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Unit I Minitest

32 Questions **30 Minutes**

This minitest is designed to assess your mastery of the content in Chapters 1 through 5 of this volume. The questions have been designed to simulate actual MCAT questions in terms of format and degree of difficulty. They are based on the content categories associated with the Foundational Concept that is the theme of this unit. They are also designed to test the scientific inquiry and reasoning skills that the test makers have identified as essential for success in medical school.

In this test, most of the questions are based on short passages that typically describe a laboratory experiment, a research study, or some similar process. There are also some questions that are not based on passages.

Use this test to measure your readiness for the actual MCAT. Try to answer all of the questions within the specified time limit. If you run out of time, you will know that you need to work on improving your pacing.

Complete answer explanations are provided at the end of the minitest. Pay particular attention to the answers for questions you got wrong or skipped. If necessary, go back and review the corresponding chapters or text sections in this unit.

Now turn the page and begin the Unit I Minitest.

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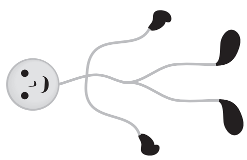
Directions: *Choose the best answer to each of the following questions. Questions 1–5 are based on the following passage.*

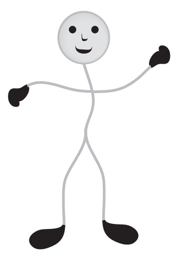
Passage I

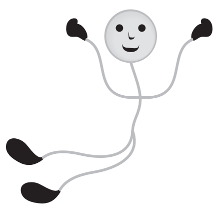
In October 2012, Felix Baumgartner attempted a world record sky-diving jump from just over 128,000 ft (39,014 m) above the Earth's surface. He was fitted with a customized, pressurized spacesuit that brought his total weight to 260 lbs (1156 N). The spacesuit was designed to collect and transmit important monitoring, communications, and tracking information throughout the jump. Mr. Baumgartner then ascended to the jumping altitude housed within a pressurized capsule of weight = 2900 lbs (12900 N) attached to a 30×10^6 cubic feet (8.5×10^8 L) helium-filled weather balloon. The weather balloon with the attached capsule ascended at a rate of 1000 ft/min (5.1 m/s), reaching the jumping altitude in approximately 2 hours.

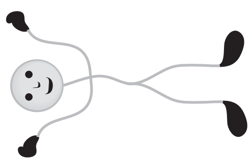
Once the capsule reached the jumping altitude, the door to the capsule was opened and Mr. Baumgartner stepped out and fell forward, beginning his free fall descent. He continued falling until he reached a maximum speed of 834 mph (373 m/s), which exceeded the speed of sound. This speed was Mr. Baumgartner's terminal velocity—the velocity attained in which he was no longer being accelerated downward due to gravity. Once he reached this speed, Mr. Baumgartner deployed his parachute and glided safely to Earth's surface.

1. The terminal velocity of a skydiver can be determined in large part by the orientation of the skydiver in free fall. Which orientation would be MOST likely to result in the largest terminal velocity for the skydiver?

A.


B.


C.


D.


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2. Assuming the density of helium is 0.1785 g/cm^3, the weight of the helium used to inflate the balloon was:

   A. 1.5×10^8 N
   B. 1.5×10^7 N
   C. 1.5×10^6 N
   D. 1.5×10^5 N

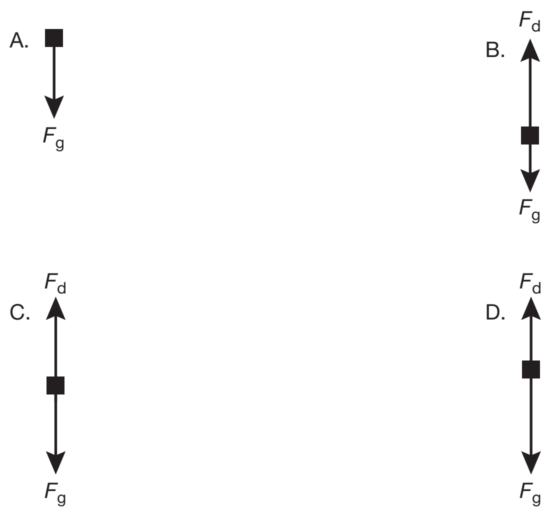
3. The distance traversed by Mr. Baumgartner before he reached maximum velocity was approximately:

