



Measurements & Kinematics

MEDICINE

Physics for the Life Sciences - M7012-2

Dr. Ramadan A. Ali



List of topics:

1.1 Introduction

1.2 The international system of units

- Prefixes
- Scientific notation

1.3 Converting units

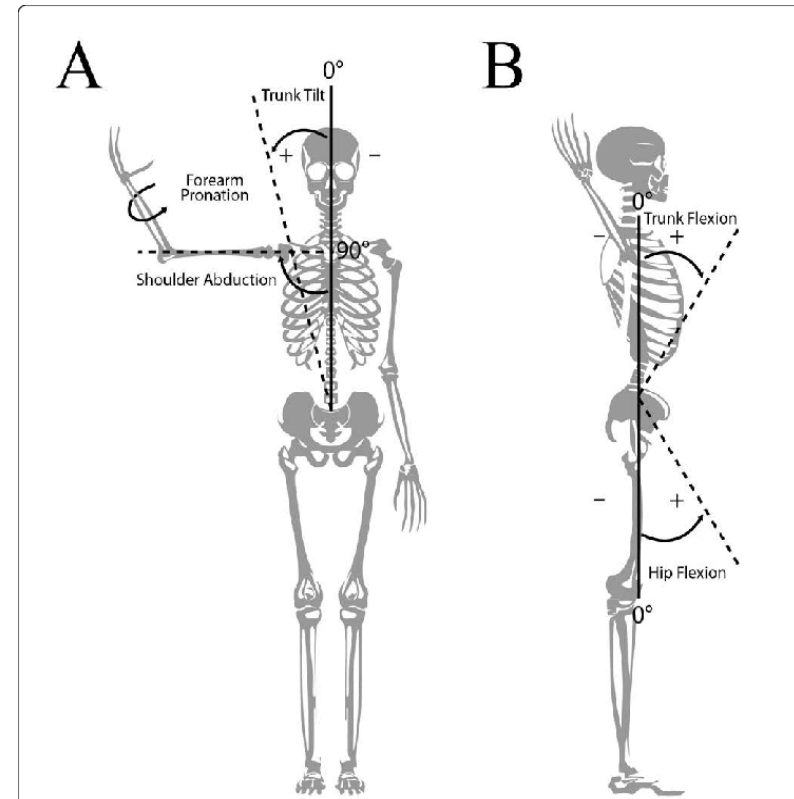
