4.1 Moment of a force (torque)

Example 4.1.1

(a) The rule has a very small mass and this can be ignored in the calculation.
Other terms: **negligible** mass or **zero** mass.

(b) Moments of F about the pivot = 20 N x (50.0 – 30.0) cm = <u>400 N cm</u>.
Direction is <u>anticlockwise</u>.

Exercises 4.1

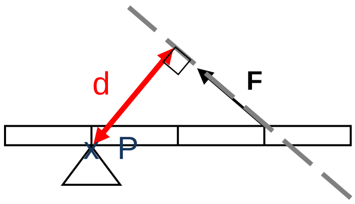
1. When the line of action of the force passes through the pivot.

2. (a) Moment = 6 Nm, Direction = anticlockwise
(b) Moment = 6 Nm, Direction = clockwise
(c) Moment = 6 Nm, Direction = anticlockwise
(d) Moment = 0, Direction = N/A (no turning effect)

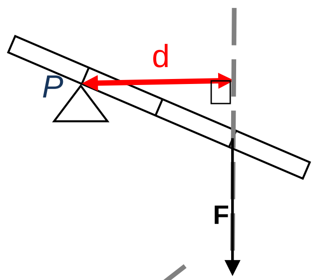
3. (a) All parts of the ruler are similar. The CG of the rule is at its centre and as such, the weight of the ruler acts right through the centre.

b) (i) Resultant Moment = 30 Nm, Resultant motion: **Rotates** anticlockwise
(ii) Resultant Moment = 0 Nm, Resultant motion: remains at rest.
(iii) Resultant Moment = 0 Nm, Resultant motion: remains at rest.
(iv) Resultant Moment = 32.5 Nm, Resultant motion: **Rotates** anticlockwise
(v) Resultant Moment = 20 Nm, Resultant motion: **Rotates** anticlockwise
(vi) Resultant Moment = 0.5 Nm, Resultant motion: **Rotates** anticlockwise

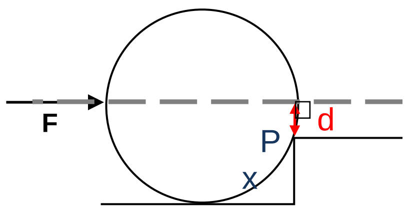
4 (a)



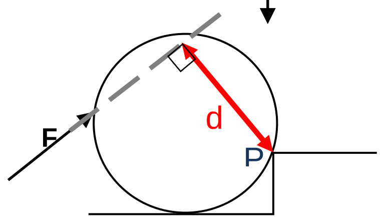
(b)



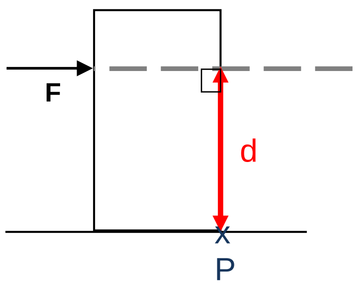
(c)



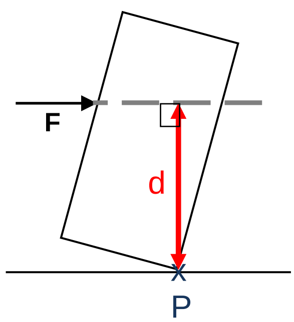
(d)



(e)



(f)



