KAZAKH KBTU BRITISH
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Physics 1

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Lecture 2

SUBJECTS:

- Forces in mechanics
- Dynamics
- Newton’s laws

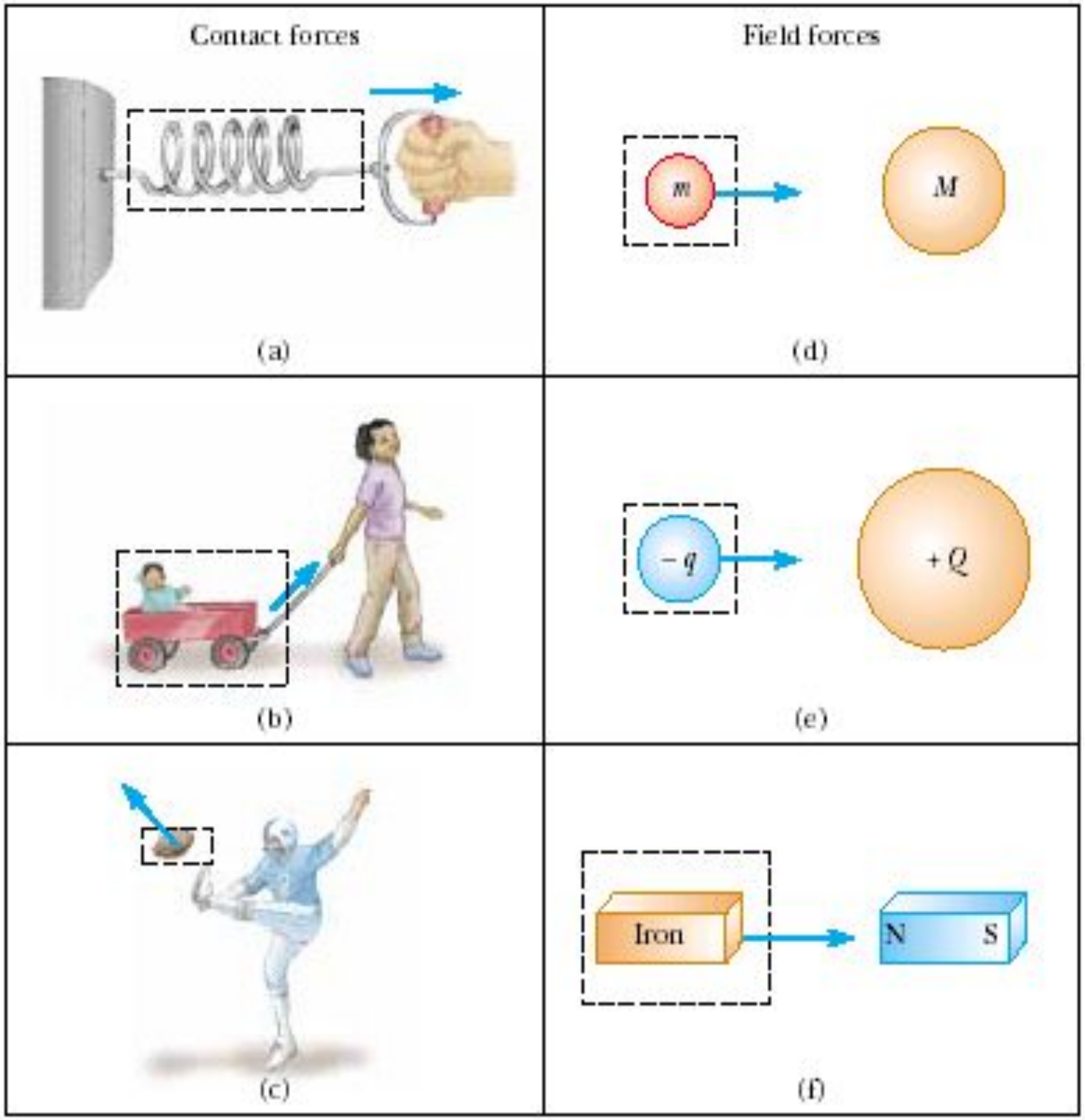
Dynamics

- **Dynamics** studies the cause of changes in motion.
- Forces act on an object and influences its motion.

