CHAPTER 4 – DYNAMICS, NEWTON'S LAW OF MONITION

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THE NEXT FEW SLIDES ARE FOR REVISION ONLY!

1–5 UNITS, STANDARDS, AND THE SI SYSTEM

- Base vs. Derived Quantities
  → Physical quantities can be divided into two categories: base quantities and derived quantities
  → A **base quantity** must be defined in terms of a standard
  → All other quantities can be defined in terms of these seven base quantities, and hence are referred to as **derived quantities**. An example of a derived quantity is speed, which is defined as distance divided by the time it takes to travel that distance

TABLE 1–5 SI Base Quantities and Units

Quantity	Unit	Unit Abbreviation
Length	meter	m
Time	second	s
Mass	kilogram	kg
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

2.0 INTRODUCTION

Mechanics

The study of the motion of objects, and the related concepts of force and energy

kinematics

description of how objects move

dynamics

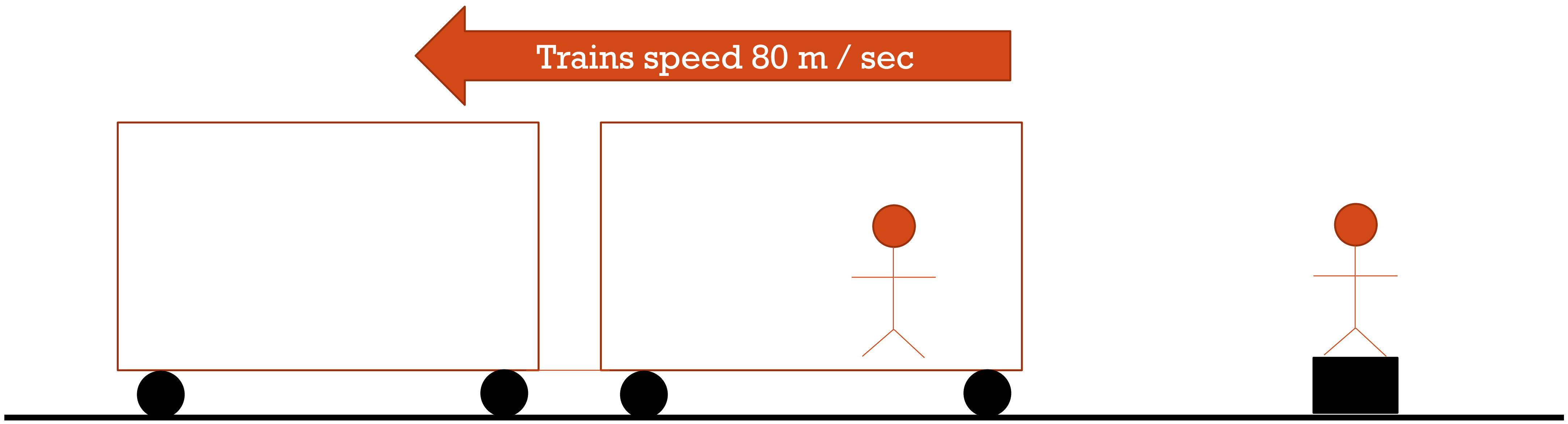
deals with force and why objects move as they do

In Chapter 2 we will be concerned with describing an object that moves along a straight-line path, which is one dimensional translational motion.

In Chapter 3 we will describe translational motion in two (or three) dimensions along paths that are not straight.

2.1 REFERENCE FRAMES AND DISPLACEMENT

- Frame of reference : نقطة الإسناد
- E.g. on frame of reference: A person walked to a train at a speed of 2 m/s, when he got in the train, the train moved at a speed 80 m / sec, then this person walked in the train while it's moving at a speed of 2 m/s, what is the:
  Person speed while he is walking on the floor when the floor is the frame of reference? 2m/s
  person speed in the train while he is walking when the train is the frame of reference? 2m/s
  person speed in the train while he is walking when the floor is the frame of reference? 82m/s



- Inertial frame of reference : when the frame of reference is constant or moving at a constant speed (Newton's law applies in this field)

SO NOW LETS START!