1.4 Scalar vs Vector Units

1.5 Motion

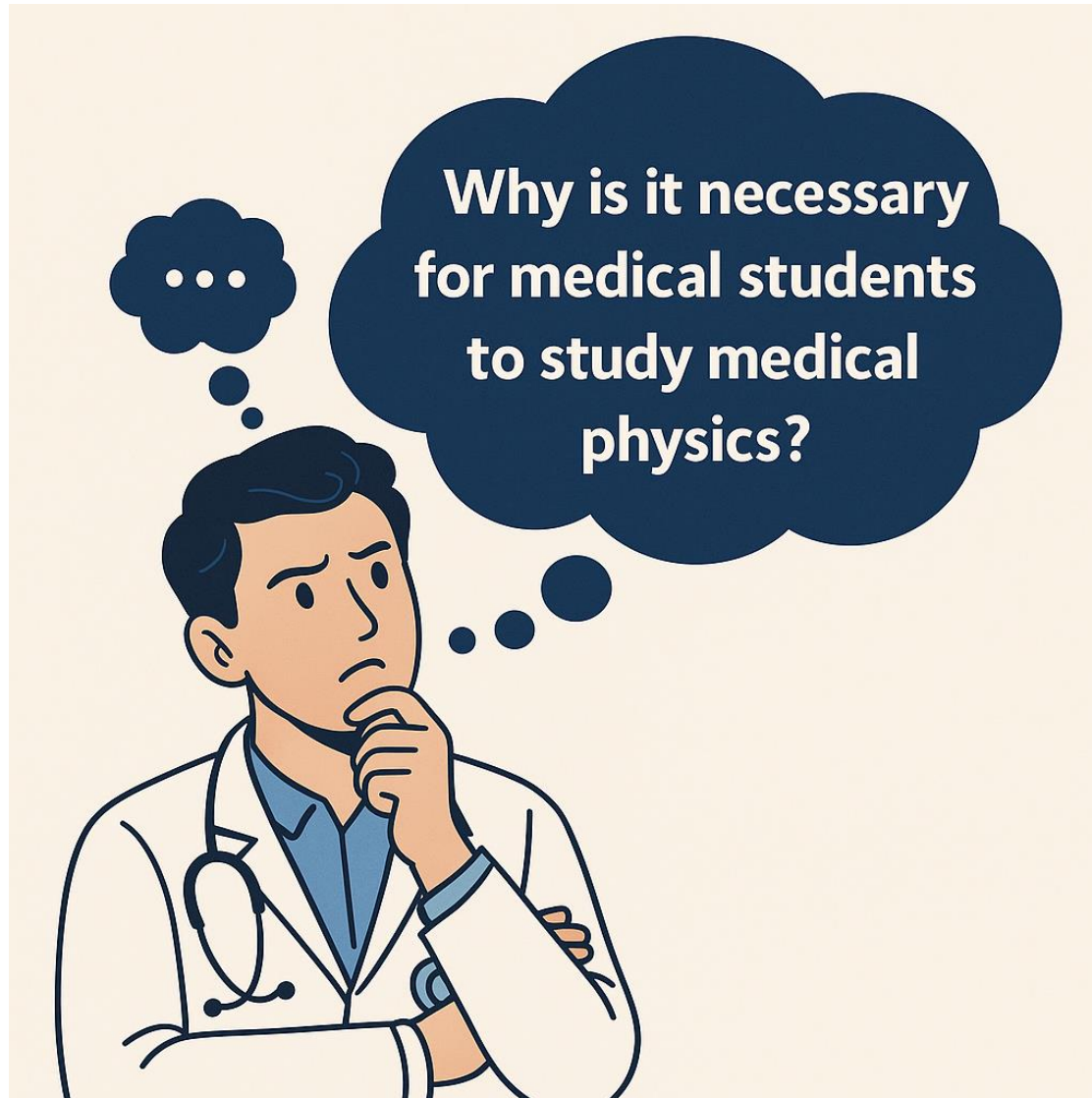
1.6 Position and Displacement

1.7 Average velocity and average speed

1.8 Instantaneous velocity and speed

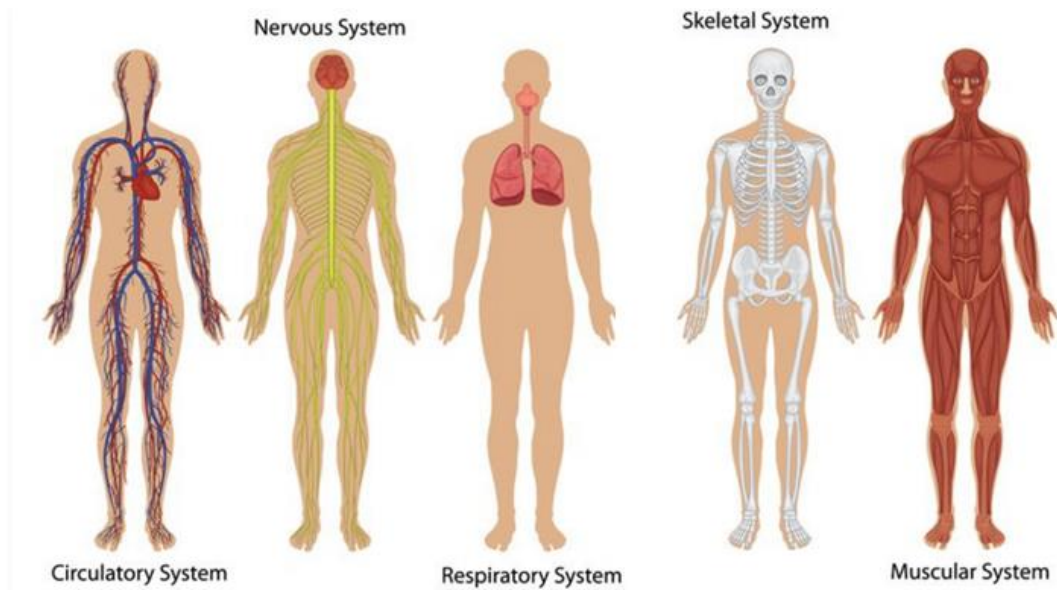


Lecture (1)



What is medical physics?

