Structural Analysis III

Qualitative Analysis

2009/10

Dr. Colin Caprani

Contents

1. Introduction

1.1 Background

The ability to 'see' and interpret structural behaviour is a core ability of a structural engineer. At the initial stage of a structural scheme design, we are not interested in numbers, or amounts, only the sense of a load effect. Some examples of what we mean by sense are:

- Is there tension on the top or bottom of a beam?
- Does the tip of a cantilever deflect up or down?
- Is the moment reaction clockwise or anti-clockwise?

Getting this level of analysis right is not only the first step, but the most important step. If we don't get this level right, then the answers to a more complicated analysis will be meaningless.

The ability to get the right answers to this level is called *Structural Intuition*. The better your structural intuition, the better you will be a designer. This ability reduces errors both in design practice but also whilst in college: since you will already 'see' the answer it is easier to catch errors in calculations.

1.2 Reading Material

Some good books on structural behaviour are:

- Brohn, D., *Understanding Structural Analysis*, 4th Edn., New Paradigm Solutions, 2005.
- Jennings, A., *Structures: from theory to practice*, Spon Press, 2004.
- Ji, T., and Bell, A., *Seeing and Touching Structural Concepts*, Taylor & Francis, 2008.
- Hilson, B., *Basic Structural Behaviour: Understanding Structures from Models*, Thomas Telford, 1993.
- Pippard, A.J.S., *The Experimental Study of Structures*, Edward Arnold & Co., London, 1947.
- I.Struct.E., *Qualitative Analysis of Structures*, London, 1989.

Due to its importance, the Ove Arup Foundation sponsored the report: *The Teaching of Structural Analysis* by Prof. Ian May and Dr. David Johnson. It is accessible here: http://www.jbm.org.uk/uploads/StructuralAnalysiswithCover.pdf.

A summarized version of the report appeared in *The Structural Engineer*, Vol.81, No.7, 2003, p.33-37, available at this link: http://www.istructe.org/thestructuralengineer/Abstract.asp?PID=7904

1.3 Software

In developing your structural intuition, it is very helpful to model structures using a appropriate computer program – especially when the structure behaves counter-intuitively. Most structural analysis programs today are extremely complex with many options and capabilities and this can often obscure the modelling process.

An appropriate program (for a few reasons) is *LinPro* – freely available from www.line.co.ba. You should install *LinPro* on your own computer. Also, it is installed on the computers in Rm 392.

The program is intuitive to use and comes with a reasonable help file. If you have any difficulties using the program, please ask the lecturer.

2. Methods in Qualitative Analysis

2.1 Main Points

The following are some points that will help you carry out the analyses:

- To find a support reaction, remove the restraint offered by the reaction and draw the deflected shape of the resulting structure. Apply the support reaction in such to as to bring the structure back to where it should be.
- Use *Points of Certainty* – where you know the deflected position, for example at a support the deflection is zero, and usually the structure moves away from the applied load (though there are rare exceptions).
- Remember the basic moment = force × distance. Also recall the shapes of BMD and SFD under the different types of loading (rectangular, triangular, parabolic).
- Remember, fixed supports will have a moment reaction, pinned supports will not, though there may be an external moment applied at a pinned support.
- There is zero bending moment at a hinge.
- Keep in mind: deflections are always small and we neglect the self weight of the structures – only analyse for the loads shown.
- Rigid joints in frames must keep the same angle as they rotate.
- No transverse load or end shear force on a frame member means there is constant BM along the member (constant may equal zero).
- Remember: shear is rate of change of moment.
- For unbraced frames, only symmetrical such frames symmetrically loaded will not sway.
- Members with no bending moments remain straight, but may move.
- Deflected shapes are always very smooth curves, except at a hinge.

