بسم الله الرحمن الرحيم

وزارة التعليم العالي
Ministry of Higher Education

King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)

CHAPTER 5: THE LAWS OF MOTION (PART 2)

LECTURE NO. 8

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Lecture Outline

- Here is a quick list of the subjects that we will cover in this presentation. It is based on Serway, Ed. 6

- *Applications on Newton's Laws*
- *Objects in Equilibrium*
- *Traffic Light at Rest*
- *Weighing a Fish in an Elevator*
- *The Atwood Machine*
- *Acceleration of Two Objects Connected by a Cord*
- *5.8 Forces of Friction*
- *Examples*
- *Activity Flash*
- *Lecture Summary*
- *Quizzes*

5.7 Applications of Newton's Laws

- ***when we apply Newton's laws to an object, we are interested only in external forces that act on the object***
- **Objects in Equilibrium:**

If the acceleration of an object is zero, the particle is in **equilibrium**

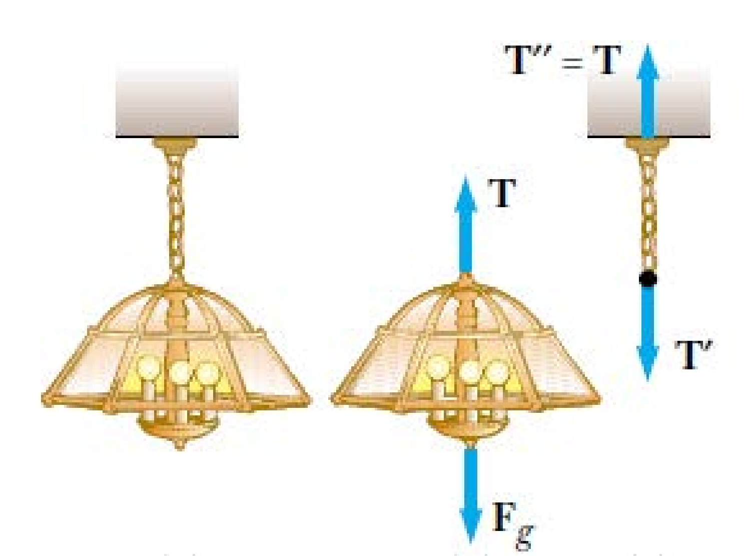
$$\sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum F_z = 0$$

- For example: a lamp hang by a robe from the ceiling, is in equilibrium because:

$$\sum F_y = T - mg = 0$$

$$\Rightarrow ma = 0 \Rightarrow a = 0$$

- A lamp suspended from a ceiling by a chain of negligible mass balanced Under the effect of two forces **T** and $\mathbf{F}_g$.

