

EDEXCEL NATIONAL CERTIFICATE/DIPLOMA

MECHANICAL PRINCIPLES AND APPLICATIONS NQF LEVEL 3

OUTCOME 1 - LOADING SYSTEMS

TUTORIAL 2 SIMPLY SUPPORTED BEAMS

1. Be able to determine the effects of loading in static engineering systems

Non-concurrent coplanar force systems: graphical representation e.g. space and free body diagrams; resolution of forces in perpendicular directions e.g. $F_x = F \cos\theta$, $F_y = F \sin\theta$, vector addition of forces, conditions for static equilibrium ($\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma M = 0$), resultant, equilibrant, line of action

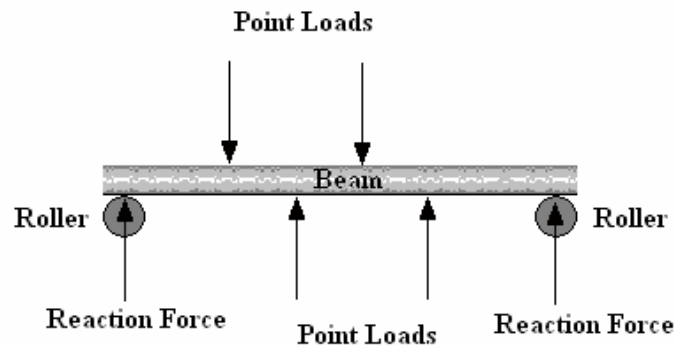
Simply supported beams: conditions for static equilibrium; loading (concentrated loads, uniformly distributed loads, support reactions)

Loaded components: elastic constants (modulus of elasticity, shear modulus); loading (uniaxial loading, shear loading); effects e.g. direct stress and strain including dimensional change, shear stress and strain, factor of safety

INTRODUCTION

The importance use of the knowledge gained from tutorial No.1 is in the solution of problems involving beams and other structures. These problems require us to solve the reaction forces where they rest or are attached to the surroundings and the solution of the forces and moments inside the material of the structures. Fortunately in this unit you are only required to study simply supported beams.

You might be asking the question, what is a beam? Well a beam is a structure that is loaded laterally (sideways) to its length. These loads produce bending and bending is the most severe way of stressing a component. Suppose you were given a simple rod or a ruler and asked to break it. You would struggle to break it by stretching it or twisting it but it would be easily to break it by bending it. A beam may be obvious when it is a girder or a length of timber like a plank but a beam can be any structure with side loads. So what is a simply supported beam? Quite simply it is a beam that rests on supports without being attached to them. We usually idealise the supports as sharp edges or rollers so that the force acting at these points can only be normal (90°) to the length. The forces that act at the resting points are called the reaction forces and you need to be able to calculate these first.



SIMPLY SUPPORTED BEAM

1. FINDING THE REACTION FORCES

REACTION FORCES

A reaction force is the force applied to a beam or other structure when it rests against something. In this tutorial we are only going to examine the reactions to the loads acting on a beam resting on simple supports as shown in the diagram. The loads are point loads. The rests are knife edges or rollers. We consider that a knife edge pushes upwards vertically with reaction forces R_a and R_b as shown. Reactions are solved by applying two simple rules.

- A body in equilibrium has no resultant force in any direction. $\Sigma F_y = 0$
- A body in equilibrium has no resultant turning moment in any direction. $\Sigma M = 0$

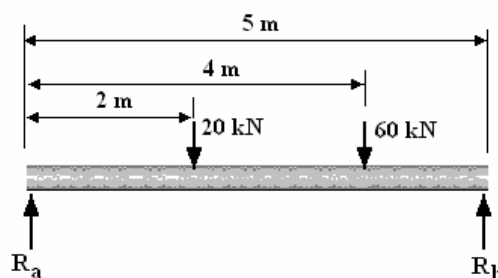
By applying these principles we can solve the reactions.

POINT LOADS

A point load is a load or force that acts at a single point on a structure and it is depicted by a single arrow on diagrams.

WORKED EXAMPLE No. 1

The free body diagram shown is for a simply supported beam with point loads. Calculate the reaction forces R_a and R_b .



