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Pearson BTEC Levels 4 and 5 Higher Nationals in Engineering (RQF)

Unit 3: Engineering Science (core)

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Mechanical Engineering Systems

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INTRODUCTION

Determine parameters within mechanical engineering systems.

Static and dynamic forces:

- Representing loaded components with space and free body diagrams.
- Calculating support reactions of objects subjected to concentrated and distributed loads.
- Newton's laws of motion, D'Alembert's principle and the principle of conservation of energy.

Fluid mechanics and thermodynamics:

- Archimedes' principle and hydrostatics.
- Continuity of volume and mass flow for an incompressible fluid.
- Heat transfer due to temperature change and the thermodynamic process equations.

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner, it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

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Mechanics can be split into two distinct systems, static or dynamic. Static means that the system is in equilibrium and in a steady state. Dynamic systems are time dependent and will change depending on the timeframe that the system is observed.

2.1 Statics

Statics are most commonly associated with beams and support systems, by determining the reaction forces of the support beams we can look into more advanced details of the system, such as (but not limited to) the deflection of the beam from its original, unloaded position, or the rate at which the deflection changes, or the bending moment on the system.

2.1.1 Free Body Diagrams

When analysing mechanics problems, its always best to start off with a free body diagram (FBD), this helps clear the picture of what is happening in the system. A FBD is a drawing of all the forces that are acting on the system. Including all moments as well. Fig.2.1 shows a free body diagram of a beam.

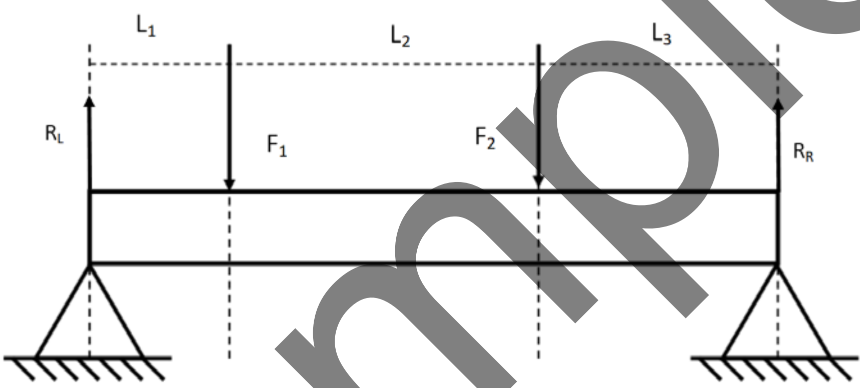

Fig.2.1: FBD of a beam supported at two ends with two vertical forces acting on it

2.1.2 Finding Static Equilibrium

The most important part about statics is that all forces are balanced: horizontal, vertical and moments are all equal (see Eq.2.1, 2.2, 2.3). If it is not, then the system is not stable, and in real applications this can be catastrophic.

$$\sum \mathrm{F_x} = 0 \qquad \text{(Eq.2.1)}$$

$$\sum \mathrm{F_y} = 0 \qquad \text{(Eq.2.2)}$$

$$\sum \mathrm{M} = 0 \qquad \text{(Eq.2.3)}$$

So, in the case of the FBD in Fig.2.1:

- There are no horizontal forces, so we know that this is balanced.
- There are four vertical forces, we generally take up as positive and down as negative and our equations is therefore:

$$\mathrm{R}_L - \mathrm{F}_1 - \mathrm{F}_2 + \mathrm{R_R} = 0$$

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- You can take moments about any point on the beam, however we have two unknowns, and this is the best way to eliminate one. By analysing the moments about one of the supports then (by remembering $\mathrm{M = Fd}$, then when looking at the support ($\mathrm{d = 0 \therefore M = 0}$). For convention, clockwise moments are negative, and counter-clockwise moments are positive. Looking at the moments about $\mathrm{R_L}$:

$$\mathrm{R_L(0) - F_1(L_1) - F_2(L_1 + L_2) + R_R(L_1 + L_2 + L_3)}$$

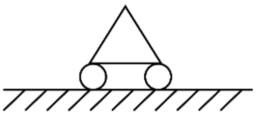
$$\mathrm{\therefore F_1(L_1) + F_2(L_1 + L_2) = R_R(L_1 + L_2 + L_3)}$$

  And if we took moments about $\mathrm{R_R}$:

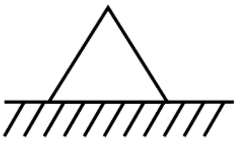
$$\mathrm{F_1(L_3 + L_2) + F_2(L_3) = R_L(L_1 + L_2 + L_3)}$$

  We will then have $\mathrm{R_L}$ or $\mathrm{R_R}$, and we can then calculate the remaining reaction force from Eq.2.1 or Eq.2.2.

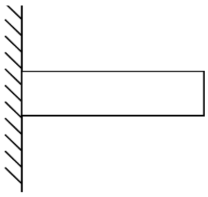
Different beam supports offer different reaction forces, such as suppressing vertical forces, horizontal forces, and moments, shown below. The application of a reaction force will add to the bending moment equation, and it’s important to know what reactions the beam will apply.



Rolling support: Provides a vertical reaction only



Pinned support: Provides a vertical and horizontal reaction



Beam is pinned directly to the surface: Provides a vertical, horizontal and moment reaction

Typically, in statics equations, we know what the forces we are looking to apply are, and so we are looking at the reaction forces that the supports will generate to fulfil the three equations above.

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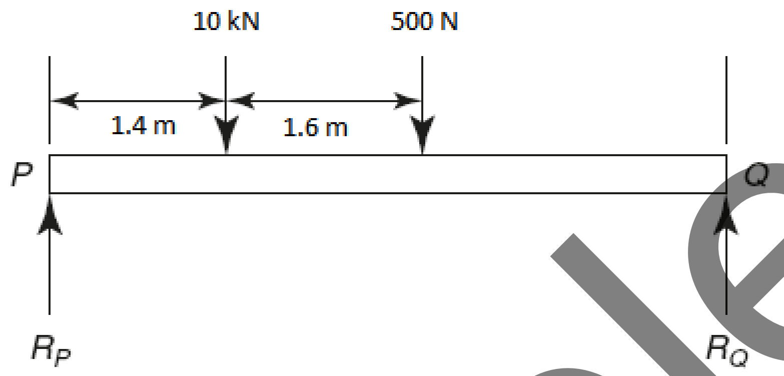
Worked Example 1

A beam PQ is 6.0 m long and is supported at its ends in a horizontal position as shown in the figure below. The mass is assumed to act as a point load of 500 N at its centre, as shown. A point load of 10 kN acts on the beam in the position shown.



When the beam is in equilibrium, determine the reactions of the supports.

ANSWER

Taking moments about P:

$$10{,}000(1.4) + 500(3) = R_Q(6)$$

$$\therefore \quad 14{,}000 + 1500 = 6R_Q$$

$$\therefore \quad R_Q = \frac{15{,}500}{6} = \mathbf{2.58\ kN}$$

Taking moments about Q:

$$500(3) + 10{,}000(4.6) = R_P(6)$$

$$\therefore \quad 1500 + 46{,}000 = 6R_P$$

$$\therefore \quad R_P = \frac{47{,}500}{6} = \mathbf{7.92\ kN}$$

CHECK: For equilibrium, upward forces must equal downward forces…

$$2.58\ kN + 7.92\ kN = 10.5\ kN = 10\ kN + 500\ N = 10.5\ kN$$

Therefore, the calculation is correct

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