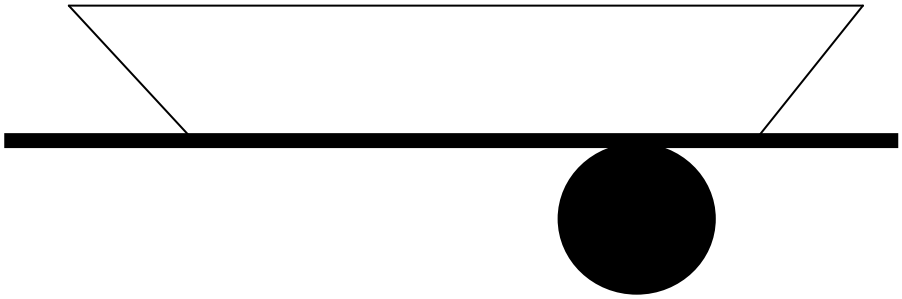
2. Which of the 2 screwdrivers shown would require the least force to unscrew bolts with? [4 marks]



3. When doing a push up how much are you effectively bench pressing compared to a machine at a gym? [4 marks]

[48 kg assuming 80 kg]

4. A boat trailer has a combined mass of 800 kg and 3.85 metres long. The centre of gravity is 65 cm in front of the axle.

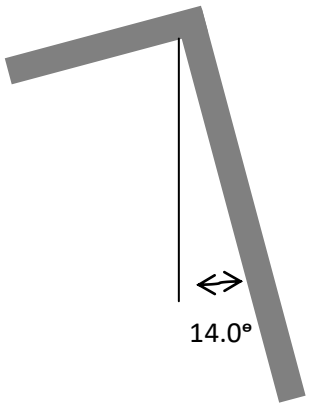


a. The boat has an outboard motor weighing 90 kg is fitted to the back of the boat 1.15 metres behind the axle. What is the force acting on the tail bar? [6 marks]

[1510]

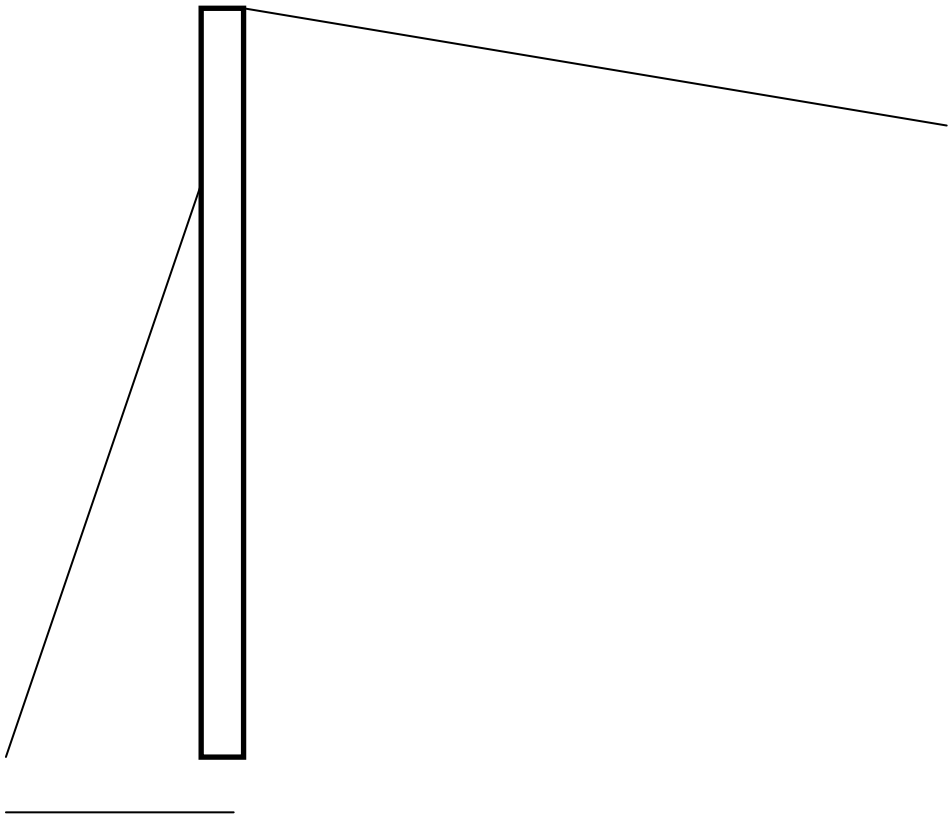
b. Explain how a person is able to life the boat onto and off the tailbar despite weighing nearly a tonne? 4 marks]

5. A thin metal rod is bent into a right angle and hung on a nail from a wall, as shown in the diagram. Assume that there is no contact between the rod and the wall. The longer side (L_2) is 0.800 m long and makes an angle of 14.0° to the vertical. The rod has uniform density and constant thickness. Calculate the length of the shorter side, L_1. Show **all** workings.[6 marks]



[0.4]

6. An electrical wire is supported by a telephone pole at an angle of 87° to the vertical as shown. If the supporting cable is attached 2 metres from the top of the 12 metre long pole.
    a. Calculate the tension in the cable if the electrical wires exert a 1500 N force on the pole. [6 marks]



4 metres

[8.05kN]

    b. Explain how the cable stops the telephone pole being pulled over. [4 marks]