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Solving Practical Engineering Mechanics Problems: Statics

Sayavur I. Bakhtiyarov
New Mexico Institute of Mining and Technology

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ABSTRACT

Engineering mechanics is one of the fundamental branches of science that is important in the education of professional engineers of any major. Most of the basic engineering courses, such as mechanics of materials, fluid and gas mechanics, machine design, mechatronics, acoustics, vibrations, etc. are based on engineering mechanics courses. In order to absorb the materials of engineering mechanics, it is not enough to consume just theoretical laws and theorems—a student also must develop an ability to solve practical problems. Therefore, it is necessary to solve many problems independently. This book is a part of a four-book series designed to supplement the engineering mechanics courses. This series instructs and applies the principles required to solve practical engineering problems in the following branches of mechanics: statics, kinematics, dynamics, and advanced kinetics. Each book contains between 6 and 8 topics on its specific branch and each topic features 30 problems to be assigned as homework, tests, and/or midterm/final exams with the consent of the instructor. A solution of one similar sample problem from each topic is provided.

This first book contains seven topics of statics, the branch of mechanics concerned with the analysis of forces acting on construction systems without an acceleration (a state of the static equilibrium). The book targets the undergraduate students of the sophomore/junior level majoring in science and engineering. The author welcomes all feedback/comments from the reader. Please feel free to contact him at sayavur.bakhtiyarov@nmt.edu.

KEYWORDS

force, moment, torque, gravity, equilibrium, center of gravity

Contents

Acknowledgments

The author acknowledges that this work is essentially a translation and a revision of selected problems provided by Professor A. A. Yablonski (*Collection of Problems for Course Projects in Theoretical Mechanics*, 2nd ed., Vischaya Shkola Publishers, 1972, in Russian). The author intended to introduce this unique work to western academia, which is the product of material covered by him in many classes over a period of four decades in a number of universities and colleges.

CHAPTER 1

Topic S-1

1.1 DETERMINATION OF THE REACTION FORCES OF SUPPORTS FOR RIGID BODY

Find reaction forces in supports of the given construction systems schematically shown in Figures 1.1–1.30. The sizes are in meters and the loads are shown in the table below.

Problem #	*G*	*P*	*M*	*q*	*α*
	kN		kN m	kN m	Degrees
1	10	5	20	1	30
2	12	8	10	4	60
3	8	4	5	2	60
4	14	-	8	3	30
5	-	6	7	1	45
6	-	10	4	2	60
7	-	6	5	1	45
8	16	7	6	2	60
9	6	6	4	2	30
10	10	8	9	1	30
11	-	4	7	0.5	45
12	10	6	8	-	45
13	12	10	6	2	30
14	10	6	10	1	45
15	4	4	4	2	60
16	20	10	-	2	45
17	25	5	-	0.5	45
18	20	10	10	-	30
19	-	4	8	1	45
20	-	10	6	0.5	45
21	-	8	7	0.5	30
22	-	10	8	1	30
23	-	7	10	2	30
24	-	6	7	1.5	30
25	-	14	20	0.5	45
26	-	16	14	1	30
27	5	4	8	2.5	45
28	-	10	7	3	30
29	-	6	8	1	15
30	15	10	14	0	30

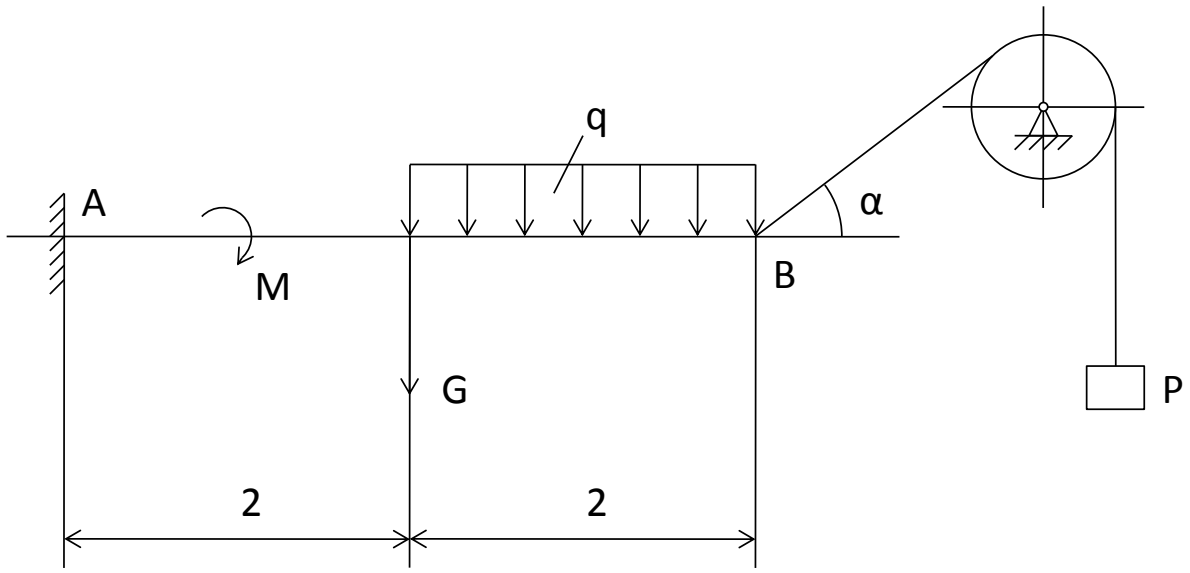
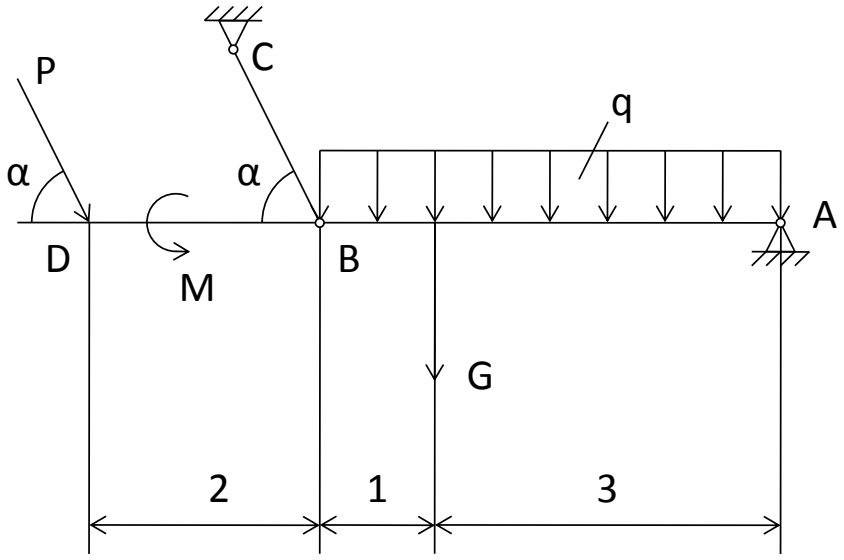


Figure 1.1.