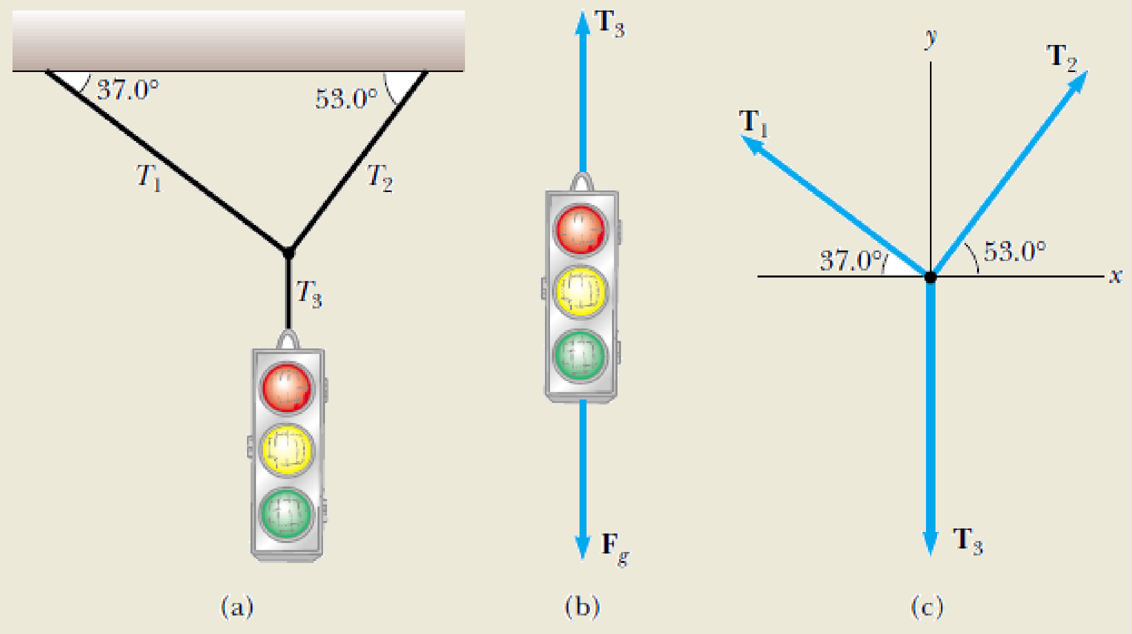


Example 5.4 A Traffic Light at Rest

- A traffic light weighing 122 N hangs from a cable tied to two other cables fastened to a support, as in Figure. The upper cables make angles of 37.0° and 53.0° with the horizontal. These upper cables are not as strong as the vertical cable, and will break if the tension in them exceeds 100 N. *Will the traffic light remain hanging in this situation, or will one of the cables break?*
- **Solution**:

We analyze forces as in the table Below.

Force	x Component	y Component
