5.1 Constraints and Static Determinacy
1. In each case, determine if the beam is partially, improperly, or properly constrained.
5.1 Constraints and Static Determinacy Example 1, page 2 of 9

Definitions: a rigid body in two dimensions is said to be

**Partially constrained**, if it has two or fewer reaction components (There are *not enough reactions* to prevent motion under all possible loading conditions);

**Improperly constrained**, if it has three or more reaction components and either a) the reaction forces are all parallel, or b) the lines of action of the reaction forces intersect at a common point, and no couple moment is present (There are *enough reactions*, but they are *not properly arranged* to prevent motion under all possible loading conditions); and

**Properly constrained**, if it is neither partially nor improperly constrained (There are *enough reactions* and they are *properly arranged* to prevent motion under all possible loading conditions):
5.1 Constraints and Static Determinacy Example 1, page 3 of 9

a)

Show the reactions. But do not show the applied 2-kN force: the reaction forces, not the applied forces, determine the constraints of the body.

1. Show the reactions. But do not show the applied 2-kN force: the reaction forces, not the applied forces, determine the constraints of the body.

2. Two or fewer reactions?
   No. Conclusion: not partially constrained.
5.1 Constraints and Static Determinacy Example 1, page 4 of 9

All reactions parallel?  
Yes. Conclusion:
  improperly constrained  ← Ans.
  (Horizontal translation not prevented.)
Two or fewer reactions?

No. Conclusion: not partially constrained.

Show the reactions.
5.1 Constraints and Static Determinacy Example 1, page 6 of 9

3 All reactions parallel?
   No. Conclusion: can't translate
   (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

4 Lines of action intersect in common point?
   Yes but a moment reaction is also present and it prevents rotation. Conclusion: can't rotate.

5 Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained. Ans. All motion is prevented.
5.1 Constraints and Static Determinacy Example 1, page 7 of 9

c)

Show the reactions.

1. Show the reactions.

2. Two or fewer reactions?
   No. Conclusion: not partially constrained.
5.1 Constraints and Static Determinacy Example 1, page 8 of 9

3 All reactions parallel?  
No. Conclusion: can't translate (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

4 Lines of action intersect in common point?  
No. Conclusion: can't rotate (For example, $R_A$ prevents rotation about point B).

5 Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained ← Ans.

All motion is prevented.
5.1 Constraints and Static Determinacy Example 1, page 9 of 9

d)

Show the reactions.

Two or fewer reactions?
Yes. Conclusion:
partially constrained
Ans.
(Horizontal translation is not prevented.)
5.1 Constraints and Static Determinacy Example 2, page 1 of 9

2. In each case, determine if the rigid body is partially, improperly, or properly constrained.

a) \[ \text{A} \] \quad \text{B} \quad \text{C} \]
\[ \begin{array}{c}
\text{A} \\
\text{B} \\
\text{C} \\
\text{D}
\end{array} \]

6 kN-m

b) \[ \text{A} \] \quad \text{B} \quad \text{C} \quad \text{D} \]

3 kN

\[ \begin{array}{c}
\text{A} \\
\text{B} \\
\text{C} \\
\text{D}
\end{array} \]

45°

300 N

\[ \begin{array}{c}
\text{A} \\
\text{B} \\
\text{C} \\
\text{D}
\end{array} \]

4 m

4 m

45°
5.1 Constraints and Static Determinacy Example 2, page 2 of 9

Definitions: a rigid body in two dimensions is said to be

**Partially constrained**, if it has two or fewer reaction components (There are *not enough reactions* to prevent motion under all possible loading conditions);

**Improperly constrained**, if it has three or more reaction components and either a) the reaction forces are all parallel, or b) the lines of action of the reaction forces intersect at a common point, and no couple moment is present (There are *enough reactions*, but they are *not properly arranged* to prevent motion under all possible loading conditions); and

**Properly constrained**, if it is neither partially nor improperly constrained (There are *enough reactions* and they are *properly arranged* to prevent motion under all possible loading conditions):
a) Show the reactions.

1. Show the reactions.

2. Two or fewer reactions?
   No. Conclusion: not partially constrained.
All reactions parallel? No. Conclusion: can't translate (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

Lines of action intersect in common point? Yes (at point A) but a moment reaction is also present and it prevents rotation. Conclusion: can't rotate.

Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained ← Ans.

All motion is prevented.
5.1 Constraints and Static Determinacy Example 2, page 5 of 9

b) A

\[3 \text{ kN}\]

1. Show the reactions.

2. Two or fewer reactions?
   No. Conclusion: not partially constrained.
5.1 Constraints and Static Determinacy Example 2, page 6 of 9

Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained  \( \rightarrow \) Ans.

All motion is prevented.

3 All reactions parallel? No. Conclusion: can't translate (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

4 Lines of action intersect in common point? No. Conclusion: can't rotate.

5 Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained  \( \rightarrow \) Ans.

All motion is prevented.
5.1 Constraints and Static Determinacy Example 2, page 7 of 9

3) Show the reactions.

Two or fewer reactions?
No. Conclusion: not partially constrained.
5.1 Constraints and Static Determinacy Example 2, page 8 of 9

All reactions parallel?

No. Conclusion: can't translate
(There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).
Lines of action intersect in common point? 
Yes. Conclusion:

improperly constrained ← Ans.

Small (actually infinitesimal) rotation about D is not prevented. The short links at A and C would have to change orientation before they could restrain the rotation; they could not restrain the rotation in their original position.
3. In each case, determine if the rectangular plate is partially, improperly, or properly constrained.
5.1 Constraints and Static Determinacy Example 3, page 2 of 9

Definitions: a rigid body in two dimensions is said to be

**Partially constrained,** if it has two or fewer reaction components (There are *not enough reactions* to prevent motion under all possible loading conditions);

**Improperly constrained,** if it has three or more reaction components and either a) the reaction forces are all parallel, or b) the lines of action of the reaction forces intersect at a common point, and no couple moment is present (There are *enough reactions,* but they are *not properly arranged* to prevent motion under all possible loading conditions); and

**Properly constrained,** if it is neither partially nor improperly constrained (There are *enough reactions* and they are *properly arranged* to prevent motion under all possible loading conditions):
Show the reactions. But do not show the applied 10-kN force: the reaction forces, not the applied forces, determine the constraints of the body.

Two or fewer reactions?
No. Conclusion: not partially constrained.
All reactions parallel?
No. Conclusion: can't translate (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

Lines of action intersect in common point?
No. Conclusion: can't rotate (For example, \( R_D \) prevents rotation about A).

Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained → Ans.

All motion is prevented.
Two or fewer reactions?  
Yes. Conclusion:  
partially constrained  
Ans.  
Small (actually infinitesimal) rotation about B is not prevented.
c) Two or fewer reactions?
   No. Conclusion: not partially constrained.

Show the reactions.
All reactions parallel?

No. Conclusion: can't translate
(There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

Lines of action intersect in common point?

No. Conclusion: can't rotate (For example, \(R_D\) prevents rotation about \(A\)).

Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained \(\leftarrow\) Ans.

All motion is prevented.
Two or fewer reactions?
No. Conclusion: not partially constrained.
5.1 Constraints and Static Determinacy Example 3, page 9 of 9

All reactions parallel?
No. Conclusion: can't translate
(There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

Lines of action intersect in common point?
No. Conclusion: can't rotate (For example, \( R_D \) prevents rotation about A).

Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained ← Ans.

All motion is prevented.
4. In each case, determine if the rectangular plate is partially, improperly, or properly constrained.

a)  

b)  

900 N

4.1 Constraints and Static Determinacy Example 4, page 1 of 8
5.1 Constraints and Static Determinacy Example 4, page 2 of 8

Definitions: a rigid body in two dimensions is said to be

**Partially constrained**, if it has two or fewer reaction
components (There are *not enough reactions* to prevent
motion under all possible loading conditions);

**Improperly constrained**, if it has three or more reaction
components and either a) the reaction forces are all parallel,
or b) the lines of action of the reaction forces intersect at a
common point, and no couple moment is present (There are
*enough reactions*, but they are *not properly arranged* to
prevent motion under all possible loading conditions); and

**Properly constrained**, if it is neither partially nor
improperly constrained (There are *enough reactions* and they
are *properly arranged* to prevent motion under all possible
loading conditions):
5.1 Constraints and Static Determinacy Example 4, page 3 of 8

a) Two or fewer reactions?
   No. Conclusion: not partially constrained.

