SPH4U UNIVERSITY PHYSICS

DYNAMICS

☞ Connected Objects (P.77-83)

Connected Objects

To avoid using complex mathematical analysis, you can make several assumptions about cables and ropes that support loads.

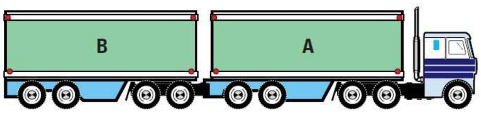
- *The mass of the rope or cable is negligible.*
- *The tension is the same at every point in the rope or cable.*
- *A pulley changes the direction of the tension force only.*

Connected Objects – Horizontal

RECALL!

To analyze the individual forces acting on each part of a train of objects, you need to apply Newton's third law to determine the action-reaction forces between each object. The solution is always a 2-step process.

1. *Consider all the objects to be one mass. Use this single mass to determine the acceleration of the system.*

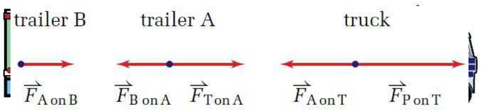


Connected Objects – Horizontal

RECALL!

To analyze the individual forces acting on each part of a train of objects, you need to apply Newton's third law to determine the action-reaction forces between each object. The solution is always a 2-step process.

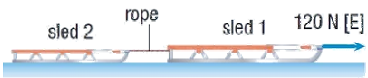
2. *Consider the masses as individual objects, all of which are accelerating at the same rate (as calculated in step 1). Draw a FBD of each mass and then analyze each to determine the action-reaction forces.*



Connected Objects – Horizontal

PRACTICE

1. Two sleds are tied together and pulled east across an icy surface with an applied force of 120 N[E]. The mass of sled 1 is 12 kg and the mass of sled 2 is 8.0 kg. Assume that no friction acts on the sleds.



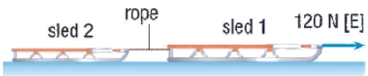
(a) Determine the acceleration of the sleds.

(a) $a = 6.0$ m/s^2[E]

Connected Objects – Horizontal

PRACTICE

1. Two sleds are tied together and pulled east across an icy surface with an applied force of 120 N[E]. The mass of sled 1 is 12 kg and the mass of sled 2 is 8.0 kg. Assume that no friction acts on the sleds.

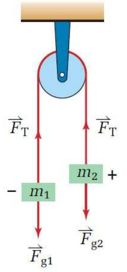


(b) Calculate the magnitude of the tension in the rope.

(b) $F_T = 48$ N

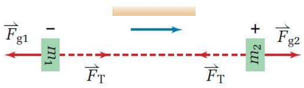
Connected Objects – 2 Hanging Masses

When two hanging objects are connected by a flexible cable or rope that runs over a pulley, such as the two masses shown, they are moving in different directions. However, as you already know, connected objects move as a unit (recall the sled problem). So how can you treat the pair of hanging objects as a unit when they are moving in different directions?



Connected Objects – 2 Hanging Masses

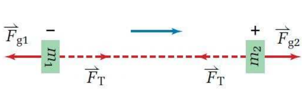
Since the connecting cable or rope changes only the direction of the forces acting on the objects and has no effect on the magnitude of the forces, you can imagine the connected objects as forming a straight line, with left as negative and right as positive.



NOTE!
Make sure that you keep the force arrows in the same relative direction in relation to the objects.

Connected Objects – 2 Hanging Masses

Now you can apply Newton's laws to the objects as a unit or to each object independently.

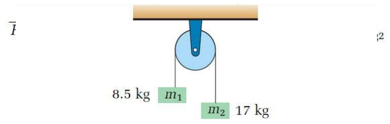


NOTE!
When you treat the objects as a unit you can ignore the tension – it becomes an internal force. However, you must include tension when you analyze the motion of a single object.

Connected Objects – 2 Hanging Masses

PRACTICE

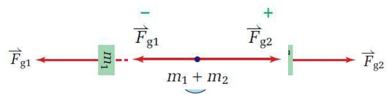
2. Two objects (m_1 = 8.5 kg and m_2 = 17 kg) are connected as shown.
   (a) Draw a FBD of the situation with the directions reassigned.



Connected Objects – 2 Hanging Masses

PRACTICE

2. Two objects (m_1 = 8.5 kg and m_2 = 17 kg) are connected as shown.
   (b) What is the acceleration of the masses?

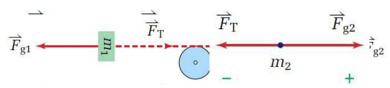


(b) Hint?
- ① draw a FBD for mass 1 and 2 together (F_T disappears)
- ② use ΣF_{net} = ma
- ☞ a = 3.3 m/s² (object 1 up and object 2 down)

Connected Objects – 2 Hanging Masses

PRACTICE

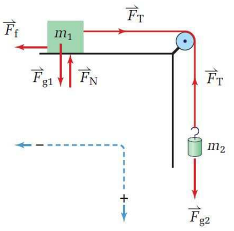
2. Two objects (m_1 = 8.5 kg and m_2 = 17 kg) are connected as shown.
   (c) What is the tension in the rope?