MOMENTS $\Sigma M = 0$ about any point so it is convenient here to use the left end at the point where R_a acts. Since the reaction at that point cannot produce a moment, it is eliminated from the balance. (Remember clockwise is negative)

$$(R_b \times 5) - (60 \times 4) - (20 \times 2) = 0$$

$$(R_b \times 5) = (60 \times 4) + (20 \times 2)$$

$$R_b = 280/5 = 56 \text{ kN}$$

VERTICAL FORCES $\Sigma F_y = 0$ (remember up is positive)

$$R_a + R_b - 20 - 60 = 0$$

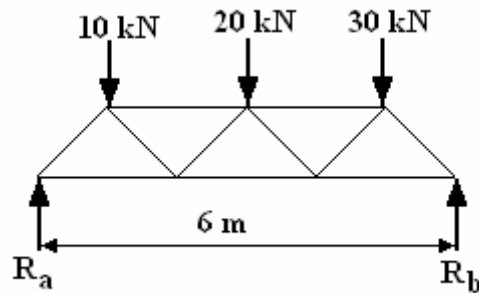
$$R_a + R_b = 80 \text{ kN}$$

$$R_a + 56 = 80 \text{ kN}$$

$$R_a = 80 - 56 = 24 \text{ kN}$$

WORKED EXAMPLE No.2

Although lattice frames are part of this unit, it is worth remembering that a rigid structure like this is really a beam. Calculate the reaction forces R_a and R_b . All the angles are 45° .



SOLUTION

Since all the angle are 45° the horizontal distances between each force must be 2 m and the end forces must be 1 m from the ends.

Take moments about R_b (you could try doing it about R_a and show that you get the right answers that way as well).

$$\Sigma M = 0$$

$$(10 \times 5) + (20 \times 3) + (30 \times 1) - (R_a \times 6) = 0$$

$$50 + 60 + 30 = 6R_a$$

$$R_a = 140/6 = 23.33 \text{ kN}$$

$$\Delta F_y = 0$$

$$R_a + R_b - 10 - 20 - 30 = 0$$

$$23.33 + R_b - 10 - 20 - 30 = 0$$

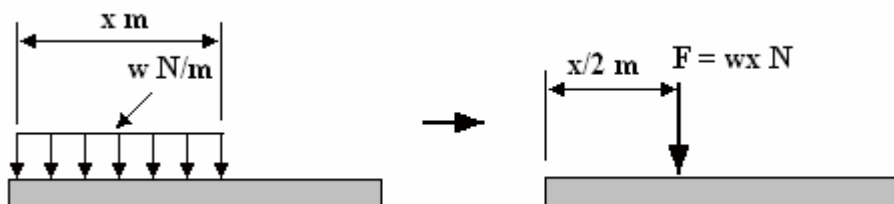
$$R_b = 60 - 23.33 = 36.67 \text{ kN}$$

UNIFORMLY DISTRIBUTED LOADS (u.d.l.)

A uniform load is one which is evenly distributed along a length such as the weight of the beam or a wall built on top of a beam. It is depicted by a series of arrows as shown. We usually denote the loading as w Newtons per metre.

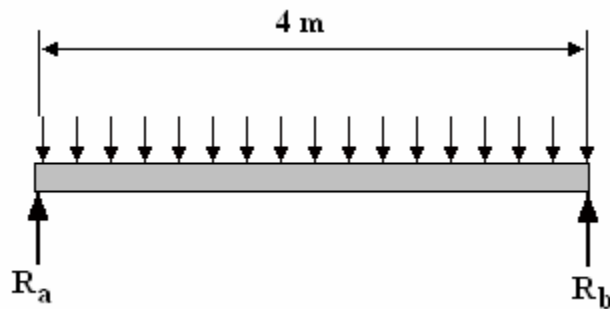
We deal with uniform loads by replacing them with an equivalent point load.

If the load extends over a length x metres then the total load is $F = wx$ Newton. We replace the u.d.l. with a single point load at the middle a distance of $x/2$ metres from the end.



WORKED EXAMPLE No. 3

A uniform load on a beam is shown below. It has a value of 2.5 kN per metre. Calculate the reaction forces.