4.2 Principle of Moments

Example 4.2.1

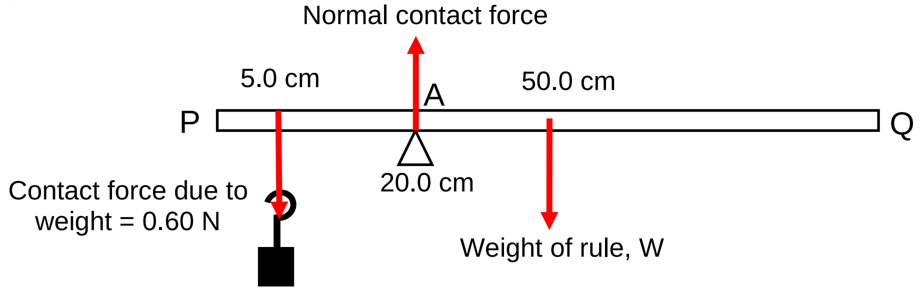
(a) For a balanced system, clockwise moment = anticlockwise moment about the pivot.
W x (90.0 – 50.0) cm = 24 N x (50.0 – 14.0) cm
W = 21.6 N = <u>22 N</u> (2 sf)

(b) As the rule is uniform, its CG is at its centre. Thus the line of action of the weight passes through the pivot resulting in zero moment.

(c) The rule would rotate anticlockwise about the pivot. The anticlockwise moment caused by the 40 N mass is larger than the clockwise moment caused by **W.**

Example 4.2.2

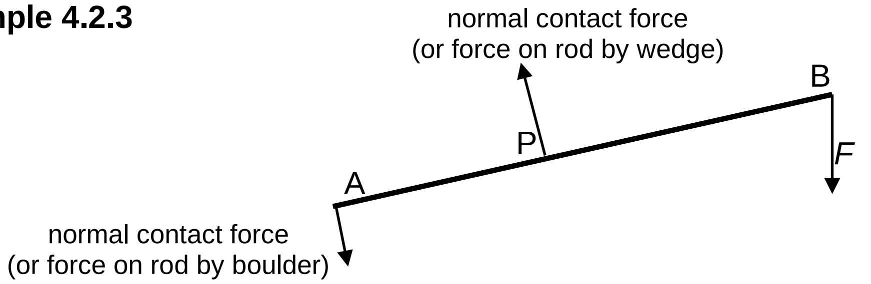
(a)



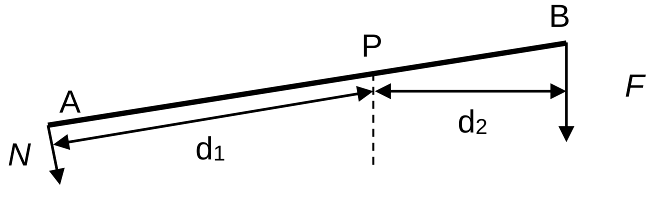
(b) System at equilibrium: apply principle of moments.
<u>Taking moments about A</u>,
clockwise moment = anticlockwise moment about A
W x (50.0 – 20.0) cm = [(60 ÷ 1000) x 10] N x (20.0 – 5.0) cm
W = 0.30 N ∴ Mass of rule = W ÷ 10 = 0.030 kg = <u>30 g</u>

Example 4.2.3

(a)

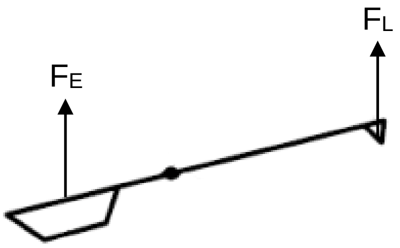


(b) Taking moments about P, at equilibrium, $N \times d_1 = F \times d_2$
$F = (N \times d_1) / d_2$, assuming N is the same.
If P is moved nearer towards B, distance d_2 would decrease, and d_1 would increase.
so F must increase.
Similarly, if P is moved nearer towards A, so F would decrease.