   A. 4800 m
   B. 5480 m
   C. 6350 m
   D. 7100 m

4. The drag force, F_{drag}, can be expressed in terms of the terminal velocity, v_t, as $F_{\text{drag}} = Cv_t^2$, where C is a drag constant. The value of the drag constant for Mr. Baumgartner is:

   A. 0.008 kg/m
   B. 0.680 kg/m
   C. 1.320 kg/m
   D. 5.640 kg/m

5. Once the skydiver has reached terminal velocity, the free body diagram that BEST describes the forces acting on a skydiver at terminal velocity is:



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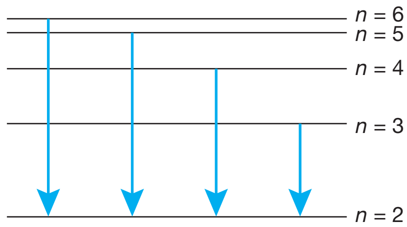
Questions 6 and 7 are not based on a passage.

6. When hydrogen is heated, the atoms that are formed enter an excited state and energy is released in the form of light. The electrons can move between the various principal energy levels as shown in the following diagram:



As a result of the electron transitions to the ground state, four bands of light called the Balmer Series are produced. Which of the four possible transitions to $n = 2$ in the visible spectrum of hydrogen has the longest wavelength?

A. 3 to 2
B. 4 to 2
C. 5 to 2
D. 6 to 2

7. Thirty milliliters of a solution drawn into a 5-g syringe has a total mass of 80 g. The density of the solution in the syringe is:

A. $1.8 \frac{g}{cm^3}$
B. $2.5 \frac{g}{cm^3}$
C. $4.2 \frac{g}{cm^3}$
D. $5.7 \frac{g}{cm^3}$

Questions 8–12 are based on the following passage.

Passage II

Bromine, discovered in the early 1800s, has an atomic number of 35 and is located in group 17. Besides being able to exist as a diatomic liquid, bromine can frequently be found in salts and is useful in preparing organic molecules with a range of functions. Some of these uses include pesticides, water purification, prescription drugs, photochemicals, and flame retardants. In some sodas, one can find brominated vegetable oil added as an emulsifying agent. In addition to its strong odor, bromine is a dark, brown-orange liquid at room temperature. Bromine has two stable isotopes, Br-79 and

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Br-81, and a relative atomic abundance which causes the atomic mass of bromine to be 79.904. Bromine-80 is one of the many unstable isotopes of bromine. It readily undergoes beta decay to form Kr-80. Bromine can also undergo other modes of decay to form Kr-80. When analyzing organic compounds that have bromine in them, the mass spectrometric analysis of the compound frequently shows a peak of equal intensity at $m/z = 79$ and $m/z = 81$ or M^+ and M^{+2} peaks of equal height as well.

8. From the masses of the isotopes and the atomic mass of bromine, you can conclude that the relative abundances of the isotopes are approximately:
   A. 35.0% Br-79 and 75.0% Br-81
   B. 50.7% Br-79 and 49.3% Br-81
   C. 100% Br-80
   D. 33.3% Br-79, 33.3% Br-80, and 33.3% Br-81

9. When a sample of Br_2 is analyzed using a mass spectrometer, the most prominent features of the analysis will be:
   A. one peak at $m/z = 80$ (100%)
   B. one peak at $m/z = 160$ (100%)
   C. two peaks at $m/z = 79$ (50%) and $m/z = 81$ (50%)
   D. three peaks at $m/z = 158$ (25%), $m/z = 160$ (50%), and $m/z = 162$ (25%)

10. Br_2 is expected to be:
    A. diamagnetic
    B. paramagnetic
    C. polar
    D. more dense than diatomic iodine

11. The effective nuclear charge experienced by the valence electrons of bromine will increase the most as you:
    A. move from top to bottom in group 17.
    B. move from bottom to top in group 17.
    C. move from left to right in period 4.
    D. move from right to left in period 4.