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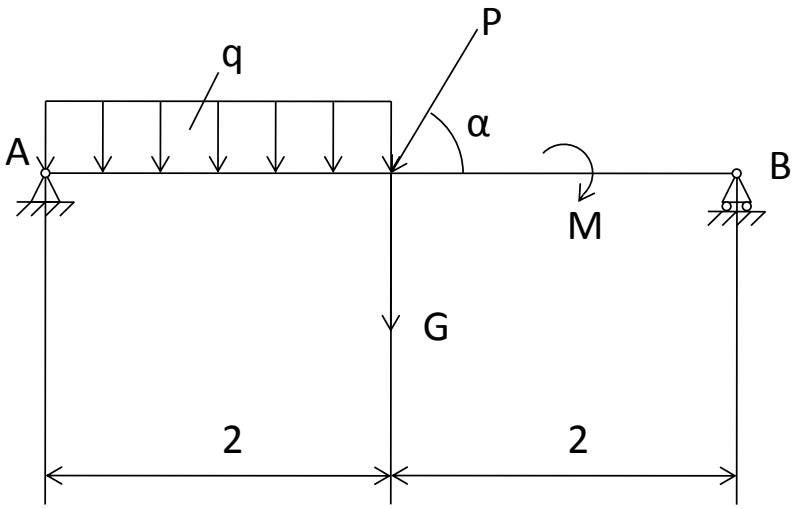

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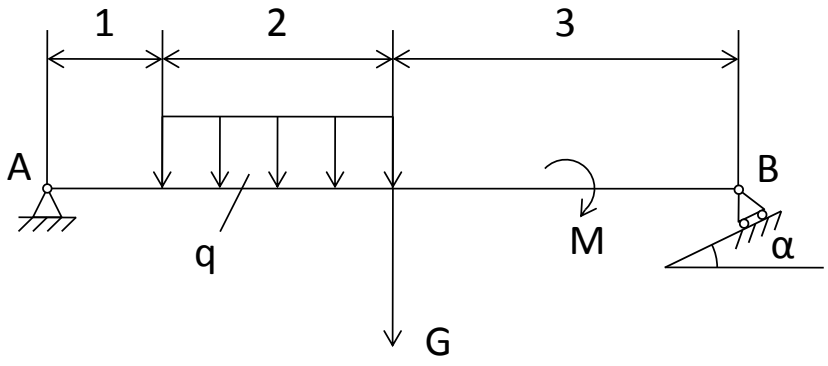

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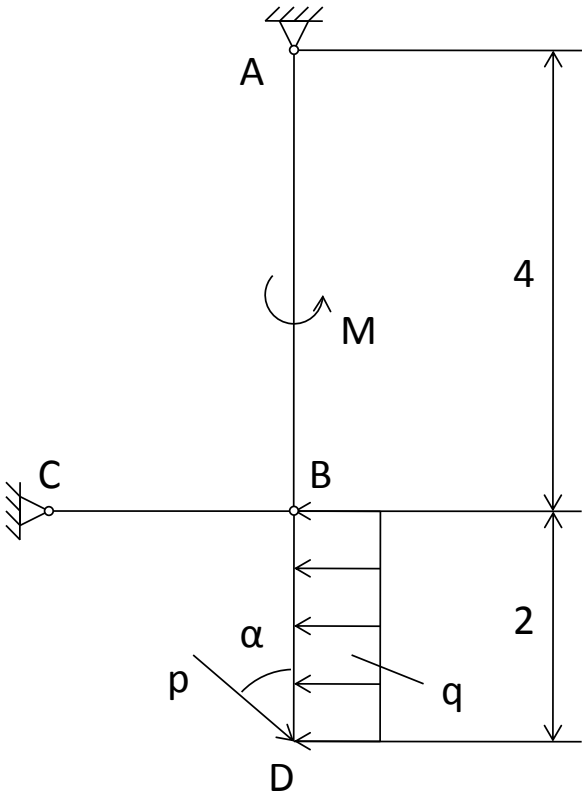

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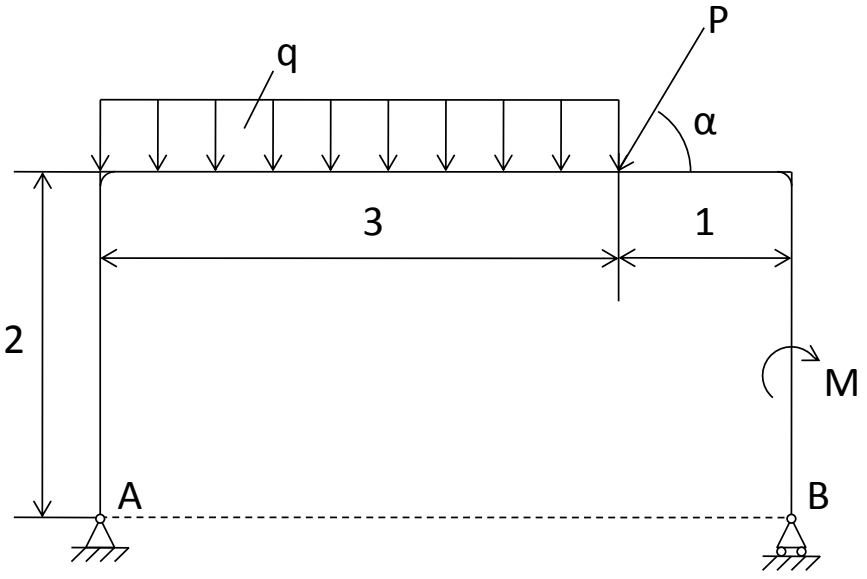

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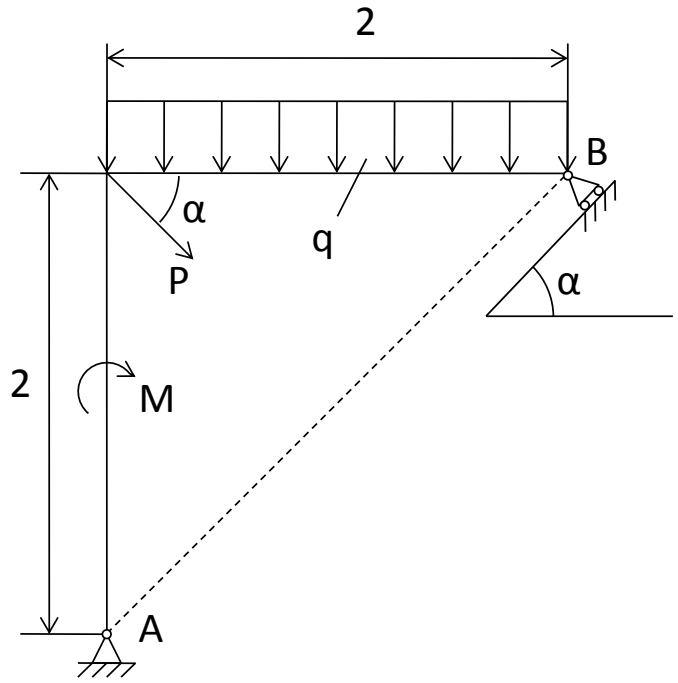