Example 4.2.4

(a)



(b) Consider forces on each tong (free-body diagram),

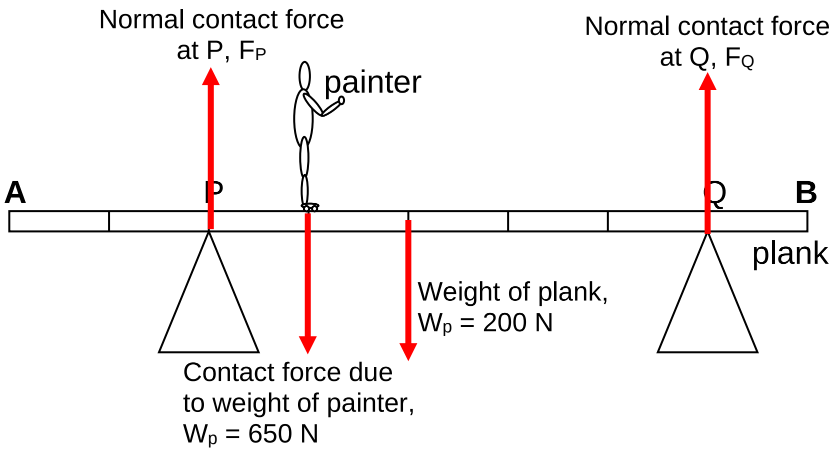
Taking moments about the pivot: $F_E \times 4.0 = F_L \times 10.0$

$F_E = 2.5\ F_L$ or $F_L = 0.40\ F_E$

(c) The distance is less than 4.0 cm. Assuming the same force F_E is exerted on the handle, $F_L < 0.40\ F_E$, the force on the load would be smaller.

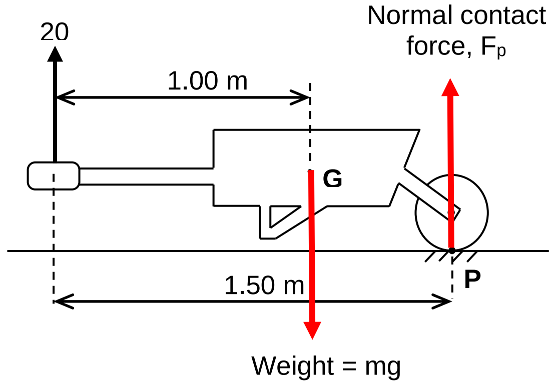
Exercises 4.2

1. (a)



(b) F_P = 640 N,
(c) F_Q = 210 N
(d) 1.4 m from A,

2. (a)

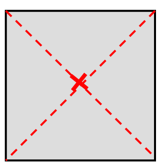


(b) (i) 30 N m clockwise
(ii) m = 6.0 kg

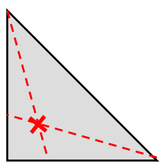
4.3 Centre of Gravity and Stability

Example 4.3.1

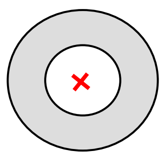
(a) (i)



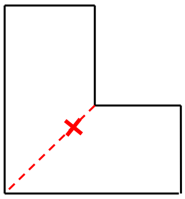
(ii)



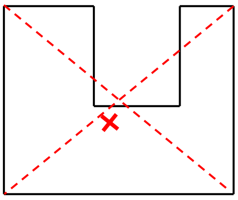
(iii)



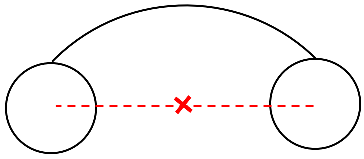
(b) (i)



(ii)



(iii)



Example 4.3.2

(a) X = stable equilibrium; Y = unstable equilibrium; Z = neutral equilibrium

(b) The C.G. of object X is on the left of the pivot. Therefore the weight, which acts from the C.G., creates an anticlockwise moment about the pivot. The object rotates anticlockwise back to its original position.

(c) The C.G. of object Y shifts to the right of the pivot. Therefore the weight, which acts from the C.G., creates a clockwise moment about the pivot. The object rotates clockwise and topples over.