12. If Br-80 were to emit a positron, ${}^{0}_{+1}e$, instead of a beta particle, it would still be possible to form Kr-80 via other modes of decay. This would need to include:
    A. one mode of beta decay
    B. two modes of beta decay
    C. one mode of alpha decay
    D. two modes of positron decay

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Questions 13–15 are not based on a passage.

13. In a direct current circuit, a voltage gradient, ΔV, generates and pushes current, I, through a wire of resistance, R, according to Ohm's law or $\Delta V = IR$. Ohm's law can analogously be applied to blood flow, Q, through a vessel of length, L, by the presence of a pressure gradient, ΔP. In this case, the variables involved in blood flow are related by Poiseuille's law or $Q = \frac{\pi r^4}{8\eta L}\Delta P$. Given this, which of the following scenarios would result in the greatest resistance of blood flow?
   - **A.** Double the length and double the radius.
   - **B.** Double the length and halve the radius.
   - **C.** Halve the length and double the radius.
   - **D.** Halve the length and halve the radius.

14. For an individual who is myopic or nearsighted, the eyeball is longer than normal, causing visual images to be focused in front of the retina. Myopia can be corrected by:
   - **A.** using a concave lens, which increases the focal length
   - **B.** using a convex lens, which increases the focal length
   - **C.** using a concave lens, which reduces the focal length
   - **D.** using a convex lens, which reduces the focal length

15. The hydrogen atom consists of a single electron of charge $q_e = -1.6 \times 10^{-19}$ C and a single proton of charge $q_p = +1.6 \times 10^{-19}$ C separated by a distance, $r_{ep} = 5.3 \times 10^{-11}$ m. The electrostatic force that exists between the proton and the electron is:
   - **A.** 3.1×10^{-8} N
   - **B.** 4.5×10^{-8} N
   - **C.** 6.8×10^{-8} N
   - **D.** 8.2×10^{-8} N

Questions 16–20 are based on the following passage.

Passage III

Electromagnetic radiation is often described in physics textbooks as a transverse wave that travels in a vacuum at a speed of $c = 3 \times 10^8$ m/s. Formed by coupled oscillating electric and magnetic fields, electromagnetic radiation comprises all of the types of waves represented within the electromagnetic spectrum, varying in frequency, f, and wavelength, λ, according to the equation, $c = f\lambda$. In addition to its wavelike properties, electromagnetic radiation also behaves as waves do. However, classic experiments in quantum physics have also discovered that light behaves as a particle. The particle of light, known as a photon, has energy $E = hf$ where h is Planck's constant ($h = 6.63 \times 10^{-34}$ J · s) and f is frequency. This apparent contradiction is accepted as the "wave-particle duality of light." Two classical experiments that substantiated the "wave-particle duality of light" were Fraunhofer single-slit diffraction and the Compton effect (see figure).

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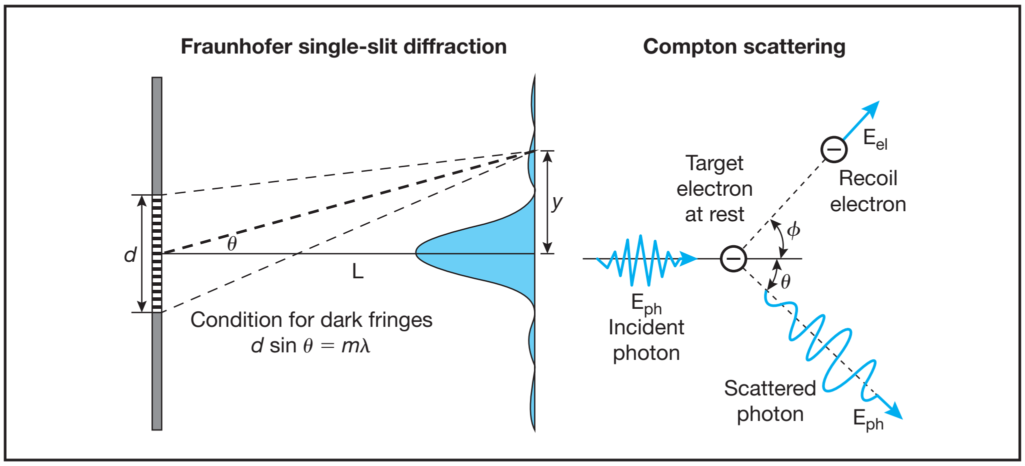