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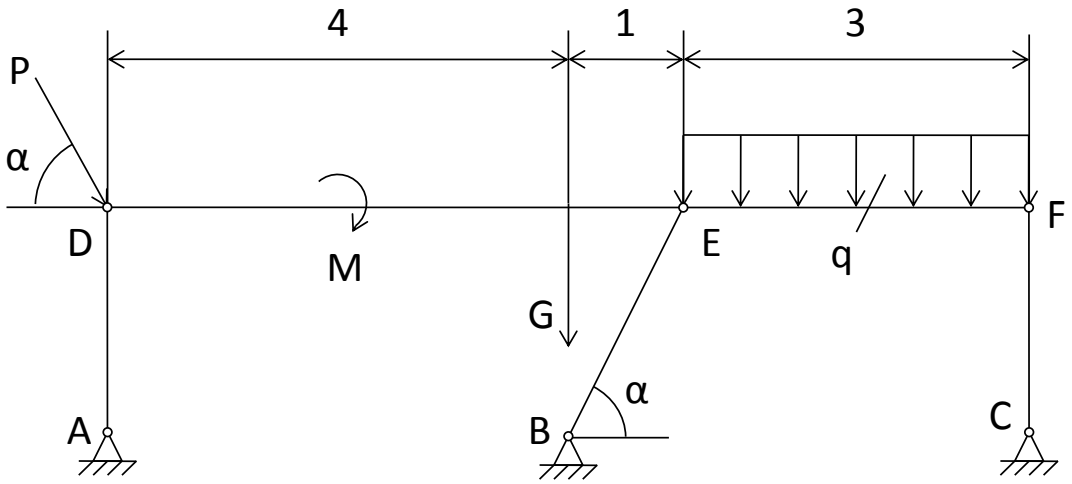

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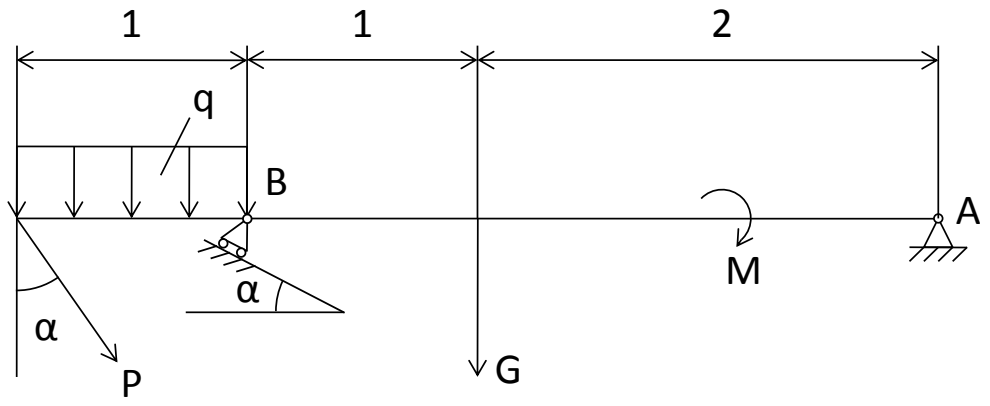

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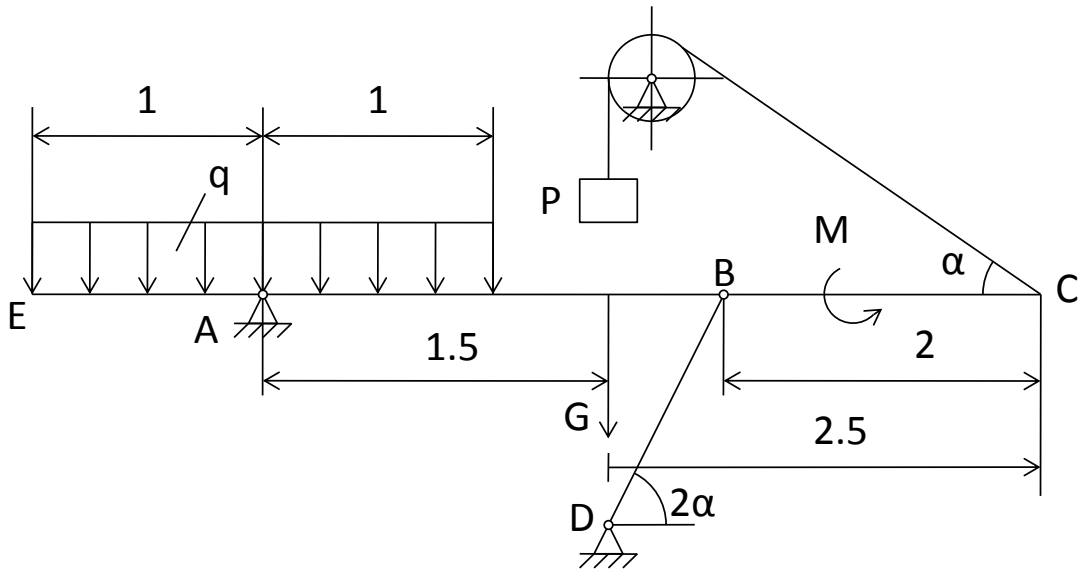

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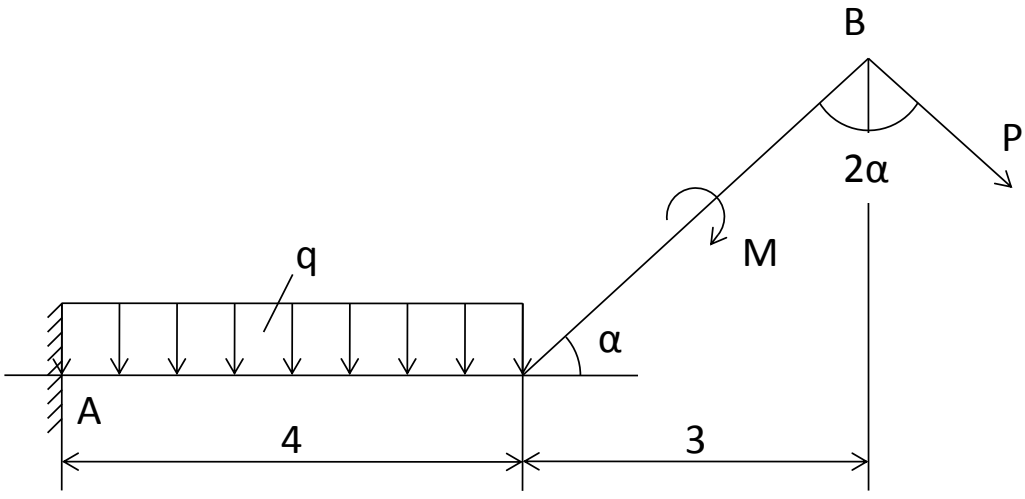