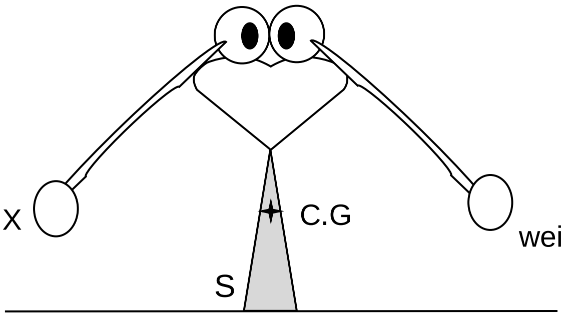
Exercises 4.3

1. (a) Minimum initial force by Mike
   Fm (1.50) = 500 (0.55); Fm = 183.3 N = <u>183 N</u> (3 s.f.)
   Minimum initial force by Pete
   Fp (1.20) = 500 (0.55); Fp = 229.2 N = <u>229 N</u> (3 s.f.)

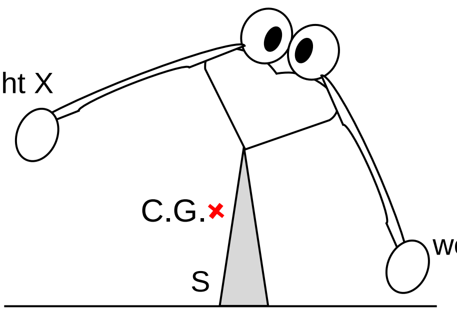
   (b) Mike applied the force at a position where its perpendicular distance from the line of action of the force to the pivot is greater. Thus, less force will be needed.

   (c) The C.G. of the block is to the right of the pivot at its base. Its weight would produce a clockwise moment and cause it to topple to towards the right.

2. (a) (i)

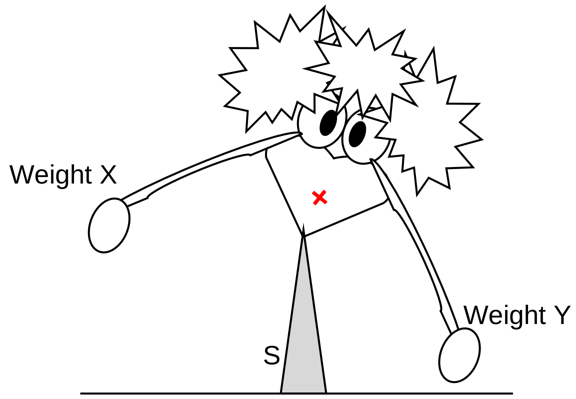


(ii)



(iii) The C.G. shifts to the left of the pivot. The weight creates an anticlockwise moment about the pivot. Therefore, the toy rotates anticlockwise and returns to its original position.

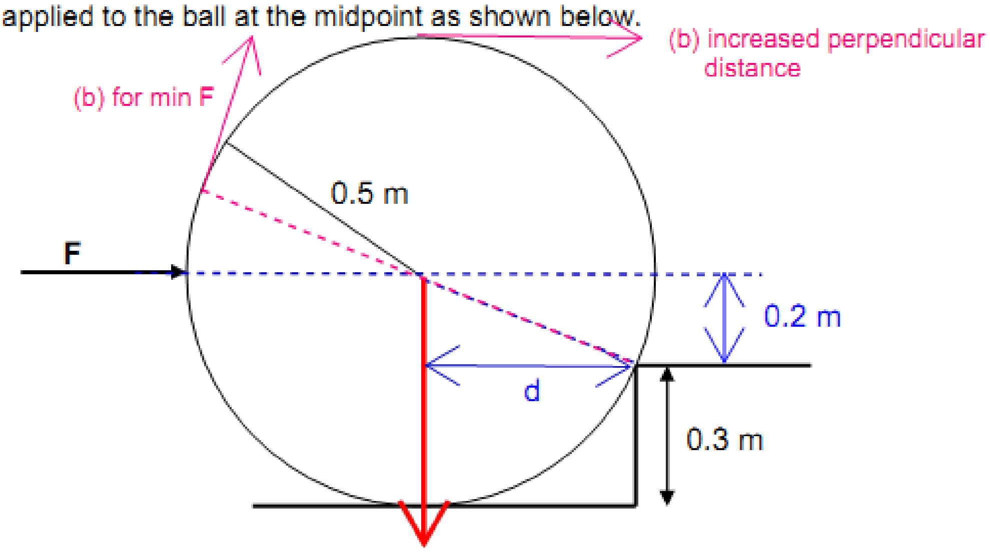
(b) The C.G. shifts to the right side of the pivot. The line of action of the weight lies outside the base and the weight creates a clockwise moment about the pivot, causing the toy to rotate clockwise and topple over.