3. Problems

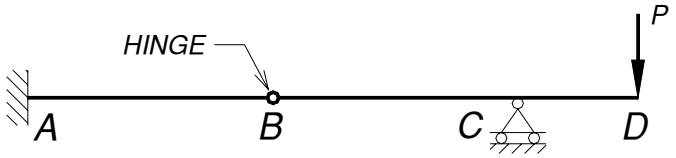
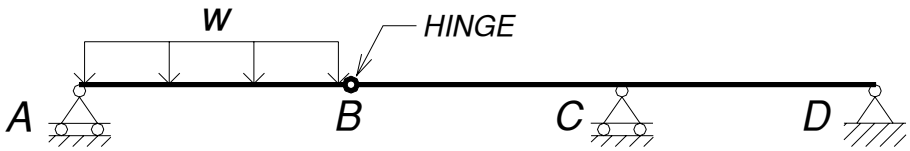
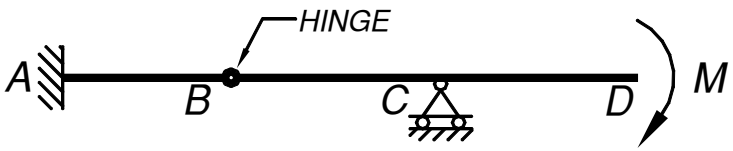
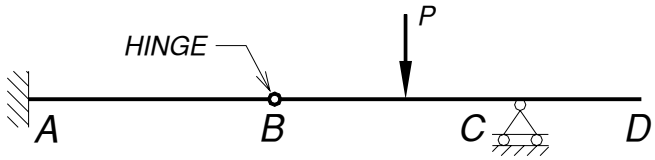
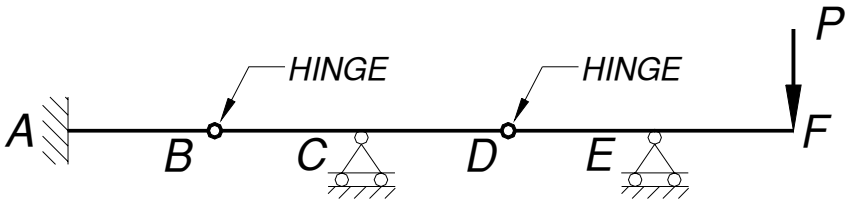
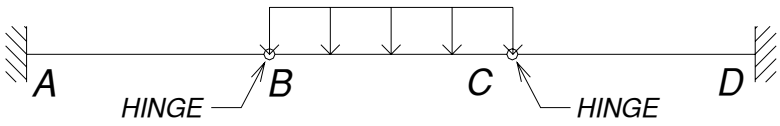
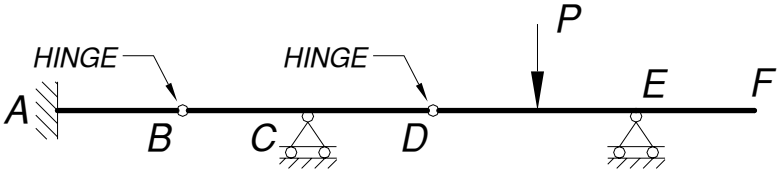
3.1 Introduction

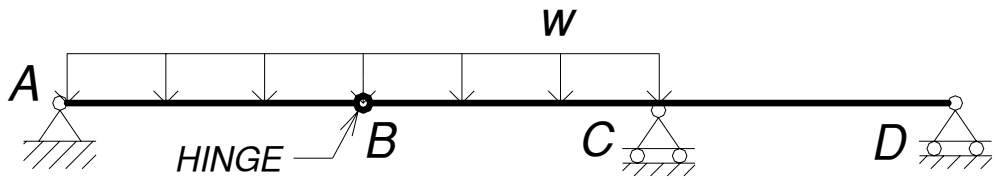
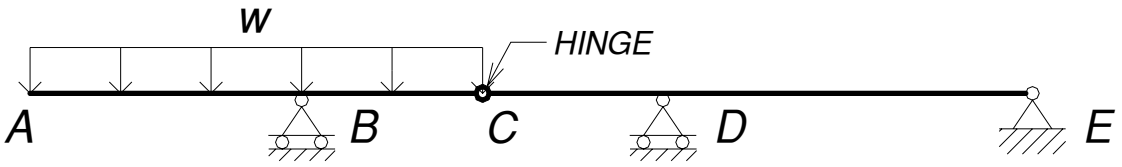
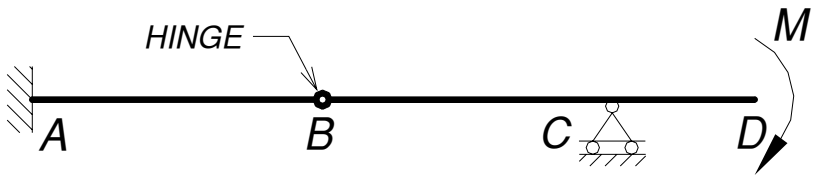
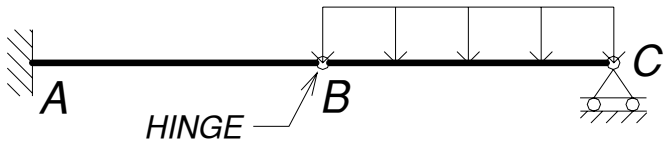
There is no better way to learn qualitative analysis than by practice. So here follows a good variety of determinate and indeterminate structures for analysis.