CONCEPTS OF THE LECTURE

- 4–1 Force
- 4–2 Newton's First Law of Motion
- 4–3 Mass
- 4–4 Newton's Second Law of Motion
- 4–5 Newton's Third Law of Motion
- 4–6 Weight—the Force of Gravity; and the Normal Force

4–1 FORCE

- Force: any kind of a push or a pull on an object (cause of motion changes)
  → It's a vector quantity
- Force can be contact (As in pushing an object) or non-contact (As in free fall)

4–2 NEWTON'S FIRST LAW OF MOTION

- 1st law: Every object continues in its state of rest, or of uniform velocity in a straight line, as long as no net force acts on it.
- Newton's first law is often called the law of inertia
- Newton's first law does hold in inertial reference frame

CONCEPTUAL EXAMPLE 4–1 **Newton's first law.** A school bus comes to a sudden stop, and all of the backpacks on the floor start to slide forward. What force causes them to do that?

RESPONSE It isn't "force" that does it. By Newton's first law, the backpacks continue their state of motion, maintaining their velocity. The backpacks slow down if a force is applied, such as friction with the floor.

4–3 MASS

- "quantity of matter." OR "the measure of the inertia of an object (how it's resistant to motion change)"
- To quantify the concept of mass, we must define a standard. In SI units, the unit of mass is the kilogram (kg)
- The terms mass and weight are often confused with one another, but it is important to distinguish between them. Mass is a scalor and defined as a property of an object itself (a measure of an object's inertia, or its "quantity of matter"). Weight, on the other hand, is a vector and defined as a force, the pull of gravity acting on an object, so it changes with the place .

4–4 NEWTON'S SECOND LAW OF MOTION

The acceleration of an object is directly proportional to the net force acting on it, and is inversely proportional to the object's mass. The direction of the acceleration is in the direction of the net force acting on the object.

NEWTON'S SECOND LAW OF MOTION

This is **Newton's second law of motion.**

Newton's second law can be written as an equation:

$$\vec{\mathbf{a}} = \frac{\Sigma\vec{\mathbf{F}}}{m},$$

where $\vec{\mathbf{a}}$ stands for acceleration, m for the mass, and $\Sigma\vec{\mathbf{F}}$ for the *net force* on the object. The symbol Σ (Greek "sigma") stands for "sum of"; $\vec{\mathbf{F}}$ stands for force, so $\Sigma\vec{\mathbf{F}}$ means the *vector sum of all forces* acting on the object, which we define as the **net force**.

We rearrange this equation to obtain the familiar statement of Newton's second law:

$$\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}. \quad \textbf{(4–1)}$$

NEWTON'S SECOND LAW OF MOTION

4–4 NEWTON'S SECOND LAW OF MOTION

- εFx = m (a_x) → Along the x-axis
- εFy = m (a_y) → Along the y-axis
- εFz = m (a_z) → Along the z-axis

- Force is measured in newton (N) → A derived quantity → $\frac{Kg\ x\ m}{s^2}$

4–4 Newton's Second Law of Motion

EXAMPLE 4–2 ESTIMATE **Force to accelerate a fast car.** Estimate the net force needed to accelerate (*a*) a 1000-kg car at $\frac{1}{2}g$; (*b*) a 200-gram apple at the same rate.

APPROACH We use Newton's second law to find the net force needed for each object; we are given the mass and the acceleration. This is an estimate (the $\frac{1}{2}$ is not said to be precise) so we round off to one significant figure.

SOLUTION (*a*) The car's acceleration is $a = \frac{1}{2}g = \frac{1}{2}(9.8\,\mathrm{m/s^2}) \approx 5\,\mathrm{m/s^2}$. We use Newton's second law to get the net force needed to achieve this acceleration:

$$\Sigma F = ma \approx (1000\,\mathrm{kg})(5\,\mathrm{m/s^2}) = 5000\,\mathrm{N}.$$

(If you are used to British units, to get an idea of what a 5000-N force is, you can divide by 4.45 N/lb and get a force of about 1000 lb.)

(*b*) For the apple, $m = 200\,\mathrm{g} = 0.2\,\mathrm{kg}$, so

$$\Sigma F = ma \approx (0.2\,\mathrm{kg})(5\,\mathrm{m/s^2}) = 1\,\mathrm{N}.$$

EXAMPLE 4–3 **Force to stop a car.** What average net force is required to bring a 1500-kg car to rest from a speed of 100 km/h within a distance of 55 m?

APPROACH We use Newton's second law, $\Sigma F = ma$, to determine the force, but first we need to calculate the acceleration a. We assume the acceleration is constant so that we can use the kinematic equations, Eqs. 2–11, to calculate it.

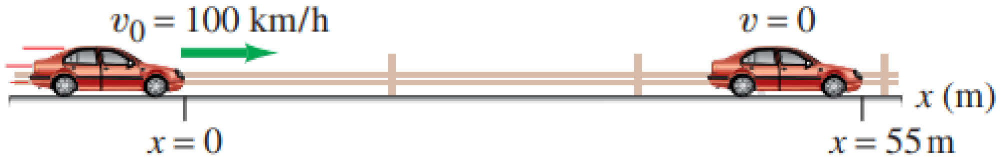


FIGURE 4–6 Example 4–3.