Force

- A force is a vector, so that it has:
  - a direction
  - a magnitude
- Forces are additive, which means that when several forces act together, the subsequent motion of the object acted on is the same as if a single force equal to the vector sum of the individual forces were acting. That single force is the net force:

$$\vec{F}_{net} = \sum_i \vec{F}_i$$



Contact forces
Field forces
m
M
(a)
(d)
(b)
− q
+ Q
(e)
Iron
N
S
(c)
(f)

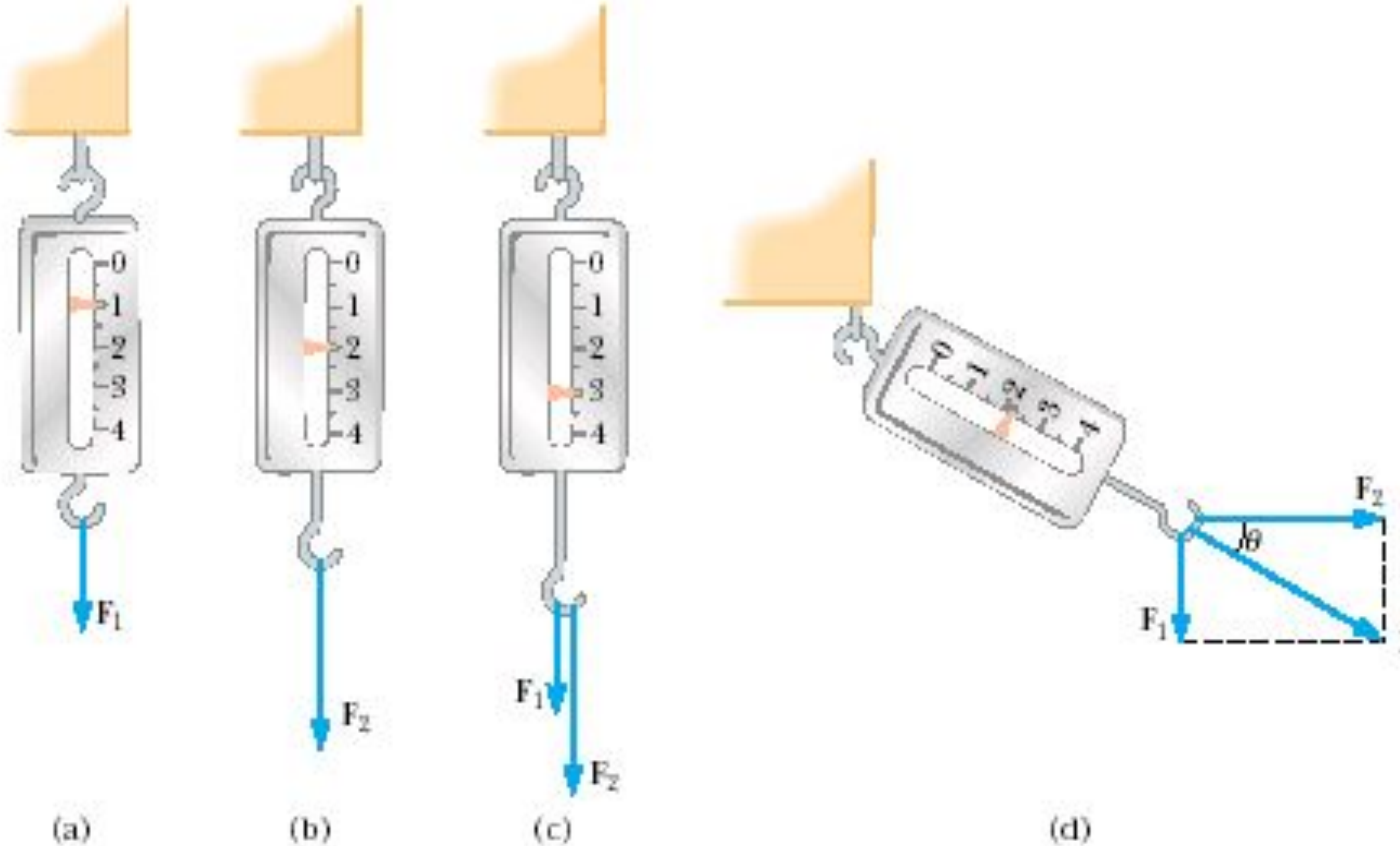


Figure 5.2 The vector nature of a force is tested with a spring scale. (a) A downward force $\mathbf{F}_1$ elongates the spring 1.00 cm. (b) A downward force $\mathbf{F}_2$ elongates the spring 2.00 cm. (c) When $\mathbf{F}_1$ and $\mathbf{F}_2$ are applied simultaneously, the spring elongates by 3.00 cm. (d) When $\mathbf{F}_1$ is downward and $\mathbf{F}_2$ is horizontal, the combination of the two forces elongates the spring $\sqrt{(1.00\text{ cm})^2 + (2.00\text{ cm})^2} = 2.24$ cm.