In Fraunhofer single-slit diffraction, monochromatic light is incident parallel to a diffraction grating with a single slit of width d. The light rays will bend around the opening of the slit and project onto a flat screen located a distance, L, from the diffraction grating as a pattern of bright and dark fringes. The pattern of dark fringes (minima) are described by $d\sin\theta = m\lambda$, $m = 1, 2, 3, \ldots$ as the integer value of the particular fringe.

In Compton scattering, a photon of initial energy E_{ph} and wavelength λ_I is incident upon an electron of mass m_e, initially at rest. Upon the collision, the photon is deflected with a scattered energy E'_{ph} at an angle θ with respect to the incident axis as well as an increased wavelength, λ_f, given by $\lambda_f = \lambda_i + \left(\frac{h}{m_e c}\right)(1 - \cos\theta)$ where h is Planck's constant, c is the speed of light, and m_e is the rest mass of the electron (9.1×10^{-31} kg). The Compton-scattered electron scatters with an energy E_{el} at an angle ϕ.

16. According to the nature and description of the two experiments in the passage, you can conclude that:
   - **A.** single-slit diffraction supports the wave nature of light, while Compton scattering supports the particle nature of light.
   - **B.** single-slit diffraction supports the particle nature of light, while Compton scattering supports the wave nature of light.
   - **C.** both single-slit diffraction and Compton scattering support the wave nature of light.
   - **D.** both single-slit diffraction and Compton scattering support the particle nature of light.

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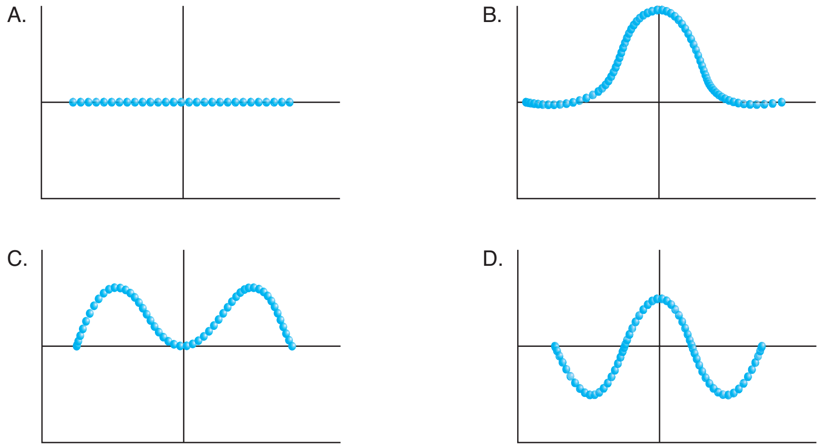
17. If the electromagnetic radiation in the single-slit diffraction experiment were to behave as a particle, the interference pattern would probably look like which of the following?