For each of the following structures, determine the:

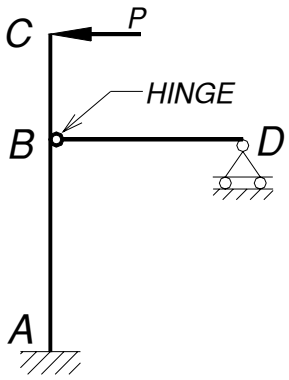
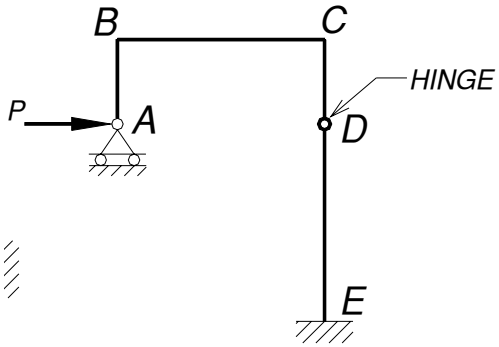
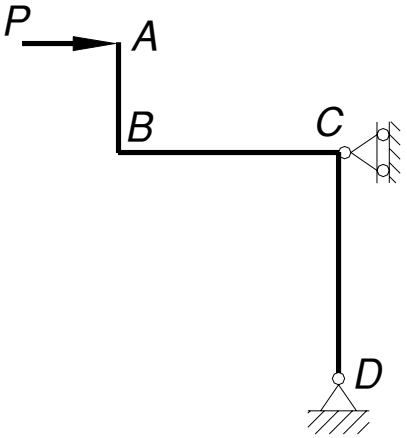
- Reactions;
- Bending moment diagram;
- Shear force diagram;
- Axial force diagram;
- Deflected shape.

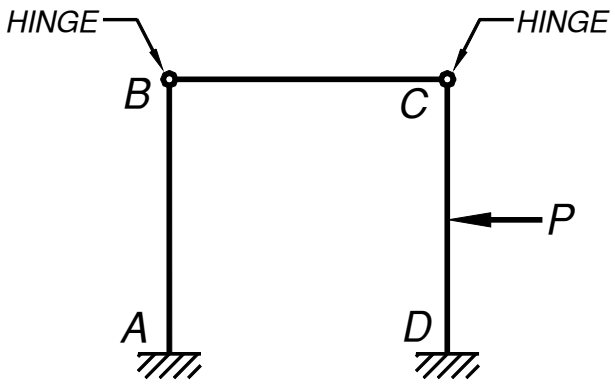
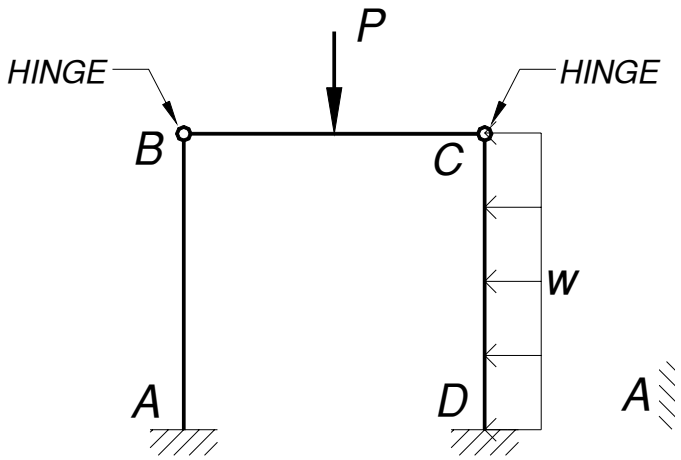
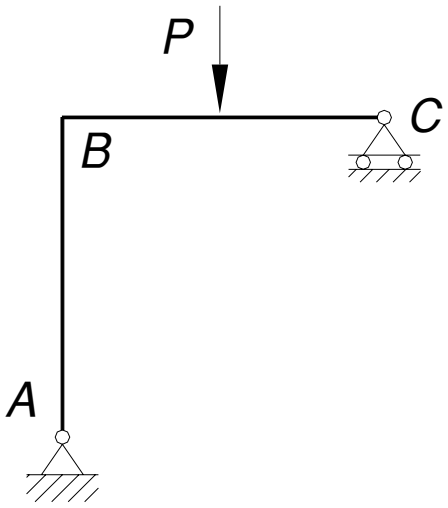
3.2 Statically Determine Beams

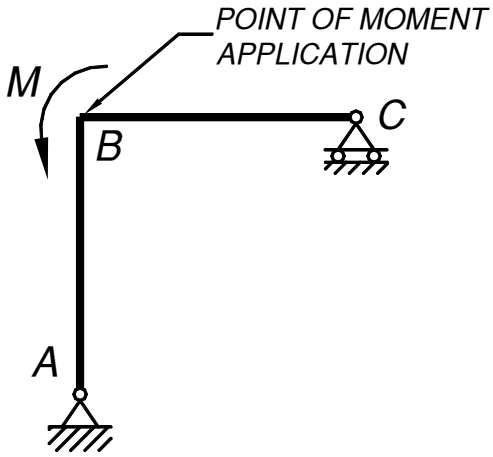
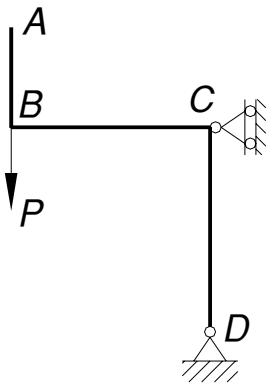
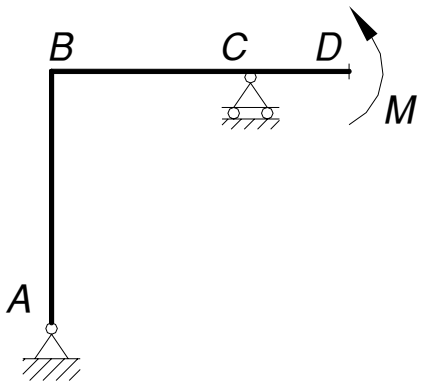
1	
2	
3	
4	
5	
6	
7	