- Medical physics refers to the application of physics to the field of medicine. The living matter as well as the inanimate matter could be subjected to the same laws of physics.
- In many situations, the behavior of biological systems is interpreted by applying physical principles.
- We can use analogy with physics to simulate the function of human body systems and to understand the connection between them.



Applications to medical diagnosis

Medical diagnosis is the most crucial procedure in medicine. Physicians start their diagnosis with handheld medical devices such as;

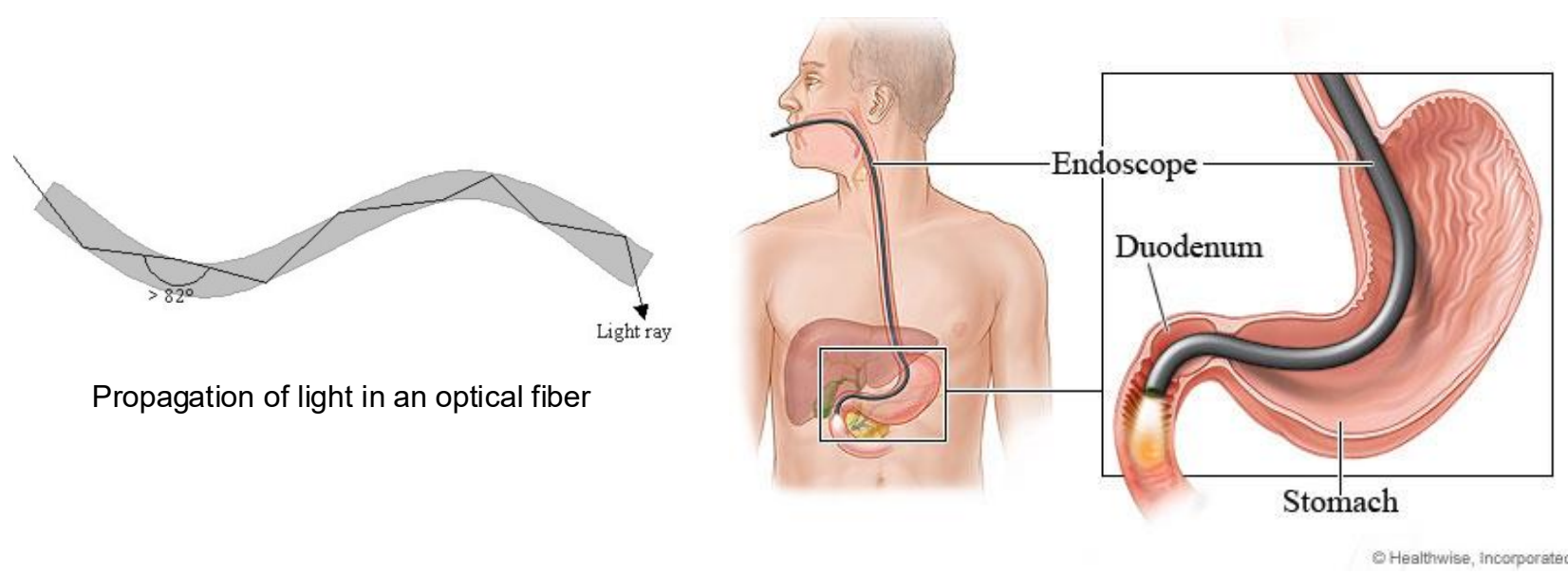
the stethoscope, the sphygmomanometer, the thermometer, the otoscope, and so on. Most of the medical instruments used for medical examination are dependent on physical principles.



Figure 3: The stethoscope

Endoscopy

An endoscope camera is based on the propagation of light in optical fibers. The light bounces off the walls of the narrow tubes, and it can be carried from one end to the other.



❑ Measurement of vital signs

Body temperature measurement

Clinical liquid-in-glass thermometers are calibrated by the thermal expansion of liquids (alcohol or mercury).

A new generation of non-contact thermometers has been developed by using infrared sensors.



Liquid thermometer



Infrared -thermometer

Blood pressure measurement

The sphygmomanometer is used to indirectly measure the arterial blood pressure.