SOLUTION We assume the motion is along the $+x$ axis (Fig. 4–6). We are given the initial velocity $v_0 = 100\text{ km/h} = 27.8\text{ m/s}$ (Section 1–6), the final velocity $v = 0$, and the distance traveled $x - x_0 = 55\text{ m}$. From Eq. 2–11c, we have

$$v^2 = v_0^2 + 2a(x - x_0),$$

so

$$a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (27.8\text{ m/s})^2}{2(55\text{ m})} = -7.0\text{ m/s}^2.$$

The net force required is then

$$\Sigma F = ma = (1500\text{ kg})(-7.0\text{ m/s}^2) = -1.1 \times 10^4\text{ N},$$

or 11,000 N. The force must be exerted in the direction *opposite* to the initial velocity, which is what the negative sign means.

NOTE If the acceleration is not precisely constant, then we are determining an "average" acceleration and we obtain an "average" net force.

4-5 NEWTON'S THIRD LAW OF MOTION

- Whenever one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first.
- it is very important to remember that the "action" force and the "reaction" force are acting **<u>on different objects</u>**

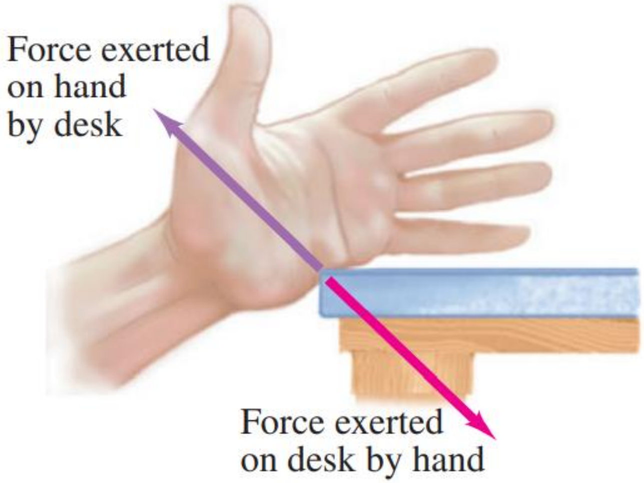


FIGURE 4–8 If your hand pushes against the edge of a desk (the force vector is shown in red), the desk pushes back against your hand (this force vector is shown in a different color, violet, to remind us that this force acts on a different object).