$\mathbf{T}_1$	$-T_1 \cos 37.0°$	$T_1 \sin 37.0°$
$\mathbf{T}_2$	$T_2 \cos 53.0°$	$T_2 \sin 53.0°$
$\mathbf{T}_3$	0	-122 N



Example 5.4 (continued)

- We should use the equilibrium conditons to solve this problem:

$$\sum F_x = 0 \qquad (1)$$

$$\sum F_y = 0 \qquad (2)$$

$$(1) \Rightarrow -T_1 \cos 37 + T_2 \cos 53 = 0 \qquad (3)$$

$$(2) \Rightarrow T_1 \sin 37 + T_2 \sin 53 - 122N = 0 \qquad (4)$$

$$(3) \Rightarrow T_2 = \frac{\cos 37}{\cos 53} T_1 = 1.33\ T_1 \qquad (5)$$

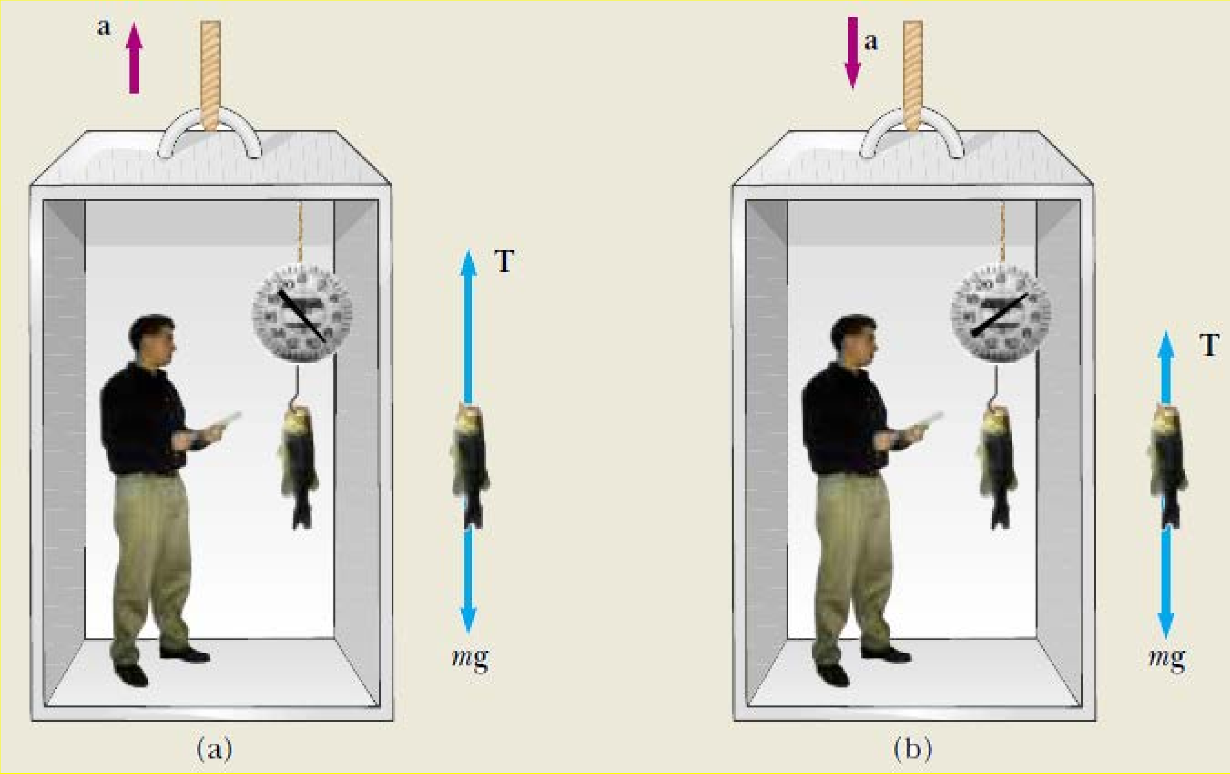
$$(5)\ \text{in}\ (4) \Rightarrow T_1 \sin 37 + 1.33 \sin 53 T_1 = 122$$