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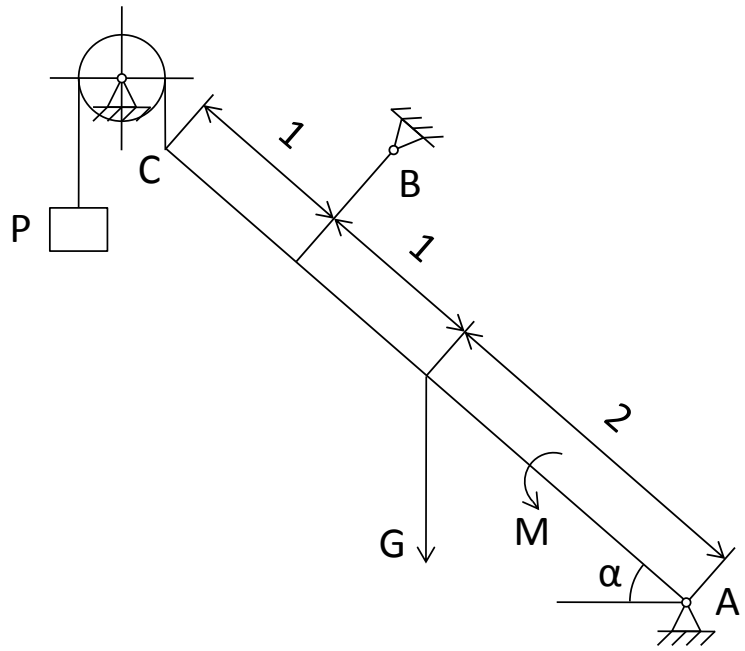

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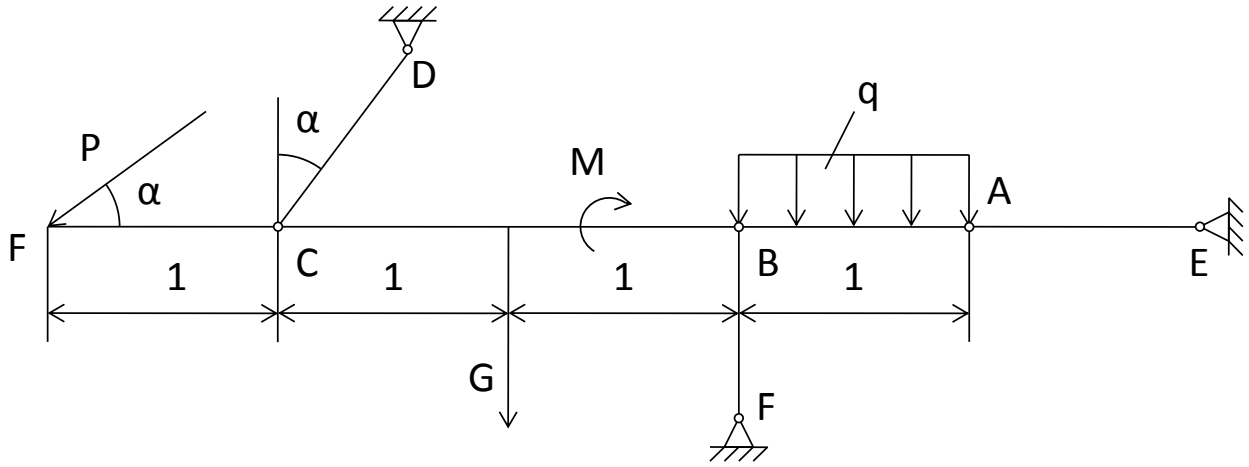

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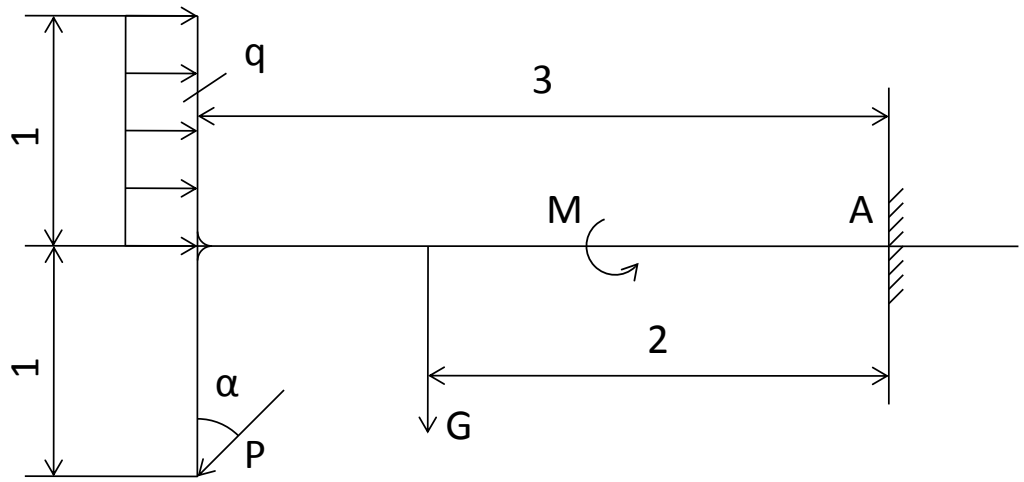

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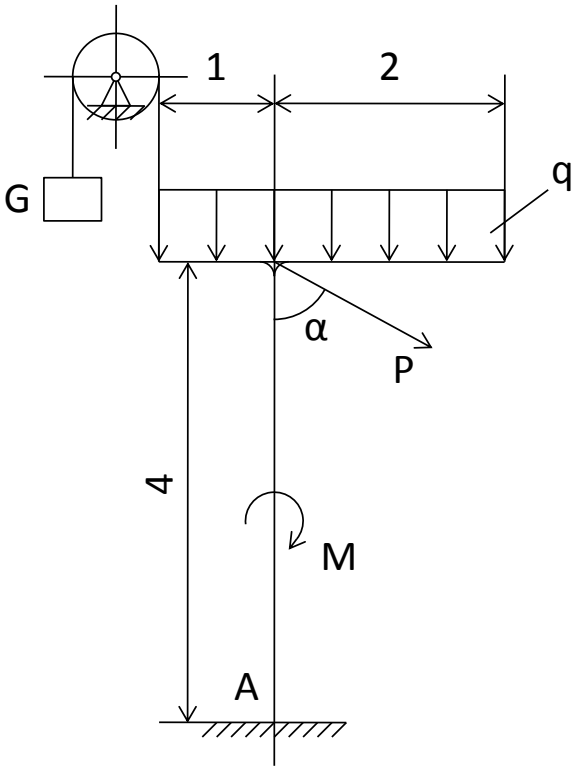

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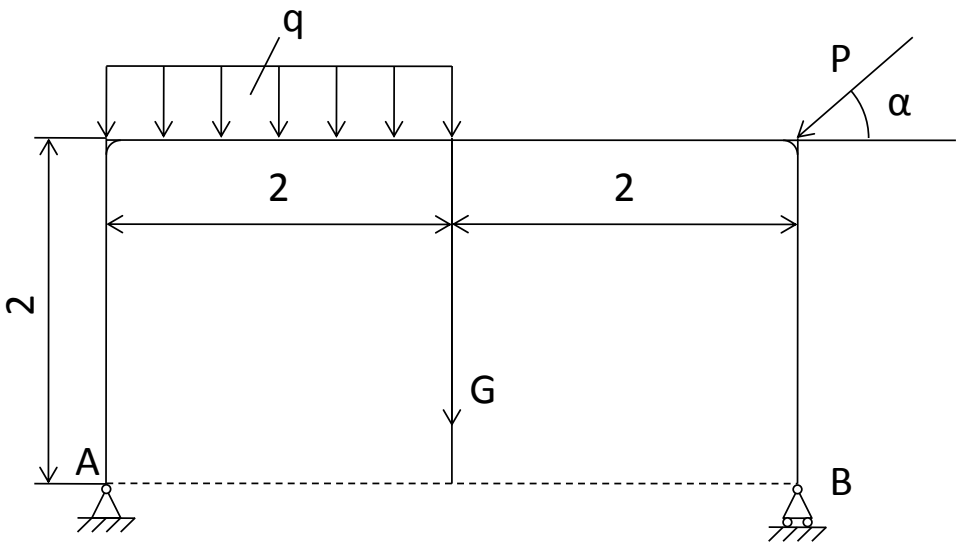