Show the reactions.

2 Two or fewer reactions?
   No. Conclusion: not partially constrained.
All reactions parallel?  
Yes.  Conclusion:

improperly constrained

Ans.

(Horizontal translation is not prevented.)
### 5.1 Constraints and Static Determinacy Example 4, page 5 of 8

b)

1. **Show the reactions.**
   - **R<sub>C</sub>**
   - **R<sub>A</sub>**
   - **R<sub>B</sub>**

2. **Two or fewer reactions?**
   - No. Conclusion: not partially constrained.

3. **All reactions parallel?**
   - No. Conclusion: can't translate (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).
Lines of action intersect in common point? 
Yes. Conclusion: 
improperly constrained
Ans.
Small (actually infinitesimal) rotation about D is not prevented.
5.1 Constraints and Static Determinacy Example 4, page 7 of 8

Two or fewer reactions?
No. Conclusion: not partially constrained.

Show the reactions.

① Show the reactions.

② Two or fewer reactions?
No. Conclusion: not partially constrained.
5.1 Constraints and Static Determinacy Example 4, page 8 of 8

All reactions parallel? Yes. Conclusion: improperly constrained ← Ans.

Translation in a direction 45° from the horizontal is not prevented. The short links at A, B, and D would have to change orientation before they could restrain the translation; they could not restrain the translation in their original position.
5.1 Constraints and Static Determinacy Example 5, page 1 of 7

5. In each case, determine if the rigid body is partially, improperly, or properly constrained.

a) 200 N

b) 6 N
20 N
Definitions: a rigid body in two dimensions is said to be

**Partially constrained**, if it has two or fewer reaction components (There are *not enough reactions* to prevent motion under all possible loading conditions);

**Improperly constrained**, if it has three or more reaction components and either a) the reaction forces are all parallel, or b) the lines of action of the reaction forces intersect at a common point, and no couple moment is present (There are *enough reactions*, but they are *not properly arranged* to prevent motion under all possible loading conditions); and

**Properly constrained**, if it is neither partially nor improperly constrained (There are *enough reactions* and they are *properly arranged* to prevent motion under all possible loading conditions):
5.1 Constraints and Static Determinacy Example 5, page 3 of 7

a) Show the reactions. But do not show the applied 200-N force: the reaction forces, not the applied forces, determine the constraints of the body.

Two or fewer reactions? No. Conclusion: not partially constrained.

Semicircles with common center at O
All reactions parallel?
No. Conclusion: can't translate
(There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).
4. Lines of action intersect in common point?
   Yes. Conclusion:
   improperly constrained

Ans.
Rotation about O is not prevented.
5.1 Constraints and Static Determinacy Example 5, page 6 of 7

b) Two or fewer reactions? No. Conclusion: not partially constrained.

① Show the reactions.

② Two or fewer reactions?
   No. Conclusion: not partially constrained.
All reactions parallel?
No. Conclusion: can't translate
(There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).

Lines of action intersect in common point?
No. Conclusion: can't rotate (For example, RD prevents rotation about A).

Because the body is neither partially constrained nor improperly constrained (can neither translate nor rotate), it is properly constrained Ans.
All motion is prevented.
6. In each case, determine if the rigid body is partially, improperly, or properly constrained.

a) Collar slides freely on smooth rod

b) Pin slides freely in smooth slot
Definitions: a rigid body in two dimensions is said to be

**Partially constrained**, if it has two or fewer reaction components (There are *not enough reactions* to prevent motion under all possible loading conditions);

**Improperly constrained**, if it has three or more reaction components and either a) the reaction forces are all parallel, or b) the lines of action of the reaction forces intersect at a common point, and no couple moment is present (There are *enough reactions*, but they are *not properly arranged* to prevent motion under all possible loading conditions); and

**Properly constrained**, if it is neither partially nor improperly constrained (There are *enough reactions* and they are *properly arranged* to prevent motion under all possible loading conditions):
5.1 Constraints and Static Determinacy Example 6, page 3 of 7

a)

Show the reactions.  

Two or fewer reactions?  
No. Conclusion: not partially constrained.
All reactions parallel?
Yes. Conclusion:

improperly constrained

Ans.