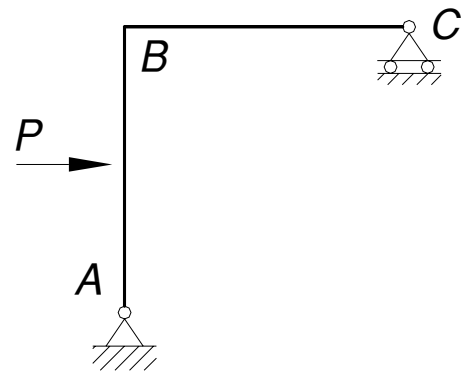
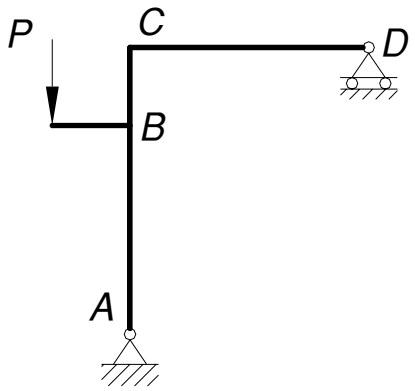
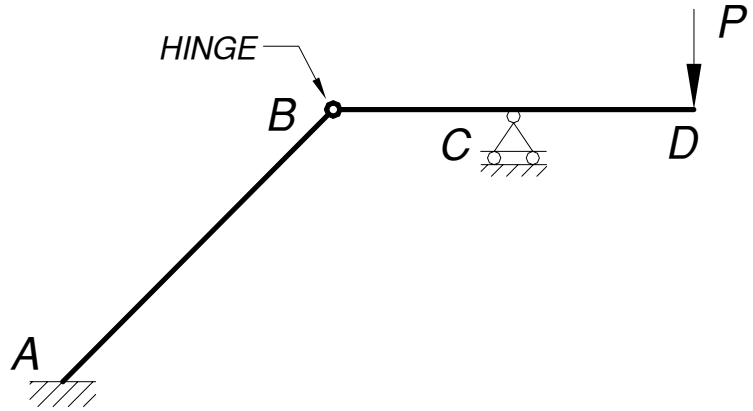
8	 w A HINGE B C D
9	 w HINGE A B C D E
10	 HINGE M A B C D
11	 A HINGE B C

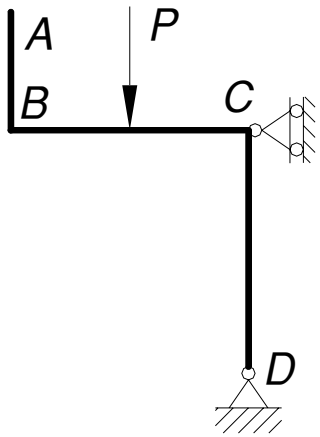
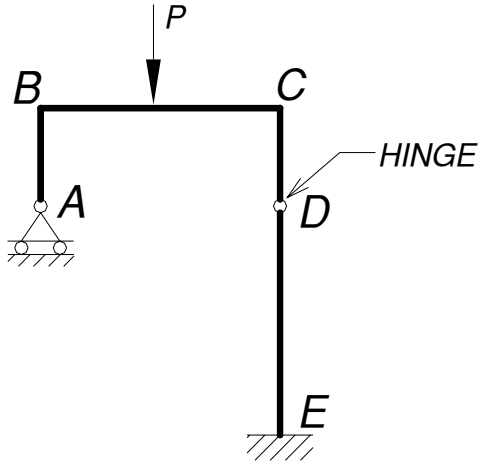
3.3 Statically Determinate Frames