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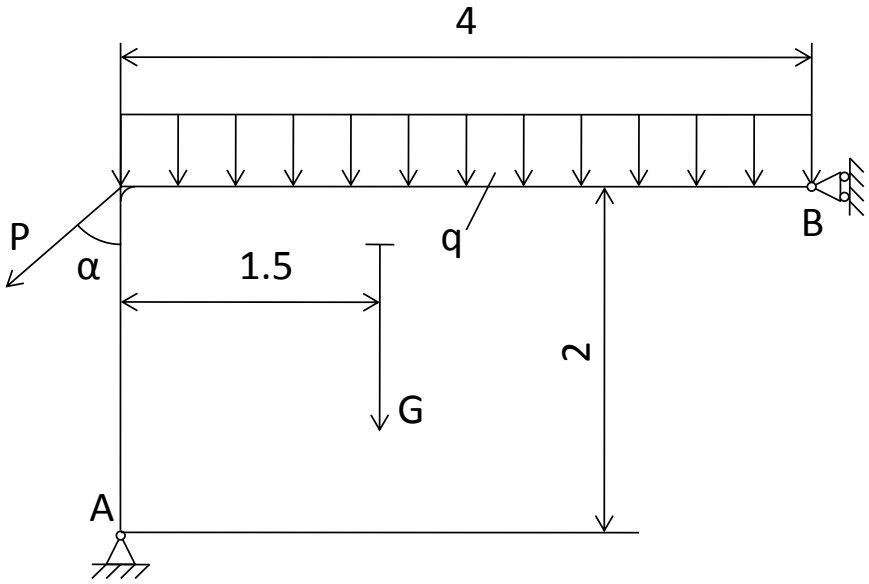

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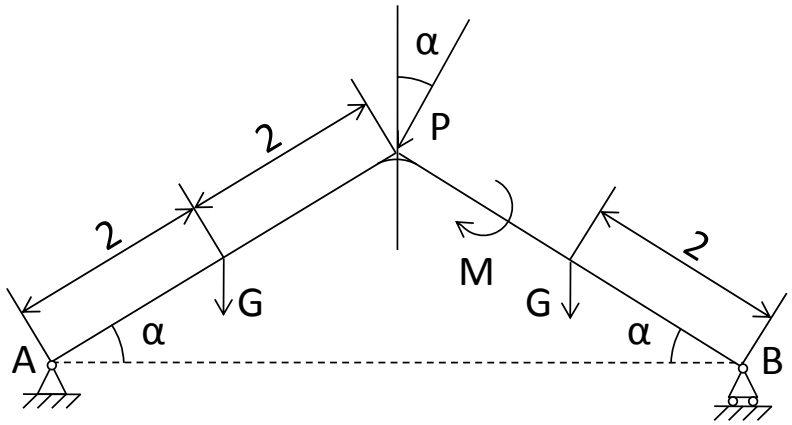

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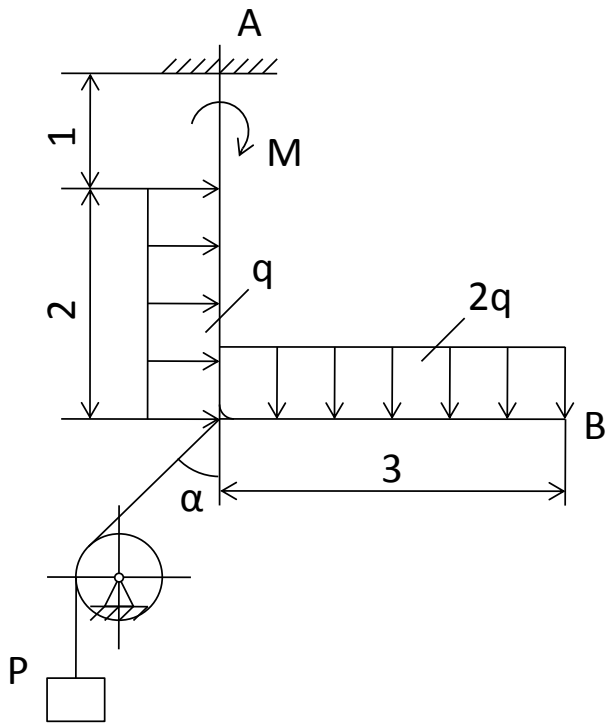

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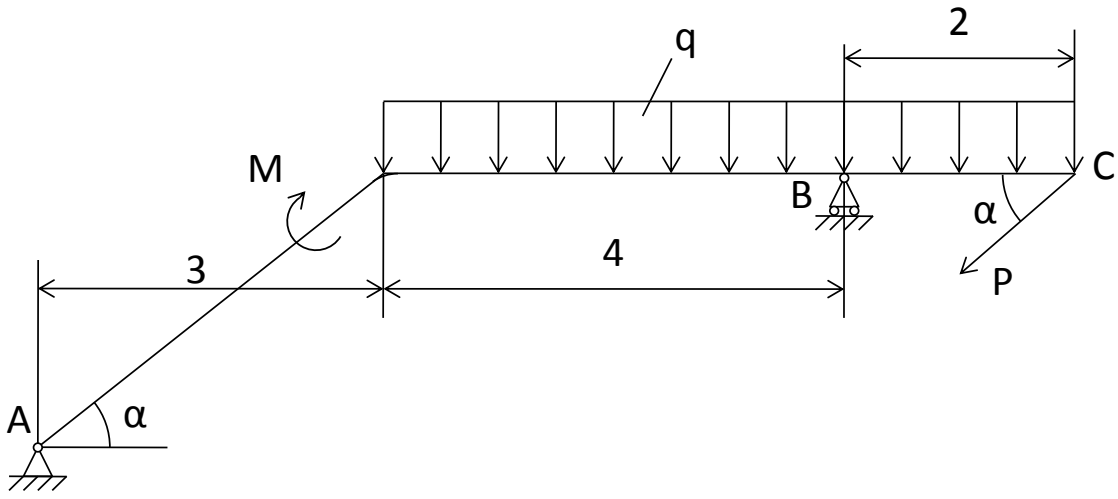