(Horizontal translation is not prevented.)
5.1 Constraints and Static Determinacy Example 6, page 5 of 7

b)

Collar slides freely on smooth rod

Pin slides freely in smooth slot

50 N
5.1 Constraints and Static Determinacy Example 6, page 6 of 7

1) Show the reactions.

Two or fewer reactions?
No. Conclusion: not partially constrained.

3) All reactions parallel?
No. Conclusion: can't translate
(There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).
Lines of action intersect in common point?  
Yes. Conclusion: 
improperly constrained ← Ans.

Small (actually infinitesimal) rotation 
about B is not prevented. The collar at A 
and the pin at C would have to move 
slightly before they could restrain the 
rotation; they could not restrain the 
rotation in their original position.
5.1 Constraints and Static Determinacy Example 7, page 1 of 4

7. Determine if the rigid body is partially, improperly, or properly constrained.
Definitions: a rigid body in two dimensions is said to be

**Partially constrained**, if it has two or fewer reaction components (There are *not enough reactions* to prevent motion under all possible loading conditions);

**Improperly constrained**, if it has three or more reaction components and either a) the reaction forces are all parallel, or b) the lines of action of the reaction forces intersect at a common point, and no couple moment is present (There are *enough reactions*, but they are *not properly arranged* to prevent motion under all possible loading conditions); and

**Properly constrained**, if it is neither partially nor improperly constrained (There are *enough reactions* and they are *properly arranged* to prevent motion under all possible loading conditions):
5.1 Constraints and Static Determinacy Example 7, page 3 of 4

1. Show the reactions.

2. Two or fewer reactions?
   No. Conclusion: not partially constrained.

3. All reactions parallel?
   No. Conclusion: can't translate (There is no direction in which the body could translate without the translation being opposed by one or more of the reaction forces).
5.1 Constraints and Static Determinacy Example 7, page 4 of 4

Lines of action intersect in common point?  Yes. Conclusion:

improperly constrained  ←Ans.

Small (actually infinitesimal) rotation about E is not prevented. The short links at A, B, C, and D would have to change orientation before they could restrain the rotation; they could not restrain the rotation in their original position.
5.1 Constraints and Static Determinacy Example 8, page 1 of 7

8. In each case, determine if the rigid body is statically determinate or indeterminate.

a)

![Diagram a]

b)

![Diagram b]
Definitions: a rigid body in equilibrium under a given loading is said to be

**Statically determinate**, if a unique set of reaction components can be found by solving the equations of statics alone (No additional equations—such as are introduced in a course in mechanics of materials—are needed); or

**Statically indeterminate**, if not all reaction components can be found uniquely by solving the equations of statics alone.
5.1 Constraints and Static Determinacy Example 8, page 3 of 7

1) Draw a free-body diagram.

There are four unknown reactions: $A_x$, $A_y$, $B_y$, and $C_y$. But there are at most three equations of equilibrium for a body in two dimensions. Because there are more unknowns than equations, a unique solution cannot be found; the rigid body is statically indeterminate. ← Ans.

2) Observation No. 1: In situations such as this, it is tempting to write four equilibrium equations by, for example, writing two force equations and moment equations about two different points. But this approach will not work, as will now be shown.
Write four equilibrium equations:

\[ F_x = 0: \ Ax + 6 \text{ kip} = 0 \]  
\[ F_y = 0: \ Ay + By + Cy = 0 \]  
\[ M_A = 0: \ By(5 \text{ ft} + 3 \text{ ft}) + Cy(5 \text{ ft} + 3 \text{ ft} + 4 \text{ ft}) - (6 \text{ kip})(4 \text{ ft}) = 0 \]  
\[ M_C = 0: \ Ax(4 \text{ ft}) - Ay(5 \text{ ft} + 3 \text{ ft} + 4 \text{ ft}) - By(4 \text{ ft}) = 0 \]

We will now show that Eq. 4 is not independent of Eqs. 1-3. Multiply Eq. 1 by 4, Eq. 2 by -12, Eq. 3 by 1 and add the results to obtain

\[ 4(Ax + 6) - 12(Ay + By + Cy) + [By(5 + 3) + Cy(5 + 3 + 4) - (6)(4)] = 0 \]