$$\Rightarrow T_1 = 73.4\,N \qquad (6)$$

$$(6)\ \text{in}\ (5) \Rightarrow T_2 = 1.33 T_1 = 97.4\ \text{N}$$

Example 5.8 Weighing a Fish in an Elevator

- A person weighs a fish of mass m on a spring scale attached to the ceiling of an elevator, as illustrated in the figure. Show that if the elevator faccelerates either upward or downward, the spring scale gives a reading that is different from the weight of the fish.



Example 5.8 Weighing a Fish in an Elevator

- **Solution:**
- We apply Newton 2nd law: $\mathbf{F}_{net} = \mathbf{ma}$

$$\sum F_y = T - mg = ma_y \qquad (1)$$

- Let us assume the weight of finsh is: 40 N, and ay=±2 m/s²

Case: $a_y = +2 \text{ m/s}^2$ (Upward):

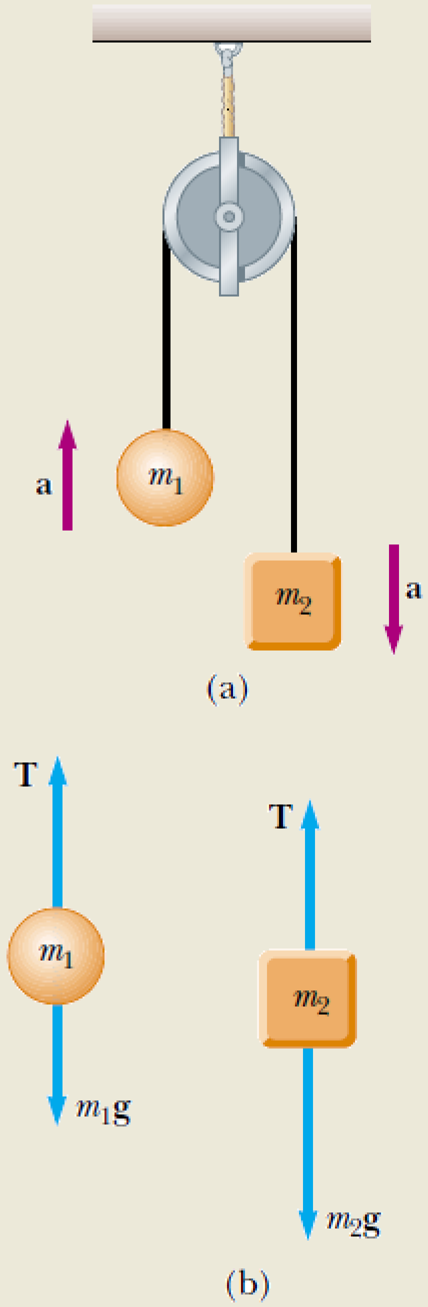
$$(1) \Rightarrow T = ma_y + mg = mg\left(\frac{a_y}{g} + 1\right) = 40\left(\frac{2}{9.8} + 1\right) = 48.2\,N$$