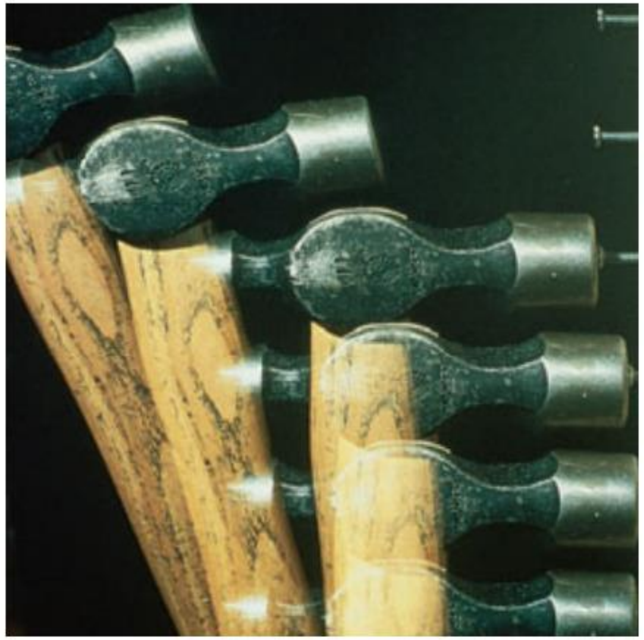
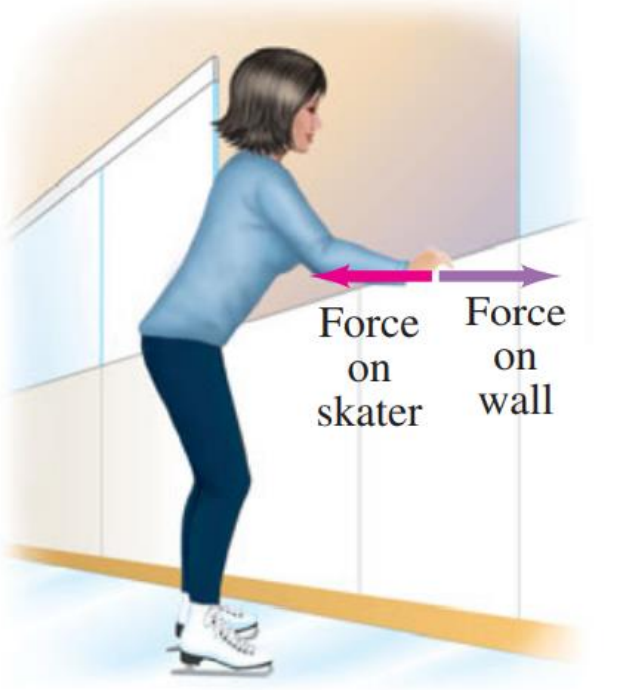
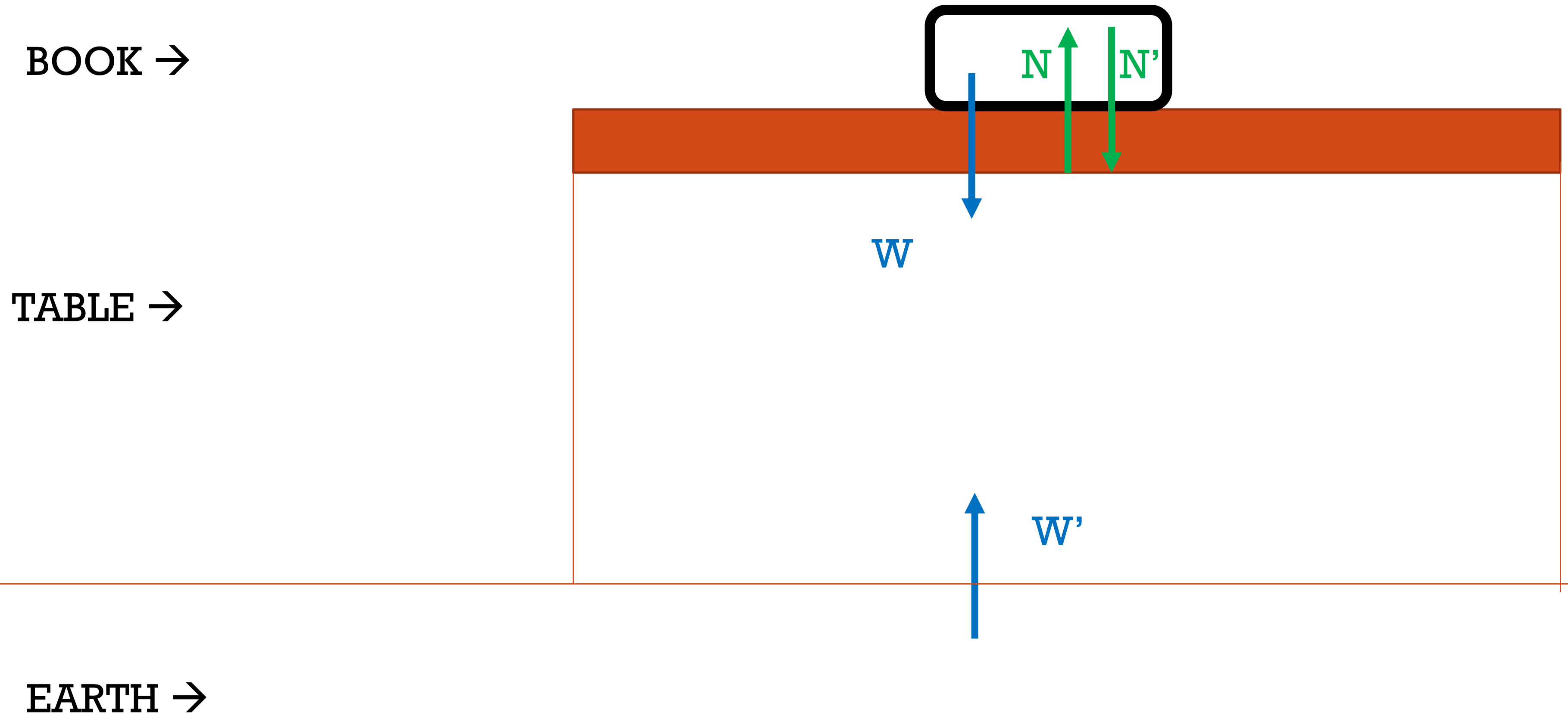


FIGURE 4–7 A hammer striking a nail. The hammer exerts a force on the nail and the nail exerts a force back on the hammer. The latter force decelerates the hammer and brings it to rest.

