Worked Solutions

Jenga Tower

Exercise 1: A jenga tower is built consisting of 7 blocks, each of mass m, arranged in 4 levels. The bottom two levels both contain one block, the next level up contains two blocks with a one-block gap between them, and the top level consists of 3 blocks stuck together. The tower rests on a table, and is stationary. Calculate the magnitude of:

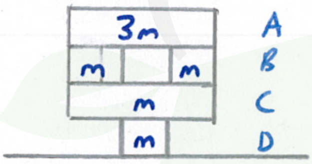
a) the normal force acting upwards on the stuck together set of top blocks from just one of the blocks on the layer below.

b) the normal force acting upwards on one of the two blocks on the second layer down, from the block on the layer below.

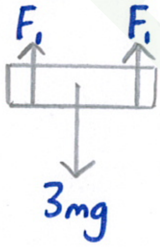
c) the normal force acting upwards on the single block on the third layer down, from the block on the bottom layer.

d) the normal force acting upwards on the single block at the bottom of the tower, from the table.

Whole System



Looking at just top layer of blocks :



Blocks are stationary, so by Newton's 1^{st} Law, the resultant force acting on the blocks is zero.

Taking upwards as positive:

$$2F_1 - 3mg = 0$$
$$2F_1 = 3mg$$
$$\underline{\underline{F_1 = \frac{3mg}{2}}}$$

Looking at one of the two blocks on the layer below:

Forces acting on block : Weight of block

Normal Reaction Force from block below

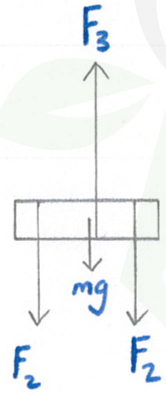
Normal Reaction Force from block above

- by Newton's 3^{rd} Law this has the same magnitude as the normal reaction force of this block (B) acting on the blocks above (A) which is F_1

From Newton's 1^{st} Law & taking upwards as positive:

$$F_2 - mg - F_1 = 0$$
$$F_2 = F_1 + mg$$
$$= \frac{3mg}{2} + mg$$
$$\underline{\underline{F_2 = \frac{5mg}{2}}}$$

Looking at single block on third layer down (c):



Forces acting on block: Weight of block

Normal Reaction Force from block below

Normal Reaction Force from each of the two blocks above

- by Newton's 3rd Law each of these have the same magnitude as the normal reaction force acting from this single block (c) on one of the blocks above, (b) which is F_2

From Newton's 1st Law & taking upwards as positive:

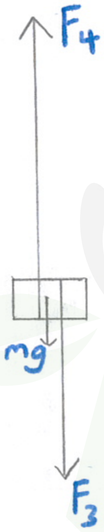
$$F_3 - mg - 2F_2 = 0$$

$$F_3 = 2F_2 + mg$$

$$= 2\left(\frac{5mg}{2}\right) + mg$$

$$\underline{\underline{F_3 = 6mg}}$$

Looking at single block on bottom layer (D):



Forces acting on block: Weight of block

Normal Reaction Force from floor

Normal Reaction Force from block above

- by Newton's 3rd Law this has a magnitude F_3

From Newton's 1st Law & taking upwards as positive

$$F_4 - mg - F_3 = 0$$

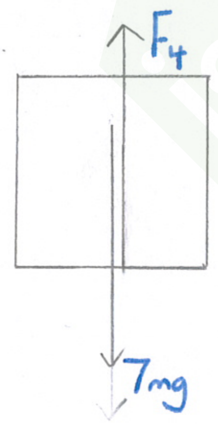
$$F_4 = F_3 + mg$$

$$= 6mg + mg$$

$$\underline{\underline{F_4 = 7mg}}$$

Alternatively this problem can be solved by considering the forces acting on different subsets of the system.

Considering all 7 blocks together, not considering "internal" forces between these blocks:



External forces acting on this set of blocks:

Weight of the blocks (i.e. gravitational attraction between Earth and the blocks)

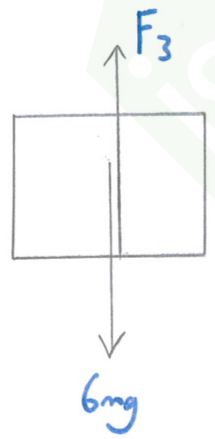
Normal Reaction Force from the table

By Newton's 1st Law, taking upwards as positive

$$F_4 - 7mg = 0$$

$$\underline{\underline{F_4 = 7mg}} \quad \text{as before}$$

Considering the top three layers of blocks:



External forces acting:

Weight of 6 blocks

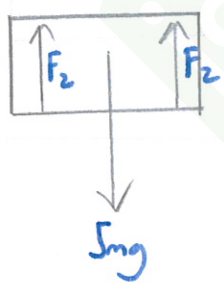
Normal Reaction Force from single block ~~on layer~~ below

By Newton's 1st Law, taking upwards as positive

$$F_3 - 6mg = 0$$

$$\underline{\underline{F_3 = 6mg}}$$

Considering the top two layers of blocks:



External forces acting:

Weight of 5 blocks

Normal Reaction Forces from layer below acting on each of the two blocks on layer B

By Newton's 1st Law, taking upwards as positive.

$$2F_2 - 5mg = 0$$
$$2F_2 = 5mg$$
$$F_2 = \frac{5mg}{2}$$

Calculation for top layer of bricks is identical to that in previous method.