Sphygmomanometer



Electronic blood pressure monitor

The Otoscope

The otoscope is a medical device typically having a light and a set of lenses, used for the visual examination of the eardrum and the canal of the outer ear.



❑ Medical Imaging

Many physical effects, such as;

X-rays, Computed Tomography (CT) Nuclear Magnetic Resonance (NMR), and Ultrasounds (US), are applied to medical imaging.

X-Ray & CT Imaging.

X-rays are electromagnetic waves with a short wavelength.

What was mysterious in this radiation is that it can penetrate matter that is opaque to light.

X-rays primarily produce 2D images, while CT scans generate detailed 3D images.



X-ray image of the hand bones



CT image

Ultrasound Imaging

Ultrasound imaging is based on the principle of sonar and radar.

The echo of the reflected ultrasonic waves emitted by a transducer through the skin is amplified to produce pictures of internal organs and tissues of the human body.



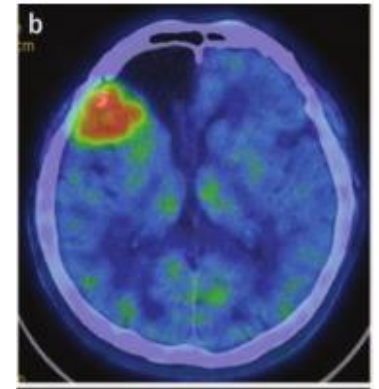
Ultrasound Imaging

Magnetic Resonance Imaging MRI

Nuclear magnetic resonance theory is the result of progress in modern physics. Hydrogen, which is a single proton atom, possesses a nuclear magnetic momentum.



Magnetic Resonance device



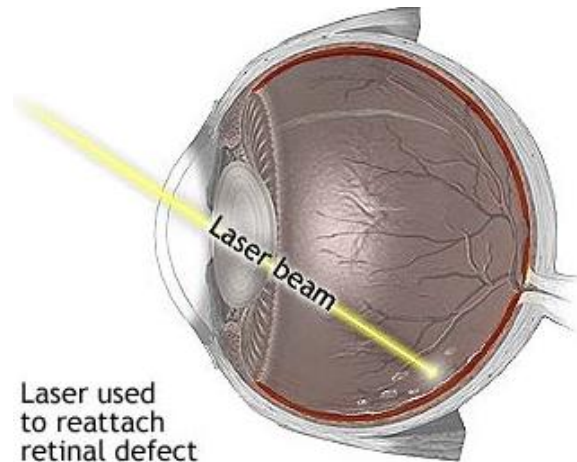
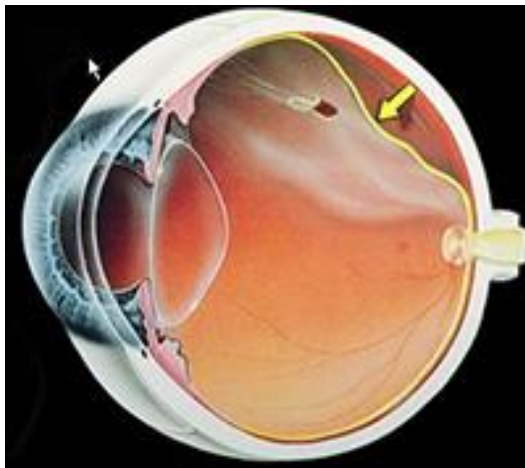
Magnetic Resonance picture

❑ Medical surgery

Different medical, surgical, and therapeutic procedures are developed on physics principles, for example, the use of LASER in surgery or the focused ultrasound surgery FUS :

Laser surgery (photocoagulation)

Retinal detachment occurs when part of it is lifted from its normal position in the back of the eyeball.



❑ Implants and Prosthetics

Prosthesis is the replacement of a missing or a defect part of the body by another made artificially and assuming the same function as the missing part, such as a hearing aid, artificial legs, and so on.