SOLUTION

If the load is 2.5 kN for each metre of length then the total load is $4 \times 2.5 = 10$ kN

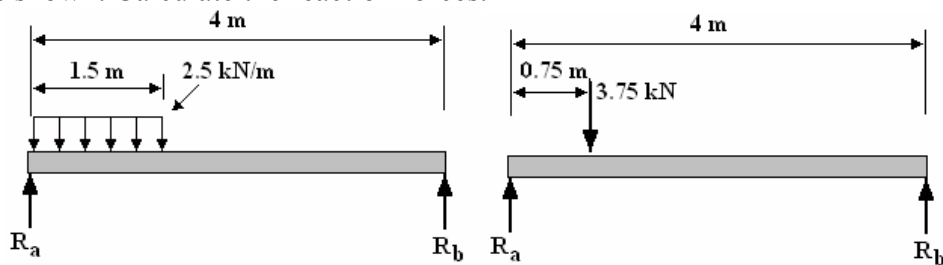
This load is equivalent to a single point load at the middle of 10 kN. It should be apparent that in this case, the reactions must be equal to half the total load so are both 5 kN acting up. Let's do the calculation anyway. Taking moments about R_b we have

$$(10 \times 2) - (R_a \times 4) = 0 \quad 4R_a = 20 \quad R_a = 5 \text{ kN}$$

$$\text{Balancing vertical forces } R_a + R_b - 10 = 0 \quad 5 + R_b - 10 = 0 \quad R_b = 5 \text{ kN}$$

WORKED EXAMPLE No. 4

A beam 4 m long rests on simple supports and carries a uniform load of 2.5 kN/m over the first 1.5 m as shown. Calculate the reaction forces.



The total load is now $1.5 \times 2.5 = 3.75$ kN This acts at the middle of the length 0.75 m from the end. Balancing moments about R_a we have

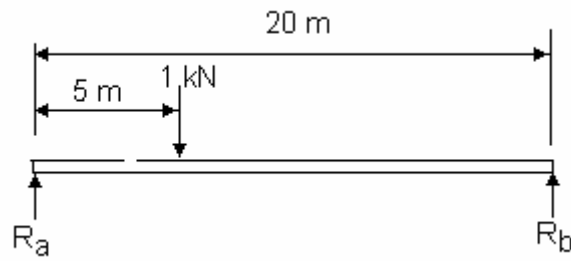
$$(R_b \times 4) - (3.75 \times 0.75) = 0 \quad R_b = 2.8125/4 = 0.703 \text{ kN}$$

$$\text{Balancing vertical forces } R_b + R_a = 3.75 \quad R_a = 3.75 - 0.703 = 3.05 \text{ kN}$$

SELF ASSESSMENT EXERCISE No. 1

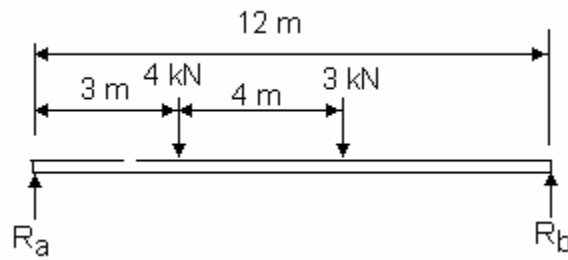
Solve the reactions for each case below.

1.



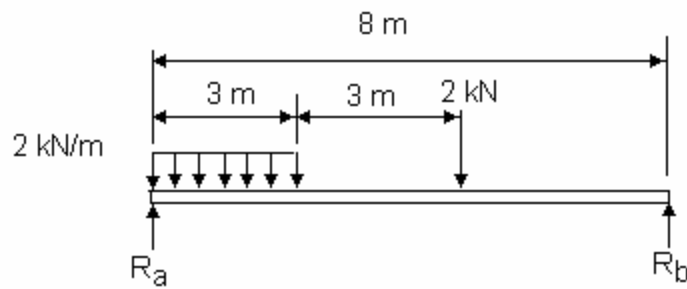
(Answers 0.75 and 0.25 kN)

2.



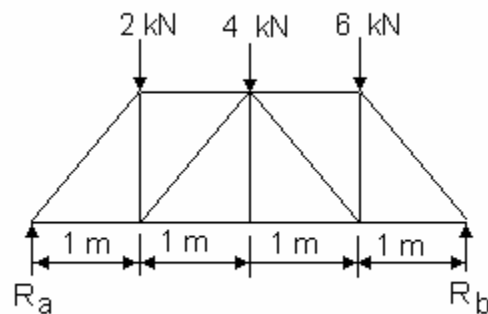
(Answers 4.25 and 2.75 kN)

3.



(Answers 5.375 and 2.625 kN)

4.



(Answers 5 kN and 7 kN)