Three fundamental forces

- **Gravitational** force.
- **Electroweak** force: a united force of electromagnetism and the weak force, responsible mainly for some types of radioactive processes in nuclei and.
- **Strong force** – a nuclear force.

The electromagnetic force is responsible for most of the secondary forces: tension, friction, pull and push forces, spring forces.

Newton’s first law of motion

two equivalent variants:

1. When there is no net force acting on an object, that object maintains its motion with a constant velocity.
2. If an object does not interact with other objects, it is possible to identify a reference frame in which the object has zero acceleration.

- Such a reference frame is called an inertial frame of reference.
- Newton’s first law does *not* say what happens to an object with *zero net force*; it says what happens ***<u>in the absence of a force</u>***. This is a subtle but important difference that allows us to define force as that which ***<u>causes a change in the motion</u>***. The description of an object under the effect of forces is covered by Newton’s second law.

Newton’s second law of motion

- When viewed from an inertial reference frame, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

$$\vec{F}_{\text{net}} = m\frac{d\vec{v}}{dt}.$$

$$F_{x,\text{net}} = ma_x = m\frac{dv_x}{dt};$$

$$F_{y,\text{net}} = ma_y = m\frac{dv_y}{dt};$$

$$F_{z,\text{net}} = ma_z = m\frac{dv_z}{dt}.$$

Newton's third law of motion

When a force due to object B acts on object A, then an equal and opposite force due to object A acts on object B.

$$\vec{F}_{BA} = -\vec{F}_{AB}$$

Mass and Weight

- <u>**Mass**</u> is that property of an object that specifies how much resistance an object exhibits to changes in its velocity. The greater the mass of an object, the less that object accelerates under the action of a given applied force.

- The attractive force exerted by the Earth on an object is called the gravitational force F_g. This force is directed toward the center of the Earth, and its magnitude is called the weight of the object.

$$\vec{F}_g = m\vec{g}$$

- Thus, the weight of an object, being defined as the magnitude of F_g, is equal to *mg*. Because it depends on *g*, weight varies with geographic location. Because it decreases with increasing distance from the center of the Earth, objects weigh less at higher altitudes than at sea level.

Mass and weight are two different quantities

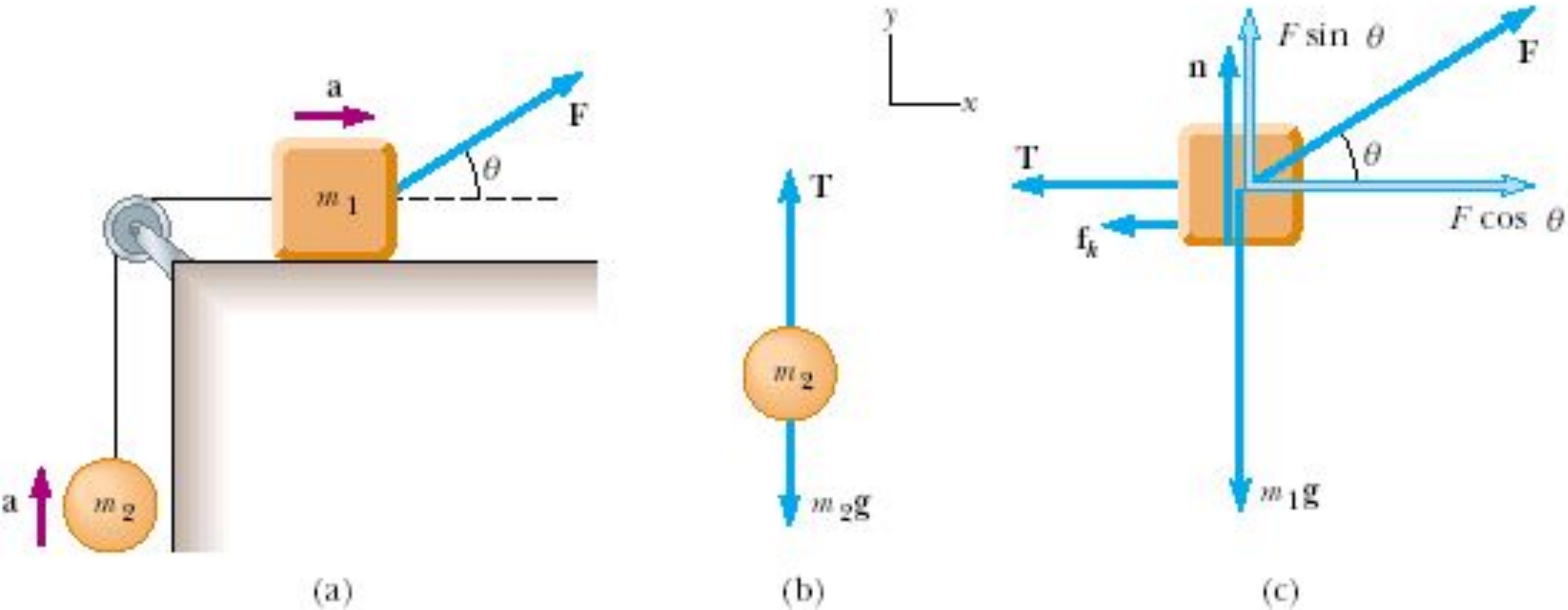
The weight of an object is equal to the magnitude of the gravitational force exerted on the object and varies with location. For example, a person who weighs 180 lb on the Earth weighs only about 30 lb on the Moon. On the other hand, the mass of an object is the same ever everywhere: an object having a mass of 2 kg on the Earth also has a mass of 2 kg on the Moon.