12	
13	
14	

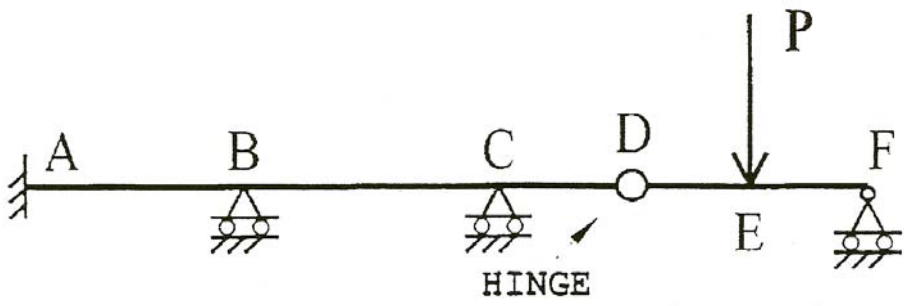
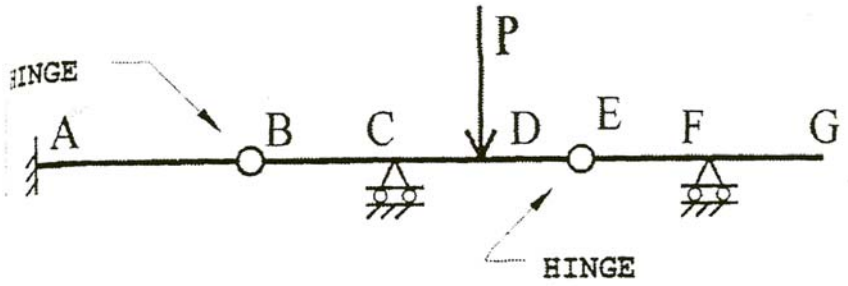
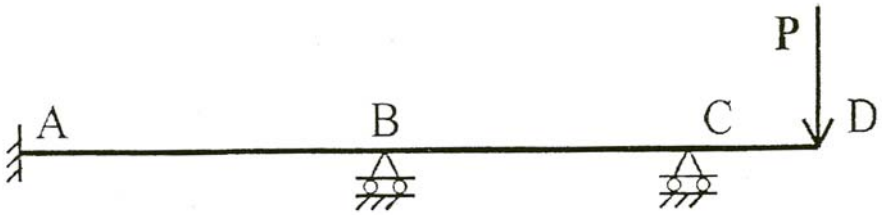
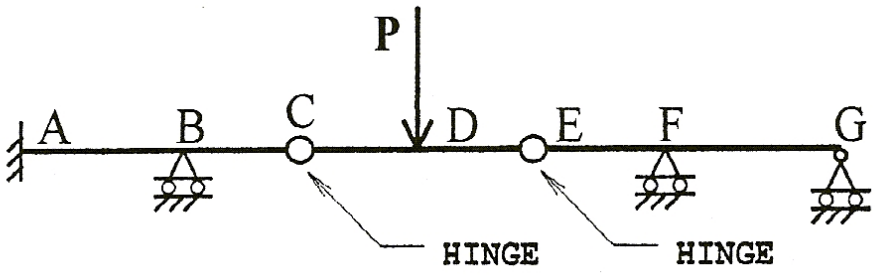
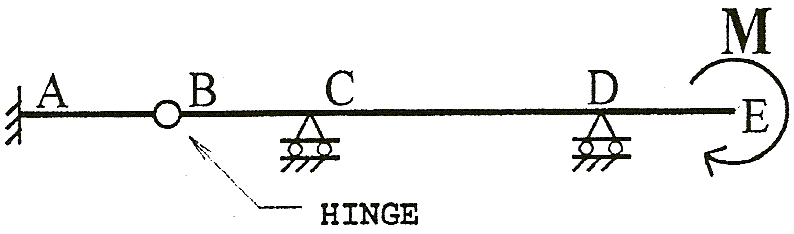
15	 HINGE HINGE B C P A D
16	 P HINGE HINGE B C w A D A
17	 P C B A

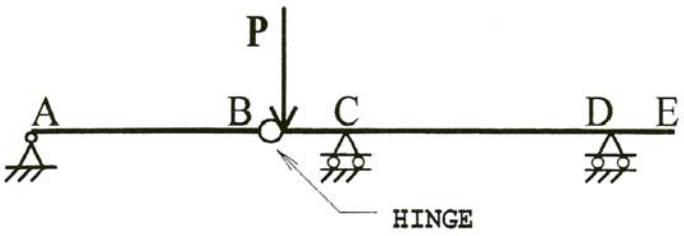
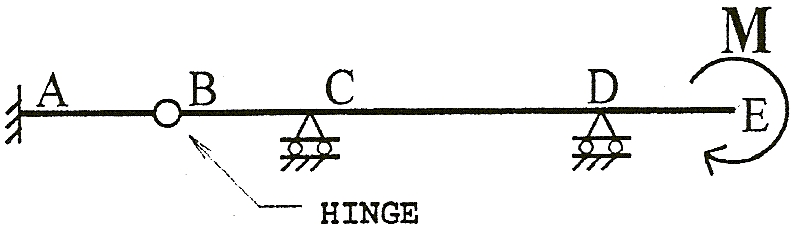
18	 POINT OF MOMENT APPLICATION M B C A
19	 A B C P D
20	 B C D M A