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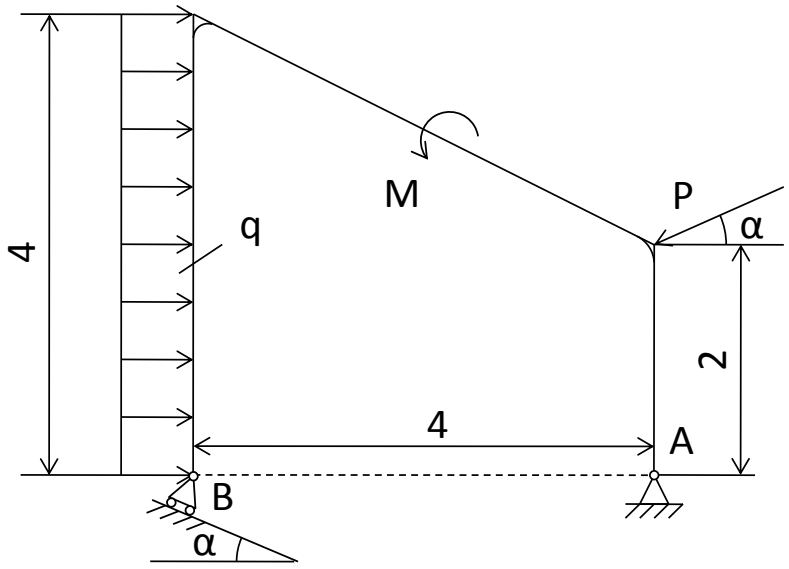

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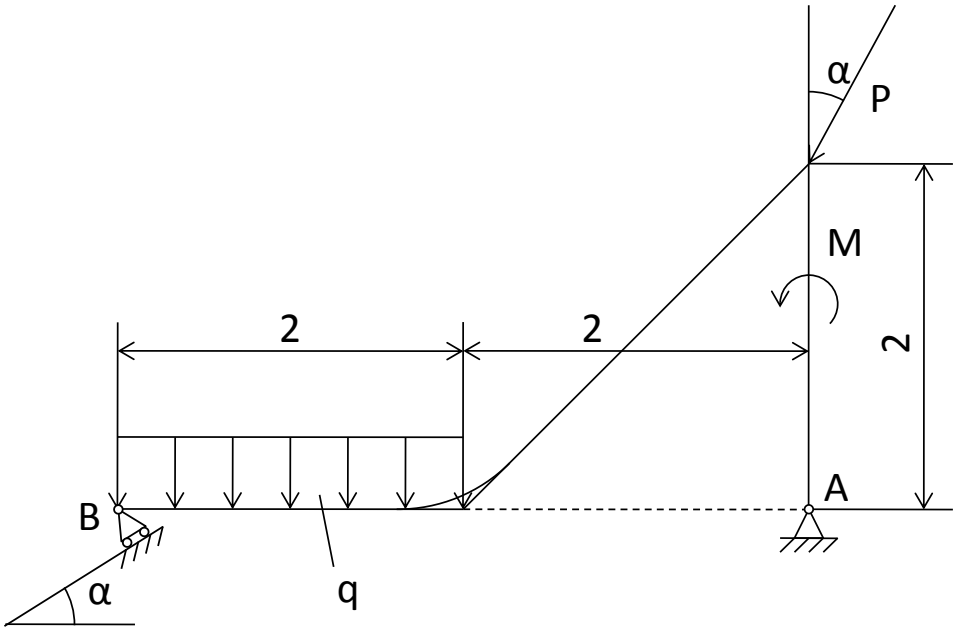

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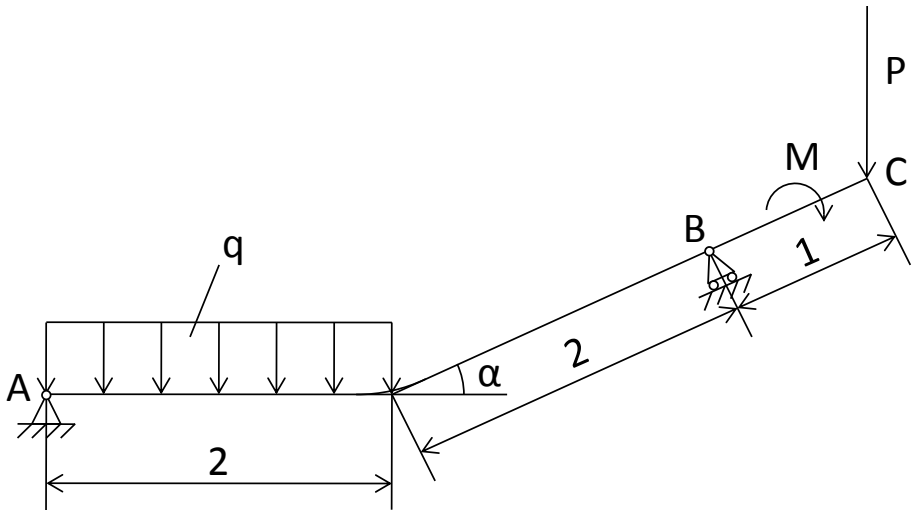

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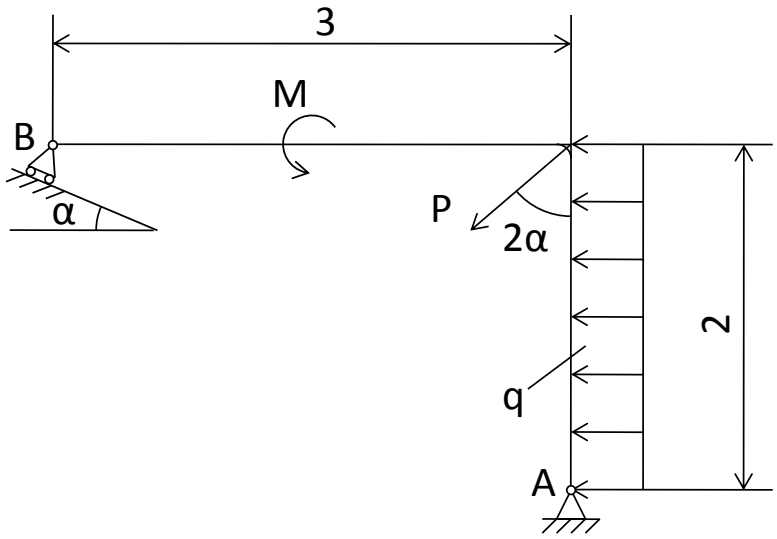

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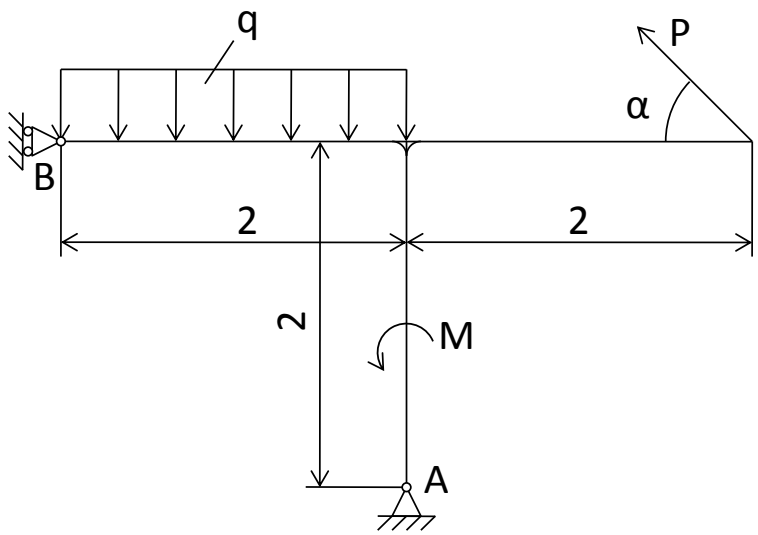