Case: $a_y = -2 \text{ m/s}^2$ (downward):

$$(1) \Rightarrow T = ma_y + mg = mg\left(\frac{-a_y}{g} + 1\right) = 40\left(\frac{2}{9.8} + 1\right) = 31.8\,N$$

Example 5.9 The Atwood Machine

- When two objects of unequal mass are hung vertically over a frictionless pulley of negligible mass, as in the figure, the arrangement is called an Atwood machine
- ***Solution***:
- We have in this example 2 objects. When we apply Newton's 2nd law, we get 2 equations (1for each object).
- We must assume a direction for the motion before we can setup the two equations.
- Let us assume Clocwise direction:
- Our strategey states that: *Net Force = ma* for each object.
- Please look at the free body diagram (b).



Example 5.9 (continued)

Solving for m_1 and m_2:

$$m_1: \quad \sum F_y = T - m_1 g = m_1 a_y \qquad (1)$$

$$m_2: \quad \sum F_y = m_2 g - T = m_2 a_y \qquad (2)$$

$$(1)+(2) \Rightarrow:$$

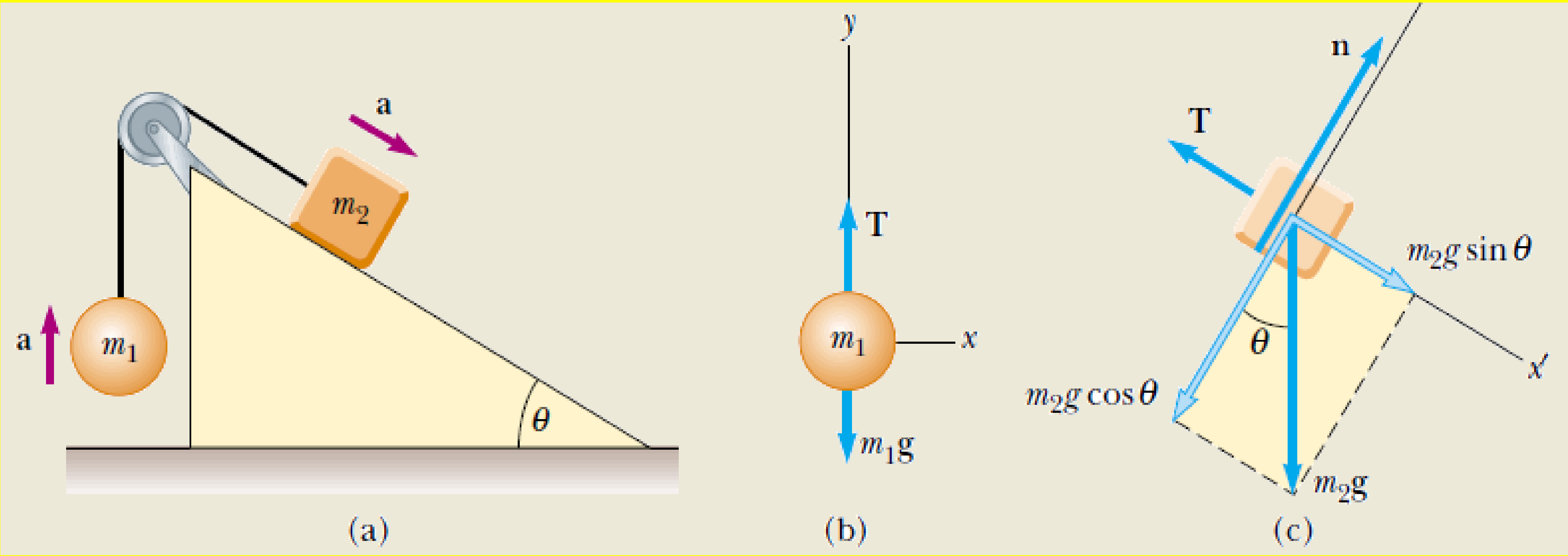
$$m_2 g - m_1 g = (m_1 + m_2) a_y$$

$$\Rightarrow a_y = \frac{m_2 g - m_1 g}{m_1 + m_2} \qquad (3)$$

$$(3)\ in\ (1): T = \frac{2 m_1 m_2}{m_1 + m_2} g \qquad (4)$$

Ex. 5.10 2 Obj. Connected by a Cord

- A ball of mass m_1 and a block of mass m_2 are attached by a lightweight cord that passes over a frictionless pulley of negligible mass, as in the figure . The block lies on a frictionless incline of angle θ. *Find the magnitude of the acceleration of the two objects and the tension in the cord.*



Ex. 5.10 2 Obj. Connected by a Cord

- Again: we have 2 bodies, thus we must have 2 equations. We call thes equations: equatoions of motion. One equation is requuired for each body.
- We must also assume a direction for the motion. We select Clockwise.
- But first; we should analys forces acting on each body.
  - Body m_1: T (up), m_1g (down)
  - Body m_2: from part (c) in previous figure: $m_2g\sin\theta$ (down the incline), T up the incline.
  - For : $m_2g\cos\theta$ component: this is not important unless there is a friction. We will get back to this issue when we consider the friction.
  - Also; the pulley is not considered now. If the pulley is not frictionless and thus rorates with motion; situation will be much different. In this case one more equation is to be added for the pulley. In this chaper; we always assume the pulley is frictionless.

Example 5.10 (continued)

$$m_1 : \; T - m_1 g = m_1 a \qquad (1)$$

$$m_2 : \; m_2 g \sin\theta - T = m_2 a \qquad (2)$$

$$(1)+(2): \; m_2 g \sin\theta - m_1 g = (m_1 + m_2)\,\mathrm{a}$$

$$\Rightarrow a = \frac{m_2 g \sin\theta - m_1 g}{m_1 + m_2} \qquad (3)$$

$$(3)\,\mathrm{in}\,(1): \; T - m_1 g = m_1 \left(\frac{m_2 g \sin\theta - m_1 g}{m_1 + m_2} \right)$$

$$\Rightarrow T = \frac{m_1 m_2 g (\sin\theta + 1)}{m_1 + m_2} \qquad (4)$$

5.8 Forces of Friction

- When an object is in motion either on a surface or in a viscous medium such as air or water, there is resistance to the motion because the object interacts with its surroundings. We call such resistance a ***force of friction***
- There are two types of frictional forces:
  - Static: f_s and kinetic: f_k
- We define these two types as:

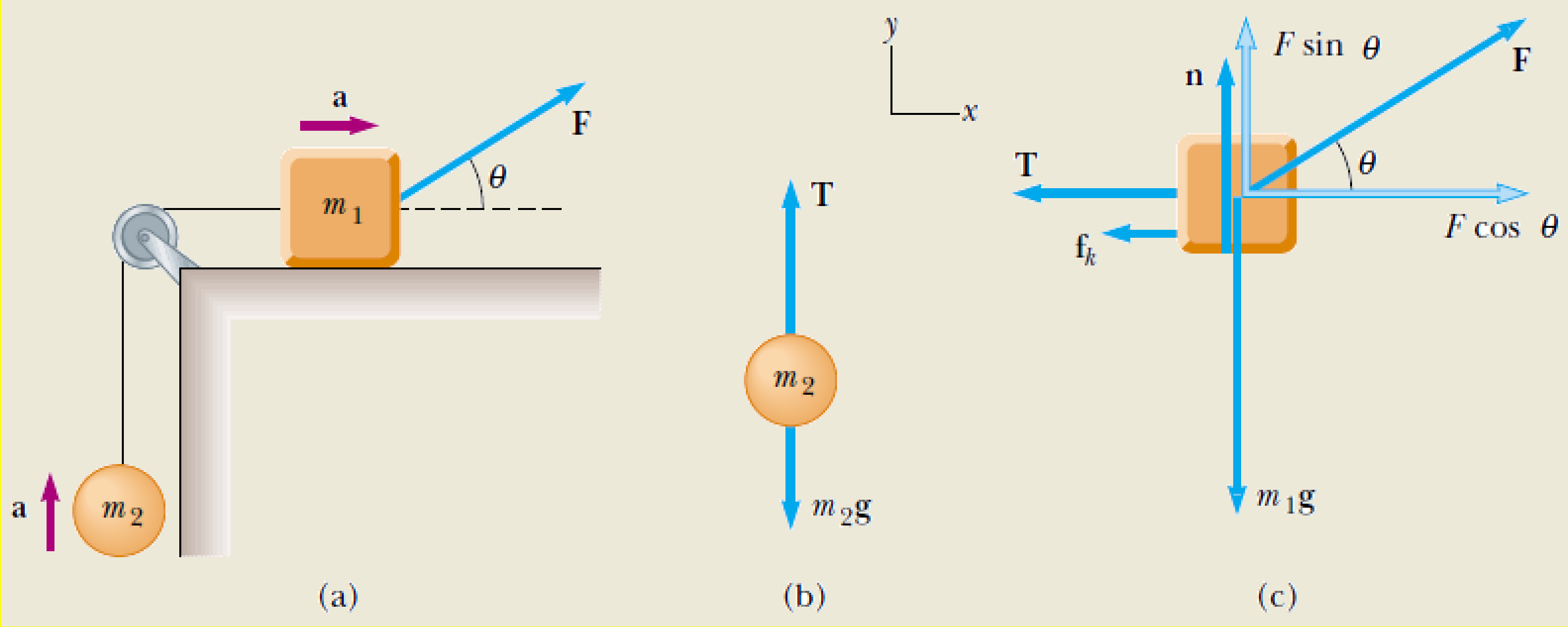
$$f_s = \mu_s n \qquad (1)$$

$$f_k = \mu_k n \qquad (1)$$

- μ_s is called coefficient of static friction, and μ_k is called coefficient of kentic friction. $\mu_s > \mu_k$, $(0 \leq \mu \leq 1)$
- The direction of the friction force on an object is parallel to the surface with which the object is in contact and ***opposite*** to the actual motion.

Ex. 5.14 Two Connected Objects with Friction

- A block of mass m_1 on a rough, horizontal surface is connected to a ball of mass m_2 by a lightweight cord over a lightweight, frictionless pulley, as shown in the figure. A force of magnitude F at an angle θ with the horizontal is applied to the block as shown. The coefficient of kinetic friction between the block and surface is μ_k . *Determine the magnitude of the acceleration of the two objects*.



Example 5.14 (Continued)

- To solve, we use same steps in Example 5.9.

$$m_1: \quad F\cos\theta - f_k - T = m_1 a \qquad (1)$$

$$m_2: \quad T - m_2 g = m_2 a \qquad (2)$$

- It is our duty to find out abut f_k.

$$\because f_k = \mu_k n$$

$$\because n = m_1 g - F\sin\theta$$

$$\therefore f_k = \mu_k (m_1 g - F\sin\theta) \qquad (3)$$

- Let use these values: m_1=10 kg, m_2=1 kg, μ_k =0.1, **F** = 30 N, θ =30^o .
- Using equations, (1), (2) and (3) we can find:
  - Acceleration: a
  - Tensin: T

Example 5.14 (Continued)