Hearing Aid

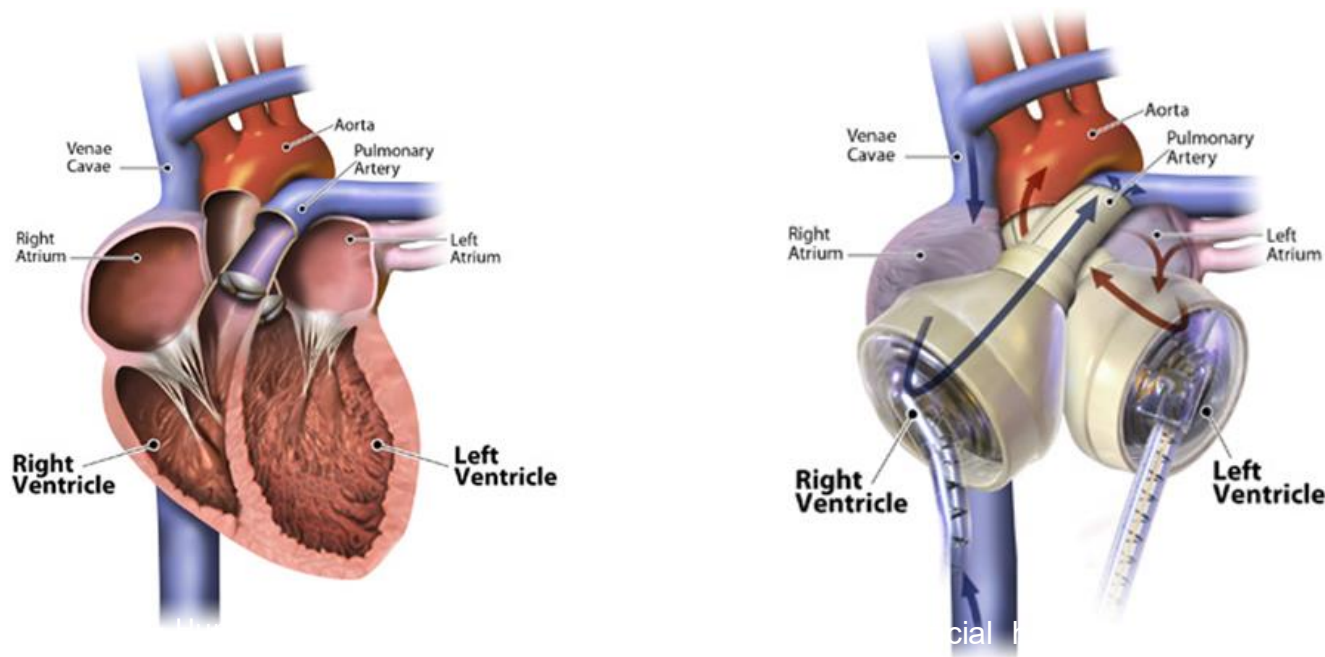


Artificial leg



Artificial Knee joint

Artificial devices to replace vital organs continue to be a dream for thousands of people around the world who are waiting for a heart or a kidney graft.



Conclusion: *In this introduction, it can be clearly seen that physics has many applications in different branches of medicine and contributes to the development and improvement of diagnosis and treatment procedures that can help physicians in their work.*

1.2 Measurements in physics

- Physical quantities are classified into two categories, **base quantities** and **derived quantities**.
- Base quantities such as length, mass, time, temperature,...
- There are seven base (or fundamental) quantities. Table 1.1
- Quantities such as velocity, acceleration, force, energy,...are derived quantities.
- Derived quantities *are combinations of two or more base quantities*.
- Such as for derived quantities, **derived units** combine **base units**.

A unit is a carefully defined amount of some quantity.

A system of units is a convention which defines the standard amounts of a set of fundamental quantities called base quantities.

1.2.1 The international system of units

- The system of units commonly used is the **SI** system (SI is an abbreviation of the French name **Système International des unités.**)
- The SI system of units is a metric system, i.e a system based on the number 10. In this system the unit of length is the meter (m), the unit of time is the second (s), the unit of mass is the kilogram (kg) . The other base units of the SI system are listed in Table 1.1

Table 1.1 : Fundamental units of the SI system

The physical quantity	The SI unit	Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg
Temperature	kelvin	K
Electric current	ampere	A
Intensity of light	candela	cd
Amount of matter	mole	mol

- There are many other units in use for quantities other than the base quantities, such as force, pressure and energy.
- Some of these quantities have their own named unit, such as newton for the force and joule for the energy.
- A short list of derived quantities are in the following table.