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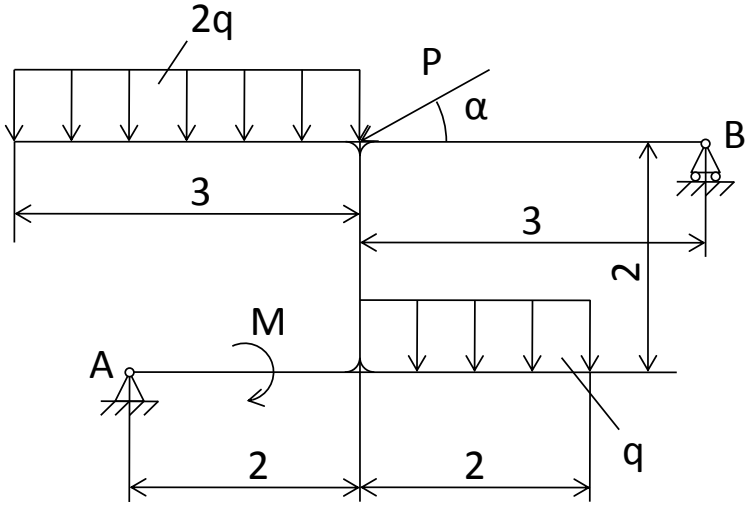

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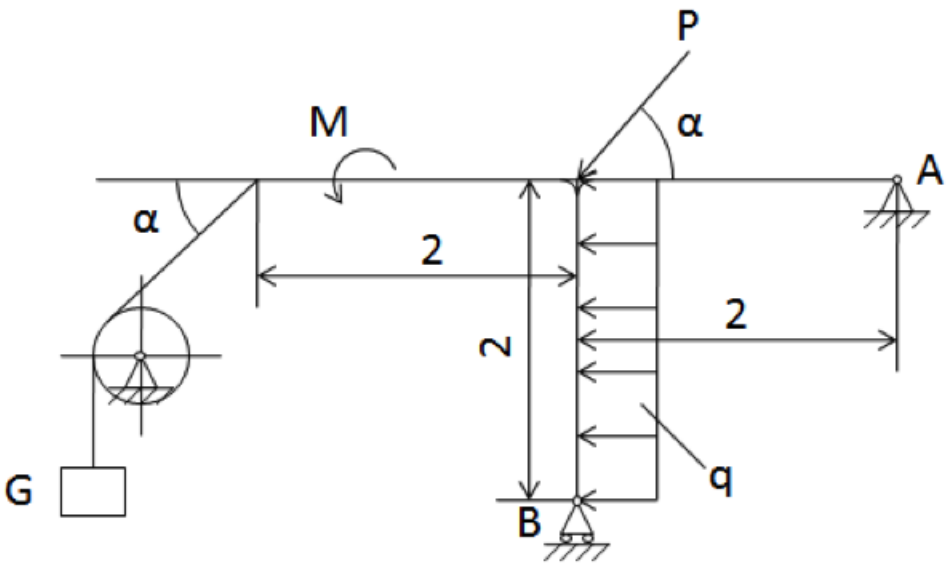

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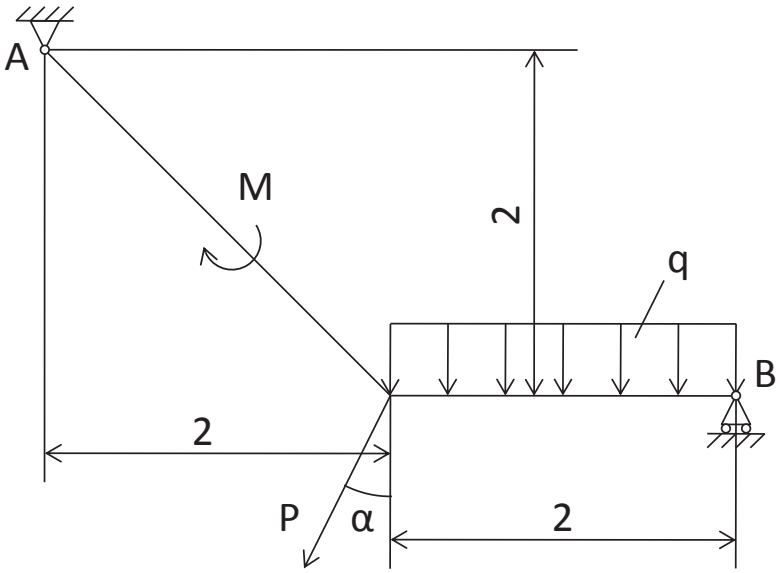

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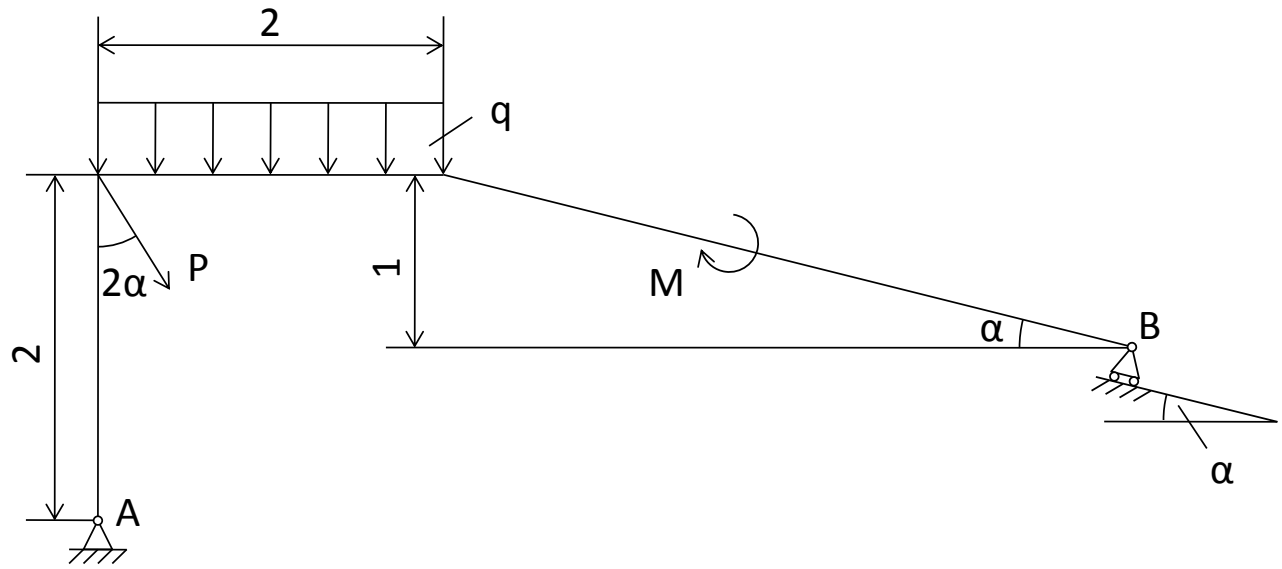

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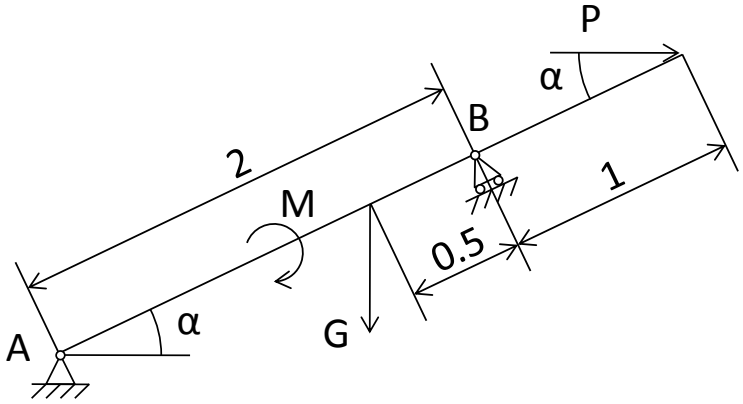

Figure 1.30.