- We can use these values to find:

$$\therefore \boldsymbol{f_k} = \mu_k (m_1 g - F \sin\theta)$$

$$\Rightarrow \boldsymbol{f_k} = 0.1(10 \times 9.8 - 30 \sin 30)$$

$$= 8.3\,\text{N} \qquad (4)$$

$$(4)\, in\, (1): 30 \times \cos 30 - 8.3 - T = 10a$$

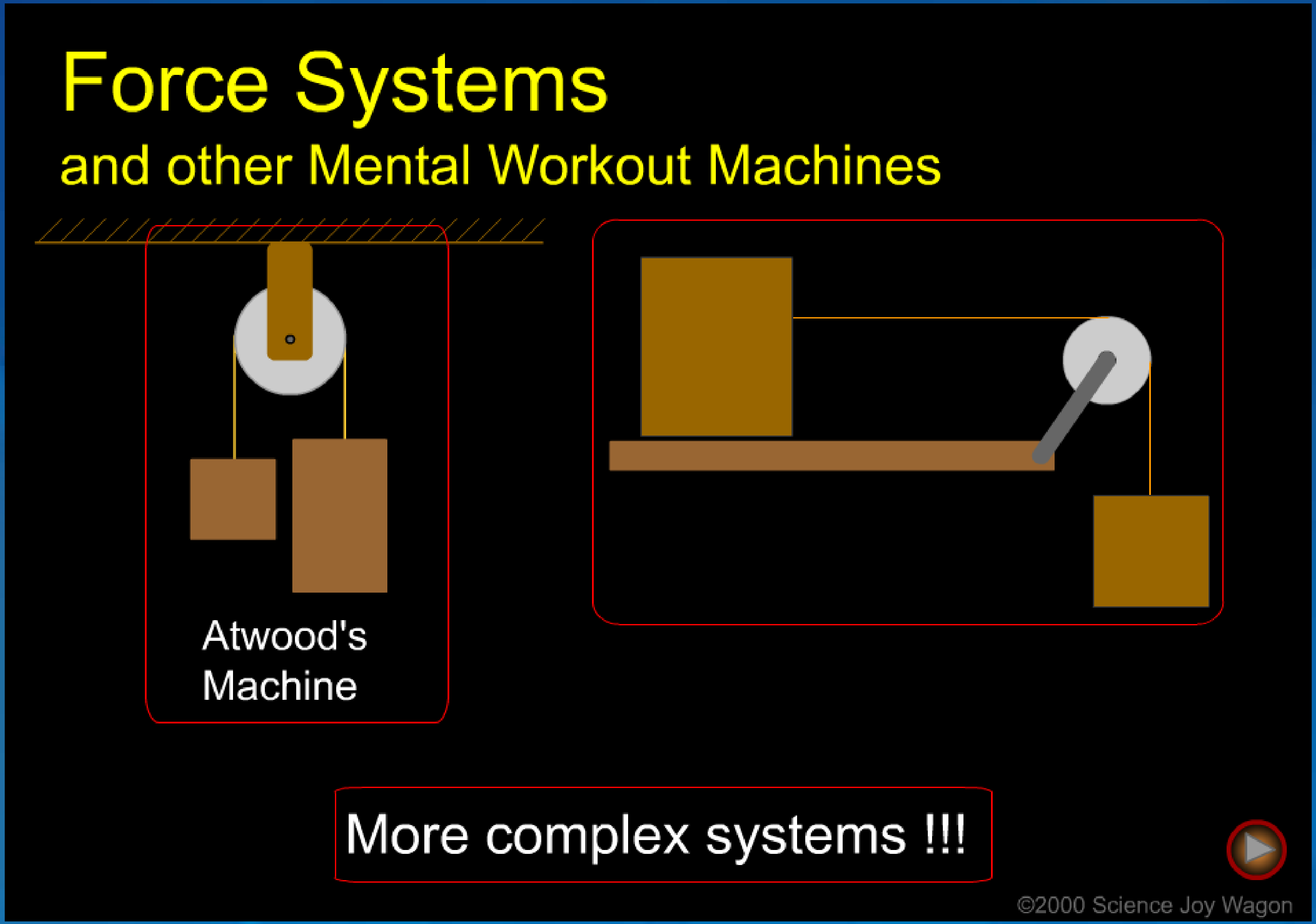
$$\Rightarrow \quad 17.68 - T = 10a \qquad (5)$$