Table 1.2 : Some derived units

Quantity	Unit	Symbol
Velocity	meters per second	$m s^{-1}$
Acceleration	meters per second square	$m s^{-2}$
Force	newtons	$kg m s^{-2}$ N
Energy	joules	$kg m^2 s^{-2}$ J
Power	watts	$kg m^2 s^{-3}$ W
Pressure	Pascals	$kg m^{-1} s^{-2}$ Pa

Prefixes

The SI system of units also specifies a set of prefixes to indicate quantities in powers of 10. These prefixes make it easier to refer to very large or very small numbers. Some of the prefixes are listed in table 3.

Table 3, Examples of some prefixes

Number	Power of 10	Prefix	symbol
0.000000001	10^{-9}	nano	<i>n</i>
0.000001	10^{-6}	micro	μ
0.001	10^{-3}	milli	<i>m</i>
1000	10^3	kilo	<i>k</i>
1000000	10^6	mega	<i>M</i>
1000000000	10^9	giga	<i>G</i>

Scientific Notation:

- Small or large numbers can be written in terms of power of 10 and a number between 1 and 10. For example the number 0.0000543 is written in scientific notation as 5.43×10^{-5} (negative power -5 because the decimal point is displaced by 5 places to the right)

Example 1: The total length of blood vessels for a human adult is about 95000 *km*. In meters and in scientific notation this number is:

a- $95.0 \times 10^7 \text{ m}$

b- $0.95 \times 10^8 \text{ m}$

c- $9.5 \times 10^7 \text{ m}$

d- $9.5 \times 10^{-7} \text{ m}$

- Calculations can be simplified using the scientific notation. For example, if we want to calculate $0.000025 \times \frac{1200000}{0.0003}$ it can be easier to do the calculation using the scientific notation:

$$\frac{2.5 \times 10^{-5} \times 1.2 \times 10^6}{3 \times 10^{-4}} = \frac{2.5 \times 1.2}{3} \times 10^5 = 10^5$$

1.3 Conversion of units

- Besides the SI system of units there are some other systems. The commonly used are the British and the CGS systems.
- In the British system for example the unit of length is the foot ($1\text{ ft} = 0.3048\text{ m}$) and the unit of mass is the pound ($1\text{ lbm} = 0.45\text{ kg}$)
- The CGS system stands for centimetre gram and second.
- To change a quantity from system to another we can follow this simple rule:

Example 2: The size of the longest nerve cell is about 5 ft : convert this length into meters

Solution

- Given the conversion factor $1\text{ ft} = 0.3048\text{ m}$ then $\frac{0.3048\text{ m}}{1\text{ ft}} = 1$
- Multiply the length to convert by one: $d = 5\text{ m} \times (1)$
- Replace (1) by the fraction that allows to cancel the unit that we want to change, then: $d =$

$$5\text{ ft} \times \left(\frac{0.3048\text{ m}}{1\text{ ft}}\right) = 1.5\text{ m}$$

Example 3: Convert the speed of $140 \frac{km}{h}$ into meters per second $m s^{-1}$

Solution:

- Here $1 km = 1000 m$ and $1 h = 3600 s$

$$\begin{aligned} 140 km h^{-1} &= 140 \frac{km}{h} \times (1) \times (1) = 140 \frac{km}{h} \times \left(\frac{1000 m}{1 km} \right) \times \left(\frac{1 h}{3600 s} \right) = \\ &= 140 \times \frac{1000 m}{3600 s} = 38.9 m s^{-1} \end{aligned}$$

Exercise 4 : A doctor prescribes to a patient a dose of $40 mg/kg$ three times per day for 6 days.

The patient weight is $70 kg$ and the drug has a concentration of $100 mg/ml$.

A- Find the volume of drug for one dose.

B- Find the total volume for the complete treatment.

C- If the drug is available in bottles of 100 ml, how many bottles the patient need?

$$A) \text{ Volume of drug for one dose.} = 40 \frac{mg}{kg} \times (1) \times (1) = 40 \frac{mg}{kg} \times 70 kg \times \left(\frac{1ml}{100 mg} \right) = 28 ml$$

$$B) \text{ Volume for complete treatment} = 28 \times 3 \times 6 = 504 ml$$

$$C) \text{ Number of 100 mL bottles needed} = 504 mL / 100 mL/bottle = 5.04 \Rightarrow \text{need } [5.04] \approx 6 \text{ bottles}$$