1.2 SAMPLE PROBLEM

Define the reaction forces in support *A* and rod *CD* of the construction schematically shown in Figure 1.31.

G = 10 kN; *P* = 5 kN; *M* = 8 kN *m*; *q* = 0.5 kN/m; *a* = 30°. The sizes are in meters.

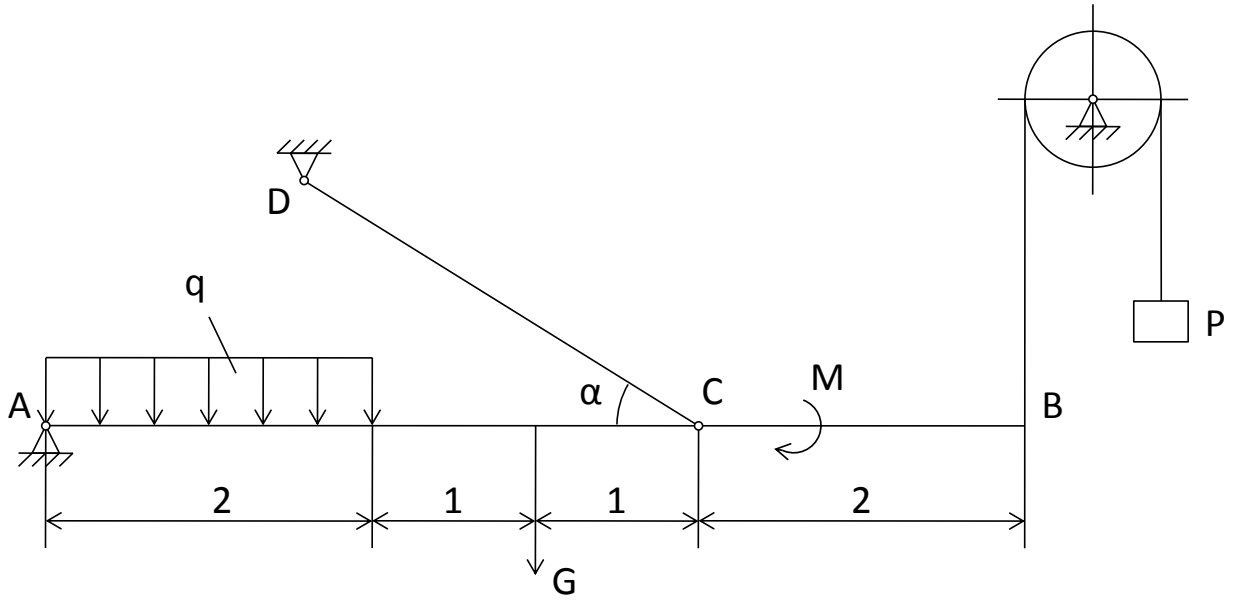

Figure 1.31.

1.3 SOLUTION

Let's consider the equilibrium of the forces applied to the stud *AB*. Remove the supports: pin support at the point *A*, the member *CD,* and the string attached to point *B*. The actions of the support are replaced by the appropriate reaction forces (Figure 1.32). Because the direction of the reaction force of the pin *A* is unknown, we need to determine its components X_A and Y_A. We also show the reaction S_{CD} in member *CD* and the reaction *S* in the string, which is by magnitude equal to *P*. Evenly distributed load of the intensity *q* is replaced by the concentrated force *Q*, which is equal: $Q = 2 \cdot q = 2 \cdot 0.5 = 1$ kN and applied in the center of gravity of the distributed forces.

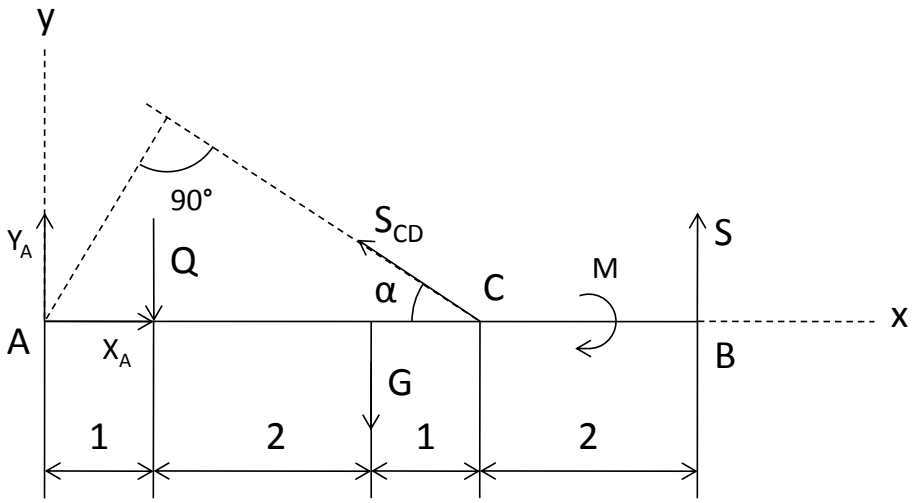

Figure 1.32.

Three equilibrium equations can be written for the plane (2D) system of forces applied to the system:

$$\sum M_{iA} = 0; -Q \cdot 1 - G \cdot 3 + S_{CD} \cdot 4 \sin 30^\circ - M + S \cdot 6 = 0 \tag{1.1}$$

$$\sum X_i = 0; X_A - S_{CD} \cos 30^\circ = 0 \tag{1.2}$$

$$\sum Y_i = Y_A - Q - G + S_{CD} \cos 60^\circ + S = 0 \tag{1.3}$$

From Equation (1.1):

$$S_{CD} = \frac{Q \cdot 1 + G \cdot 3 + M - S \cdot 6}{4 \sin 30^\circ} = \frac{1 \cdot 1 + 10 \cdot 3 + 8 - 5 \cdot 6}{4 \cdot 0.5} = 4.5 \text{ kN}.$$

From Equation (1.2):

$$X_A = S_{CD} \cos 30^\circ = 4.5 \cdot 0.866 = 3.90 \text{ kN}.$$

From Equation (1.3):

$$Y_A = Q + G - S_{CD} \cos 60^\circ - S = 1 + 10 - 4.5 \cdot 0.5 - 5 = 3.75 \text{ kN}.$$

The values of X_A, Y_A, and S_{CD} are positive. It means the assumed directions of these forces coincide with their true directions.