(c) Hint?
- ① draw a FBD for either mass 1 or 2
- ② use "ΣF_{net} = ma" on one of the objects (your choice)
- ☞ F_T = 110 N

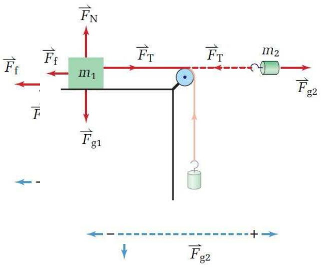
Connected Objects – 1 Hanging Mass

You can approach problems where only one of the objects is hanging in the same way you solved problems with two hanging masses – imagine the connected objects as forming a straight line, with left as negative and right as positive.



Connected Objects – 1 Hanging Mass

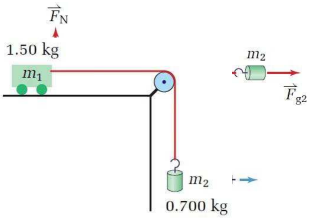
NOTE!
When you visualize the string "straightened," the force of gravity appears to pull down on mass 1, but to the side on mass 2. Although it might look strange, be assured that these directions are correct.



Connected Objects – 1 Hanging Mass

PRACTICE

3. Two objects (m_1 = 1.5 kg and m_2 = 0.70 kg) are connected as shown. Assume object 1 slides without friction.
   (a) Draw a FBD of the situation with the directions reassigned.

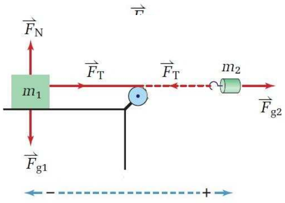


Connected Objects – 1 Hanging Mass

PRACTICE

3. Two objects (m_1 = 1.5 kg and m_2 = 0.70 kg) are connected as shown. Assume object 1 slides without friction.
   (b) What is the acceleration of the masses?

(b) Hint?
- ① FBD (1 and 2 combined)
- ② ΣF F_{net} = ma
- ☞ a = 3.1 m/s^2 (1 right an

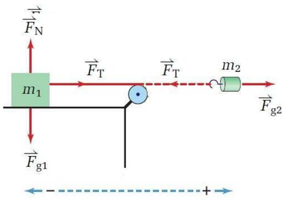


Connected Objects – 1 Hanging Mass

PRACTICE

3. Two objects (m_1 = 1.5 kg and m_2 = 0.70 kg) are connected as shown. Assume object 1 slides without friction.
   (c) What is the tension in the rope?

(c) Hint?
- ① FBD (1 or 2)
- ② ΣF F_{net} = ma (1 or 2)
- ☞ F_T = 4.7 N

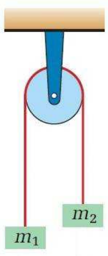


Connected Objects

PRACTICE

4. Two blocks (m_1 = 3.8 kg and m_2 = 4.2 kg) are connected by a massless string that passes over a frictionless pulley.
   (a) What is the acceleration of the masses?

(a) a = 0.49 m/s^2

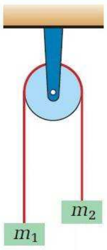


Connected Objects

PRACTICE

4. Two blocks (m_1 = 3.8 kg and m_2 = 4.2 kg) are connected by a massless string that passes over a frictionless pulley.
   (b) What is the tension in the rope?

   (b) F_T = 39 N

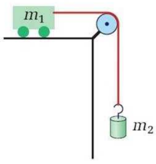


Connected Objects

PRACTICE

5. Two blocks (m_1 = 45 kg and m_2 = 12 kg) are connected by a massless string that passes over a frictionless pulley.
   (a) What is the acceleration of the masses?

   (a) a = 2.1 m/s^2

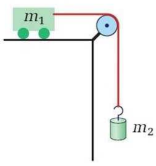


Connected Objects

PRACTICE

5. Two blocks (m_1 = 45 kg and m_2 = 12 kg) are connected by a massless string that passes over a frictionless pulley.
   (b) What is the tension in the rope?

   (b) F_T = 93 N



NOTE!

*If the surface upon which the object is sliding is **not** frictionless, make sure you remember to include friction in your FBDs and calculations.*

✔ Check Your Learning

TEXTBOOK
P.90 Q.6 (Review)

WIKI (DYNAMICS)

- 4U1 - QUIZ#3 (Forces - Part 2)