The last equation simplifies to

\[ Ax(4) - Ay(12) - By(4) + Cy(-12 + 5 + 3 + 4) + [4(6) - 6(4)] = 0 \]

which is equivalent to Eq. 4. This is a general result: You can write as many equilibrium equations as you want, but at most only three of them will be independent (for two-dimensional problems).
Observation No. 2: The difficulty is not that we can't find a solution. We can find as many solutions as we want. For example, here are two:

Solution No. 1: \( A_x = -6 \) kip, \( A_y = -3 \) kip, \( B_y = 3 \) kip, and \( C_y = 0 \).

Solution No. 2: \( A_x = -6 \) kip, \( A_y = -2 \) kip, \( B_y = 0 \), and \( C_y = 2 \) kip.

The difficulty is that we can't find the unique solution, because it is not determined by the equations of statics alone, which is another way of saying that the structure is statically indeterminate. To find the unique solution, we would have to supplement the equations of statics by introducing an equation describing material behavior—the subject of a course in mechanics of materials.
There are three unknown reactions, $A_y$, $B_y$, and $C_y$, and for a body in two dimensions, there are at most three equations of equilibrium, so it appears that the body may be statically determinate. However, let's write the equilibrium equations as a check:

1. Draw a free-body diagram.

2. There are three unknown reactions, $A_y$, $B_y$, and $C_y$, and for a body in two dimensions, there are at most three equations of equilibrium, so it appears that the body may be statically determinate. However, let's write the equilibrium equations as a check:

$$\sum F_x = 0: \quad 0 = 0 \quad (1)$$

$$\sum F_y = 0: \quad A_y + B_y + C_y - 4 \text{ kip} = 0 \quad (2)$$

$$\sum M_A = 0: \quad B_y(5 \text{ ft} + 3 \text{ ft}) + C_y(5 \text{ ft} + 3 \text{ ft} + 4 \text{ ft}) - (4 \text{ kip})(5 \text{ ft}) = 0 \quad (3)$$

Only two of the equations are independent, since Eq. 1 is $0 = 0$. Conclusion: we do not have enough equations to solve for the three reactions, so the rigid body is

- statically indeterminate.

← Ans.
Observation: The reason that the body is statically indeterminate even though there are only three unknown reactions is that the structure is improperly constrained (all reactions are parallel). In general, an improperly constrained body (in equilibrium under a set of loads) is always statically indeterminate because one of the equilibrium equations is always trivial; for example, the sum of forces in the direction perpendicular to the (parallel) reactions reduces to 0 = 0, or the sum of the moments about a point where all the reaction forces intersect reduces to 0 = 0.

A partially constrained body (in equilibrium under a set of loads), on the other hand, may or may not be statically determinate.
5.1 Constraints and Static Determinacy Example 9, page 1 of 4

9. In each case, determine if the rigid body is statically determinate or indeterminate.

a)  

![Diagram a)

b)  

![Diagram b)
Definitions: a rigid body in equilibrium under a given loading is said to be

**Statically determinate**, if a unique set of reaction components can be found by solving the equations of statics alone (No additional equations—such as are introduced in a course in mechanics of materials—are needed); or

**Statically indeterminate**, if not all reaction components can be found uniquely by solving the equations of statics alone.
There are three unknowns reactions, $A_y$, $B_y$, and $C_x$, so the body will be statically determinate if the equilibrium equations are independent. Consider the following equilibrium equations:

1. $\sum F_x = 0: \quad -C_x + 400 \text{ N} = 0$  
2. $\sum F_y = 0: \quad A_y + B_y = 0$  
3. $\sum M_A = 0: \quad B_y(4 \text{ m}) + C_x(2 \text{ m}) - (400 \text{ N})(2 \text{ m} + 1 \text{ m}) = 0$

Solving these equations yields the unique solution:

- $A_y = -100 \text{ N}$, $B_y = 100 \text{ m}$, and $C_x = 400 \text{ N}$

Thus the body is

- statically determinate.  

Answer:

(Ans.)
5.1 Constraints and Static Determinacy Example 9, page 4 of 4

b) There are four unknowns reactions, $A_x$, $A_y$, $D_y$, and $M_A$, and at most three equations of equilibrium exist, so the body is statically indeterminate. ← Ans.