21	
22	
23	

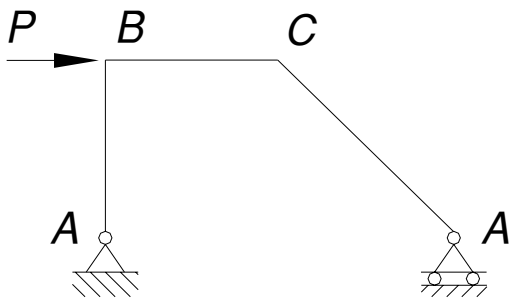
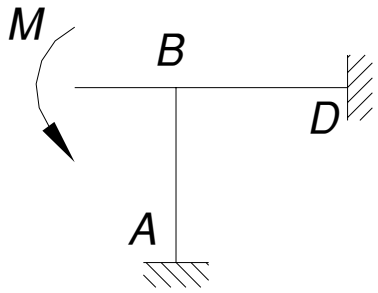
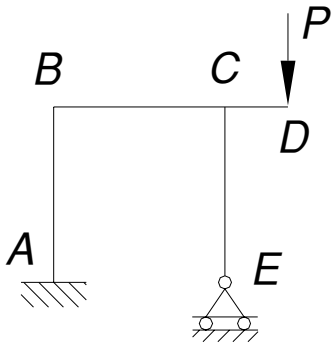
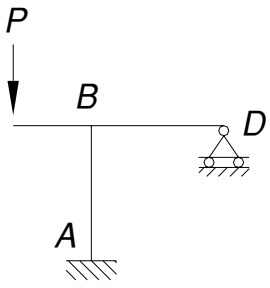
24	
25	

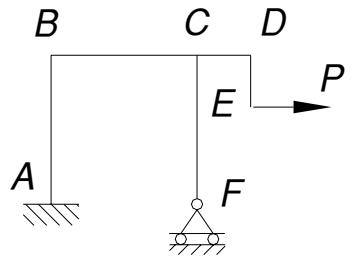
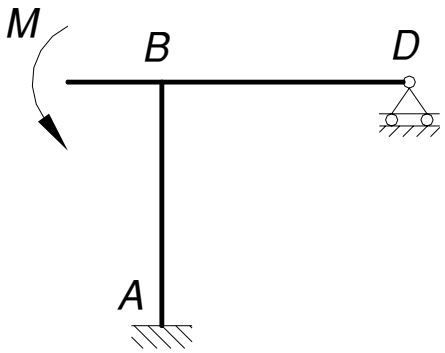
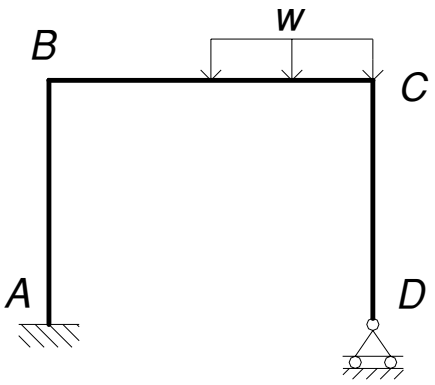
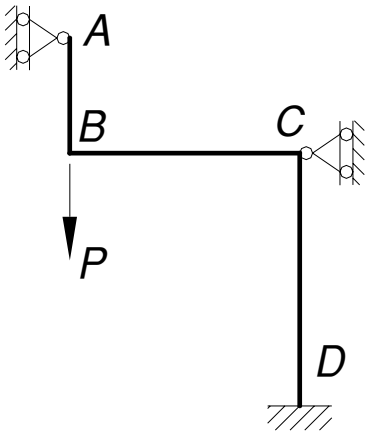
3.4 Statically Indeterminate Beams

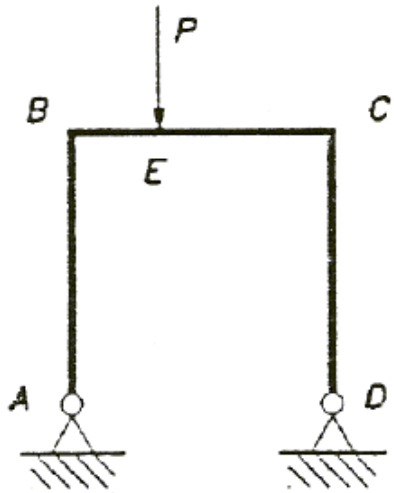
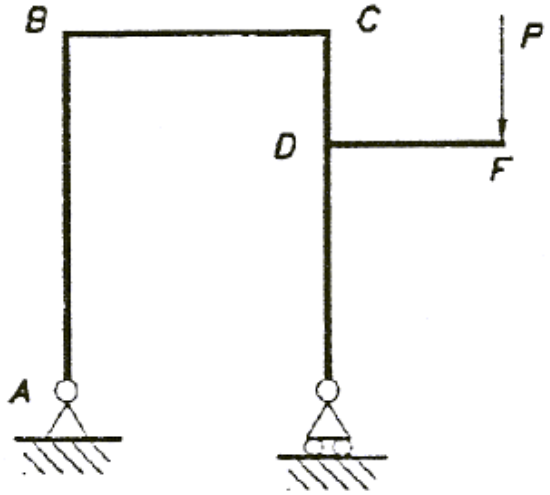
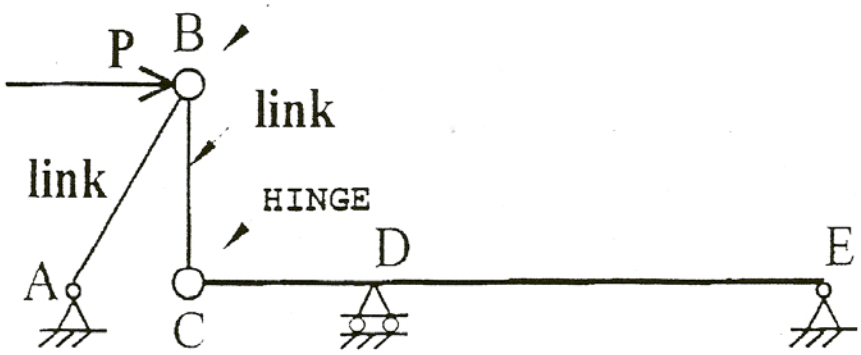
26	
27	
28	
29	
30	