$$(2) \Rightarrow T - 1 \times 9.8 = 1a \qquad (6)$$

$$(5)+(6): 7.88 = (11)a \qquad \Rightarrow a = 0.72\ m/s^2$$

$$\therefore T = 1 \times 0.72 + 1 \times 9.8 = 10.52\,N$$

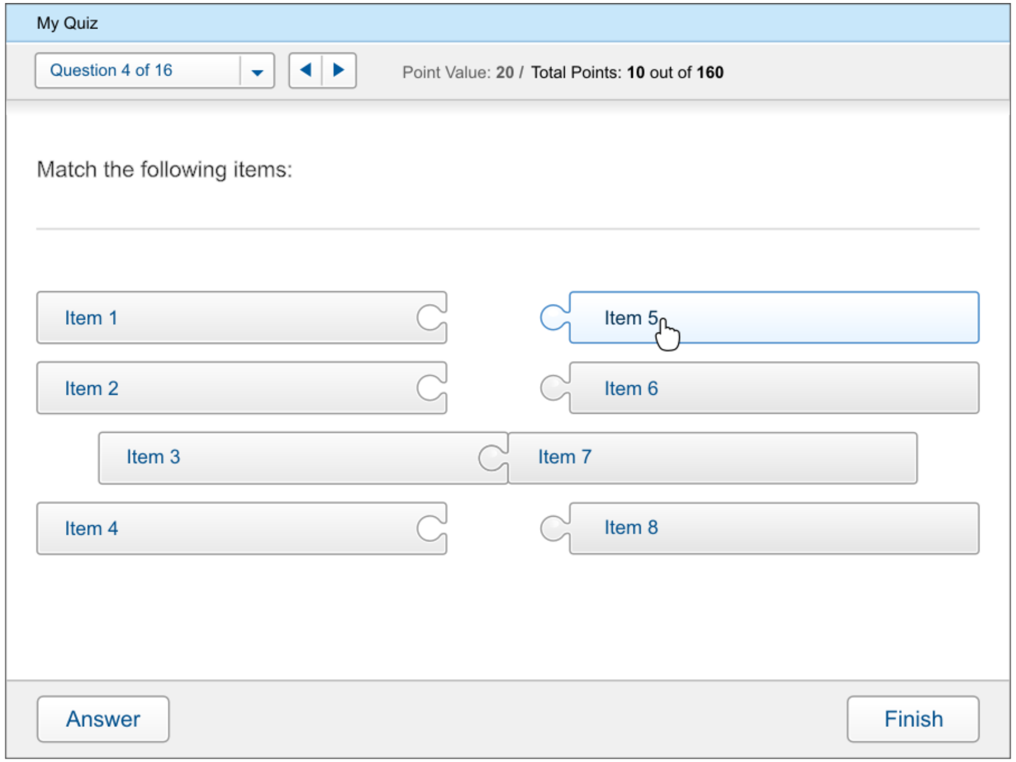
Activity Flash



Lectrue Summary

- **Newton's first law**: defined earliar.
- **Newton's second law**: defined earliar.
- **The gravitational force**: defined earliar.
- **Newton's third law**: defined earliar.
- **The maximum force of static friction** f_s,max between an object and a surface is proportional to the normal force acting on the object.
- In general, $f_s \leq \mu_s n$, where μ_s is the **coefficient of static friction** and n is the magnitude of the normal force.
- When an object slides over a surface, the direction of the force of kinetic friction f_k is **opposite** the direction of motion of the object relative to the surface and is also proportional to the magnitude of the normal force. The magnitude of this force is given by $f_k \leq \mu_k n$, where μ_k is the **coefficient of kinetic friction**.

Quiz 5.11 to 5.13



Click the **Quiz** button on iSpring Pro toolbar to edit your quiz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