1) Draw a free-body diagram.

2) There are four unknowns reactions, $A_x$, $A_y$, $D_y$, and $M_A$, and at most three equations of equilibrium exist, so the body is statically indeterminate. ← Ans.
5.1 Constraints and Static Determinacy Example 10, page 1 of 6

10. In each case, determine if the rigid body is statically determinate or indeterminate.

a) Collar slides freely on smooth rod

b) 600 N 400 N

c) 40 N

2 m
3 m
3 m
2 m
3 m
3 m
6 m

A
B
C
D
E

45°
5.1 Constraints and Static Determinacy Example 10, page 2 of 6

Definitions: a rigid body in equilibrium under a given loading is said to be

**Statically determinate**, if a unique set of reaction components can be found by solving the equations of statics alone (No additional equations—such as are introduced in a course in mechanics of materials—are needed); or

**Statically indeterminate**, if not all reaction components can be found uniquely by solving the equations of statics alone.
5.1 Constraints and Static Determinacy Example 10, page 3 of 6

1. Draw a free-body diagram.

2. There are four unknown reactions, \( A_x \), \( C_y \), \( D_y \), and \( F_E \), and at most three equations of equilibrium exist, so the body is statically indeterminate.  

\( \leftarrow \text{Ans.} \)
5.1 Constraints and Static Determinacy Example 10, page 4 of 6

b)

1. Draw a free-body diagram.

2. There are two unknown reactions, $C_y$ and $D_y$. Writing equilibrium equations gives:

\[ \sum F_x = 0: \ 0 = 0 \]  \hspace{1cm} (1)

\[ \sum F_y = 0: \ C_y - 600 \text{ N} - 400 \text{ N} + D_y = 0 \]  \hspace{1cm} (2)

\[ \sum M_D = 0: \ C_y(3 \text{ m} + 3 \text{ m}) - (600 \text{ N})(3 \text{ m}) = 0 \]  \hspace{1cm} (3)

Solving these equations gives the unique solution $C_y = 300 \text{ N}$ and $D_y = 700 \text{ N}$, so the body is

\[ \text{statically determinate.} \]

Ans.

3. Observation: There are only two unknown reactions because the body is partially constrained. However, the loading happens to be such that the two nontrivial equations of equilibrium can be satisfied. If the loading consisted of a horizontal load, then Eq. 1 could not be satisfied, and the body would not be in equilibrium.
5.1 Constraints and Static Determinacy Example 10, page 5 of 6

1. Draw a free-body diagram.

2. There are three unknown reactions, $F_A$, $F_B$, and $F_C$.
   Writing equilibrium equations gives
   
   $\pm \sum F_x = 0: \quad F_A \cos \phi - F_C + (40 \text{ N}) \cos \theta = 0 \quad (1)$
   $\uparrow \sum F_y = 0: \quad -F_A \sin \phi - F_B + (40 \text{ N}) \sin \theta = 0 \quad (2)$
   $\nwarrow \sum M_A = 0: \quad -F_B(4 \text{ m}) - F_C(2 \text{ m})$
   $\quad + [(40 \text{ N}) \sin \theta](4 \text{ m} + 2 \text{ m})$
   $\quad - [(40 \text{ N}) \cos \theta](6 \text{ m} - 2 \text{ m}) = 0 \quad (3)$

3. Geometry

   $\phi$
   $\cos \phi = \frac{2}{\sqrt{5}}$
   $\sin \phi = \frac{1}{\sqrt{5}}$

   $\sqrt{10}$
   $\cos \theta = \frac{1}{\sqrt{10}}$
   $\sin \theta = \frac{3}{\sqrt{10}}$
**5.1 Constraints and Static Determinacy Example 10, page 6 of 6**

4) If a calculator is used to invert the matrix of coefficients in the equations, the calculator will return an error message. That is, the equations are redundant and do not have a unique solution. Thus the body is

statically indeterminate. ← Ans.

The source of the redundancy can be seen by extending the lines of action of all the forces and observing that they intersect in a common point. Thus summing moments about this common point would produce the trivial equilibrium equation, $0 = 0$. Hence this body has only two independent equations of equilibrium.