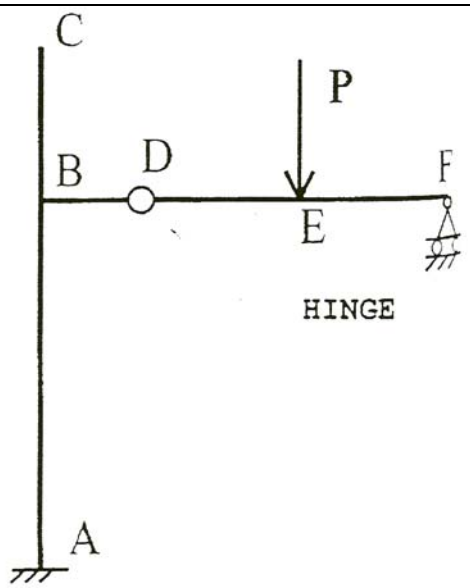
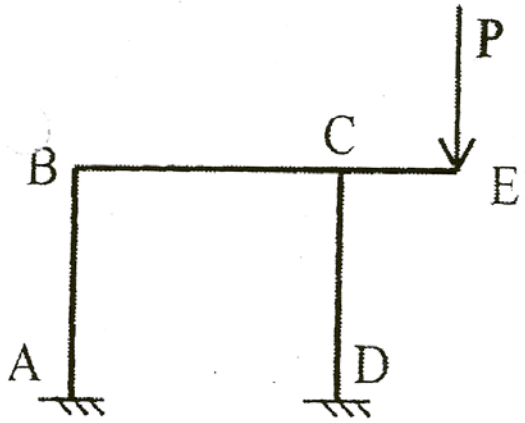
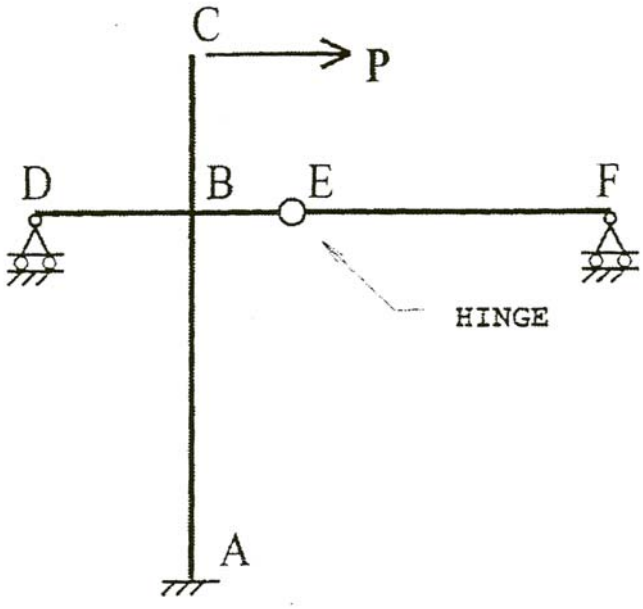
31	
32	