Action – Reaction forces

- Forces always occur in pairs, or that a single isolated force cannot exist. The force that object 1 exerts on object 2 may be called the *action force* and the force of object 2 on object 1 the *reaction force*. In reality, either force can be labeled the action or reaction force. The action force is equal in magnitude to the reaction force and opposite in direction. In all cases, the action and reaction forces act on different objects and must be of the same type.

Acceleration of Two Connected Objects When Friction Is Present

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 Figure 5.21a. 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.



a
F
θ
m_1
a
m_2
T
m_2
m_2g
y
x
F sin θ
n
F
T
θ
F cos θ
f_k
m_1g
(a)
(b)
(c)

Solution *Conceptualize* the problem by imagining what happens as **F** is applied to the block. Assuming that **F** is not large enough to lift the block, the block will slide to the right and the ball will rise. We can identify forces and we want an acceleration, so we *categorize* this as a Newton's second law problem, one that includes the friction force. To *analyze* the problem, we begin by drawing free-body diagrams for the two objects, as shown in Figures 5.21b and 5.21c. Next, we apply Newton's second law in component form to each object and use Equation 5.9, $f_k = \mu_k n$. Then we can solve for the acceleration in terms of the parameters given.

The applied force **F** has x and y components $F \cos \theta$ and $F \sin \theta$, respectively. Applying Newton's second law to both objects and assuming the motion of the block is to the right, we obtain

Motion of block: (1) $$\sum F_x = F\cos\theta - f_k - T = m_1 a_x = m_1 a$$

(2) $$\sum F_y = n + F\sin\theta - m_1 g = m_1 a_y = 0$$

Motion of ball: $$\sum F_x = m_2 a_x = 0$$

(3) $$\sum F_y = T - m_2 g = m_2 a_y = m_2 a$$

Because the two objects are connected, we can equate the magnitudes of the x component of the acceleration of the block and the y component of the acceleration of the ball. From Equation 5.9 we know that $f_k = \mu_k n$, and from (2) we know that $n = m_1 g - F \sin \theta$ (in this case n is *not* equal to $m_1 g$); therefore,

$$(4) \qquad f_k = \mu_k(m_1 g - F\sin\theta)$$

That is, the friction force is reduced because of the positive y component of $\mathbf{F}$. Substituting (4) and the value of T from (3) into (1) gives

$$F\cos\theta - \mu_k(m_1 g - F\sin\theta) - m_2(a + g) = m_1 a$$

Solving for a, we obtain

$$(5) \qquad a = \frac{F(\cos\theta + \mu_k \sin\theta) - g(m_2 + \mu_k m_1)}{m_1 + m_2}$$

To *finalize* the problem, note that the acceleration of the block can be either to the right or to the left,[5] depending on the sign of the numerator in (5). If the motion is to the left, then we must reverse the sign of f_k in (1) because the force of kinetic friction must oppose the motion of the block relative to the surface. In this case, the value of a is the same as in (5), with the two plus signs in the numerator changed to minus signs.

Units in SI

- Force F $N = kg*m/s^2$
- Acceleration a,g m/s^2