FIGURE 4–9 An example of Newton's third law: when an ice skater pushes against the wall, the wall pushes back and this force causes her to accelerate away.



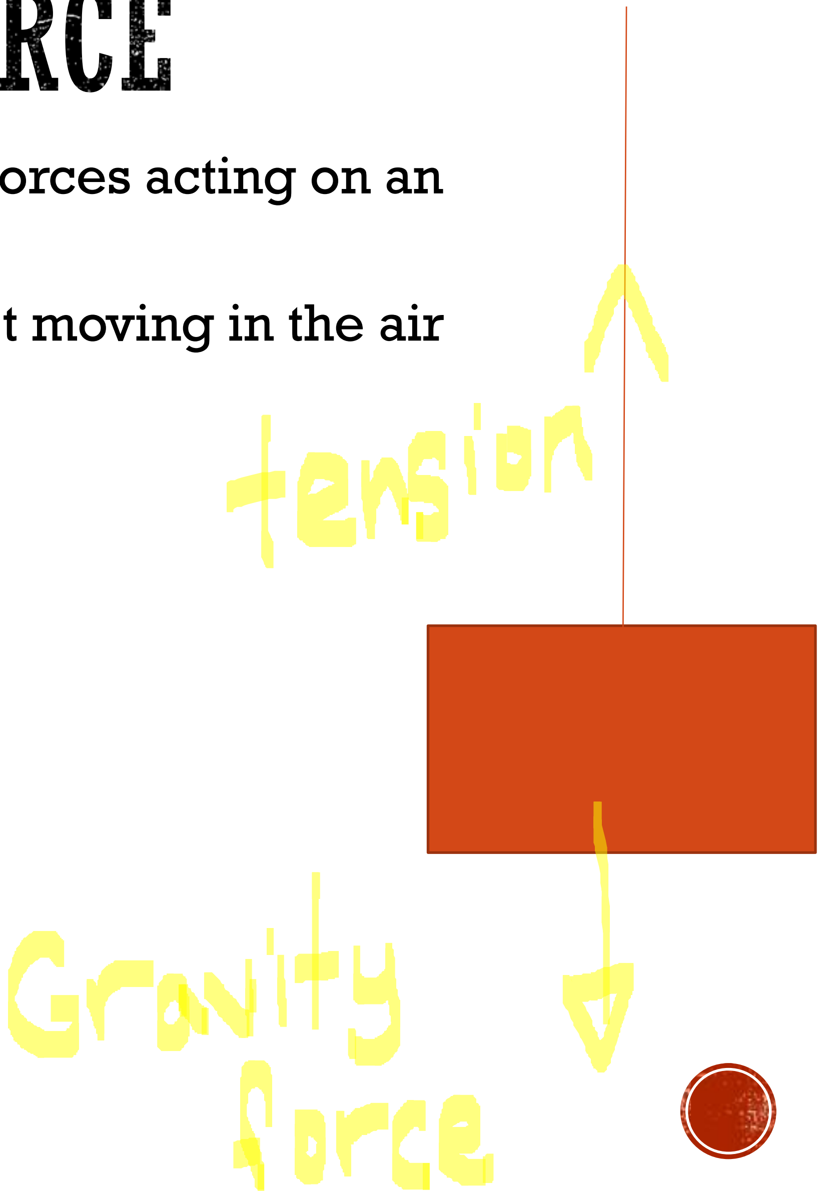
4–6 WEIGHT—THE FORCE OF GRAVITY; AND THE NORMAL FORCE



- **W: Force OF earth on book, called action**
- **W': Force of book on earth, called reaction**
- **N:Force of table on book, called action**
- **N': Force of book on table, called reaction**
- **Remember: Action and reaction forces NEVER act on the same object**

4–6 WEIGHT—THE FORCE OF GRAVITY; AND THE NORMAL FORCE

- Free body diagram: A diagram that shows all the external forces acting on an object
- This block next to the slide is in static equilibrium as it's not moving in the air
- So: €F = 0 OR tension – gravity force = zero



قَالَ رَسُولُ اللهِ صَلَّى اللهُ عَلَيْهِ وَسَلَّمَ

«مَن أعانَ عبداً في حَاجَتِهِ ثَبَّتَ اللهُ لهُ مَقامَهُ يَوَمَ تَزُولُ الأقدام»

الصحيحة(906)

قناة بئرخادم الدعوية