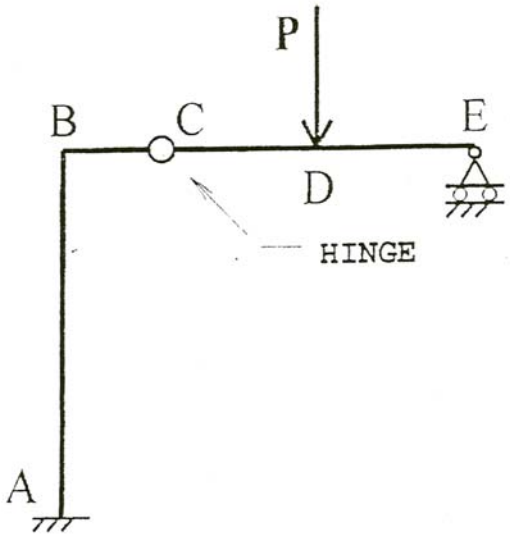
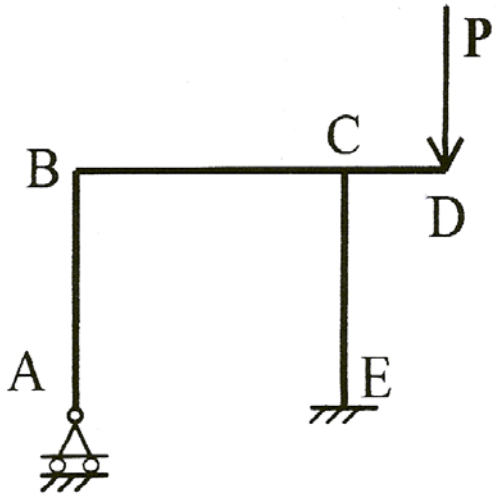
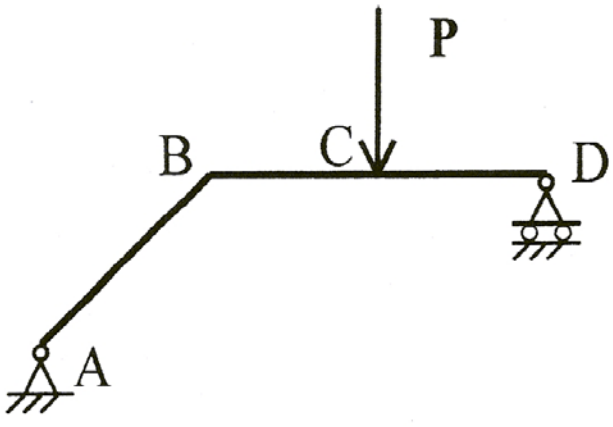
3.5 Statically Indeterminate Frames

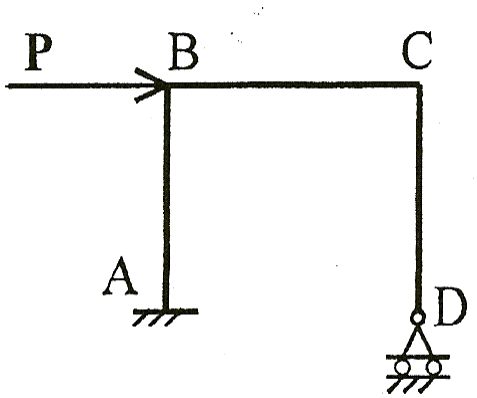
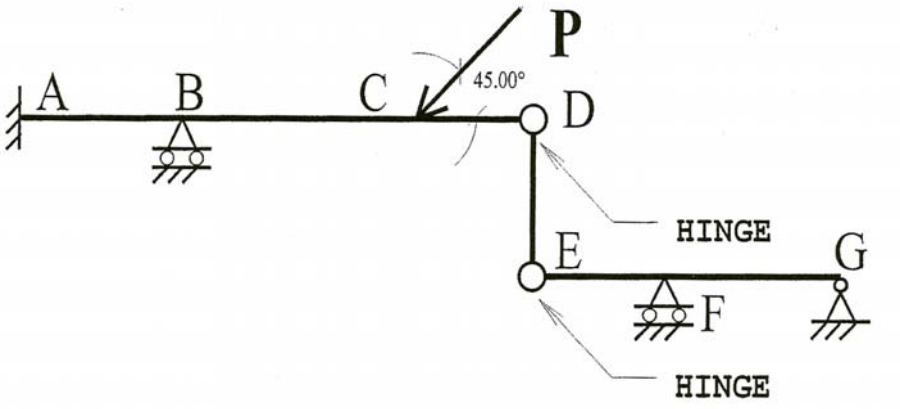
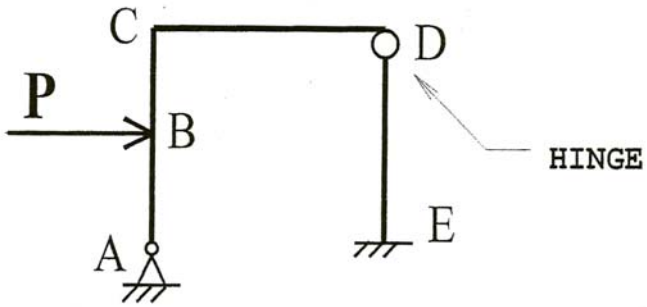
33	
34	
35	
36	

37	 B C D P E A F
38	 M B D A
39	 w B C A D
40	 A B C P D

41	 P B C E A D
42	 B C P D F A
43	 P B link link HINGE A C D E

44	 C P B D F E HINGE A
45	 P C B E A D
46	 C P D B E F HINGE A

47	 P B C E D HINGE A
48	 P C B D A E
49	 P B C D A

50	 P B C A D
51	 P 45.00° A B C D HINGE E G F HINGE
52	 C D P B HINGE E A