Note:

- The base is a point.
- The main difference between this and the earlier part is that the position of C.G. here is ABOVE the level of the pivot while the earlier part the C.G. is BELOW the level of the pivot. This is what results in the toy having stable equilibrium earlier and unstable equilibrium here.

3. A ball, of radius 0.5 m and mass 2 kg, is resting against a step of height 0.3 m. A horizontal force, **F**, is applied to the ball at the midpoint as shown below.



(a) Taking moments about P,
Sum of CW moments = Sum of ACW moments
F (0.20) = 20 (d)

To find distance, d, using Pythagoras Theorem,
d = sqrt (0.50^2 - 0.20^2); d = 0.4583 m

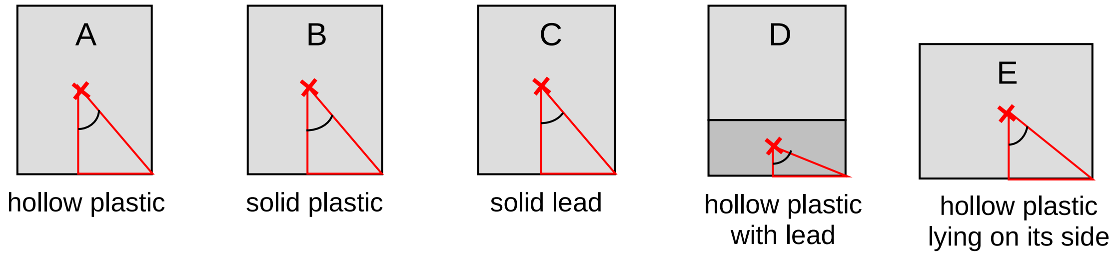
Therefore, min. F = $\dfrac{20 \text{ N} \times 0.4583 \text{ m}}{0.20 \text{ m}}$ = <u>45.8 N</u>

(b) In order to exert less force to produce the same moment to overcome the weight, the perpendicular distance from the line of action of the force to the pivot must increase. The minimum force required is when the distance is the maximum.

Enrichment (Angle of tilt)

Example 1

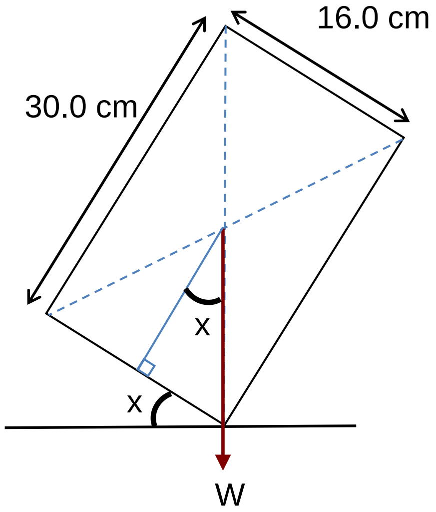
(a)



(i) D (ii) A, B, C

(iii) Hardest to topple is C.
The weight of C is the largest and thus it creates the greatest moment about the pivot. Therefore, the toppling force to overcome this moment is the largest.

Example 2



Let x be the maximum angle of tilt.

$\tan x = 8.0 / 15.0$

$x = \tan^{-1} (0.533) = \underline{28^o}$