18. The Compton-scattered photon, compared to the incident photon, possesses:
   A. higher energy, higher frequency, smaller wavelength
   B. higher energy, lower frequency, smaller wavelength
   C. lower energy, higher frequency, longer wavelength
   D. lower energy, lower frequency, longer wavelength

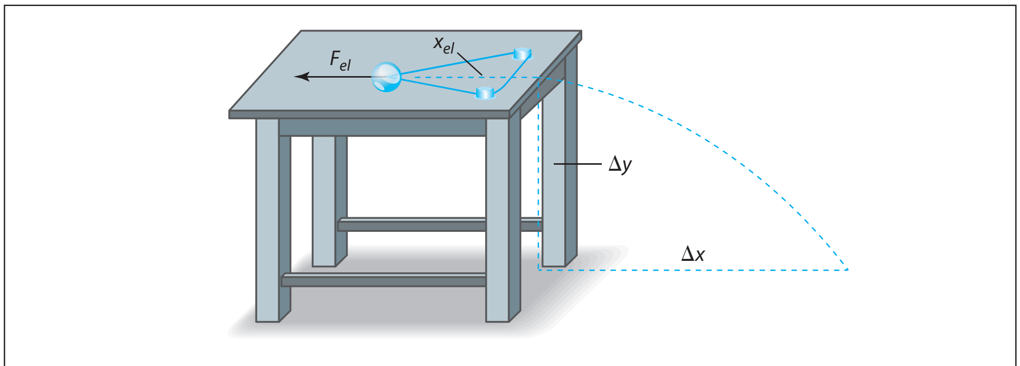
19. In the Compton scattering experiment, the energy of the Compton-scattered electron, E_{el}, can be expressed in terms of the energies of the incident, E_{ph}, and Compton-scattered, E'_{ph} photons by:
   A. $E_{\mathrm{el}} = \dfrac{\left[E_{\mathrm{ph}} - E'_{\mathrm{ph}}\cos(\theta)\right]}{\cos(\phi)}$
   B. $E_{\mathrm{el}} = \dfrac{\left[E_{\mathrm{ph}} - E'_{\mathrm{ph}}\cos(\theta)\right]}{\sin(\phi)}$
   C. $E_{\mathrm{el}} = \dfrac{\left[E_{\mathrm{ph}} - E'_{\mathrm{ph}}\sin(\theta)\right]}{\cos(\phi)}$
   D. $E_{\mathrm{el}} = \dfrac{\left[E_{\mathrm{ph}} - E'_{\mathrm{ph}}\sin(\theta)\right]}{\sin(\phi)}$

20. An expression for the momentum of a Compton-scattered photon in terms of Planck's constant, h, is:
   A. h/λ
   B. hv
   C. λh
   D. λ / h

Questions 21–26 are based on the following passage.

Passage IV

A group of students were assigned the task of assembling a slingshot constructed from rubber bands secured with clamps at the edge of a tabletop that is a known distance, Δy, from the floor and then predicting the horizontal range distance, Δx, that a launched projectile (marble) will land from the base of the table. A schematic of the rubber band slingshot is shown in the following illustration:



Before the slingshot was constructed, a series of measurements were performed on the rubber band to determine the stretching distance, x_{el}, as a function of an elastic force, F_{el}, applied to the rubber band. The data are shown here:

F_{el} (N)	2	3	4	5
x_{el} (cm)	14	21	26	30

The students used the data above to theoretically determine the landing distance of a marble. To compare the effectiveness of their theoretical calculations, the students then launched a marble by stretching the rubber band slingshot to four different values of x_{el}, and recorded the corresponding landing distances, Δx. The data are shown in the following table:

Stretch Distance, x_{el}	2.00 cm	4.00 cm	6.00 cm	8.00 cm
Predicted Value, Δx_{pr}	3.94 m	5.63 m	7.18 m	8.45 m
Observed Value, Δx_{ob}	2.64 m	4.55 m	6.01 m	8.04 m

21. The spring constant for the rubber band used as a slingshot is:
    A. 18.8 N/m
    B. 1.88 N/m
    C. 0.188 N/m
    D. 0.0188 N/m

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22. The velocity that the marble leaves the table upon release of the stretched rubber band is:
    A. kmx_{el}
    B. $\frac{k}{m}x_{el}$
    C. $\sqrt{km}x_{el}$
    D. $\sqrt{\frac{k}{m}}x_{el}$

23. The percent error between the values collected for a stretch distance of 2.0 cm is:
    A. 12%
    B. 26%
    C. 33%
    D. 42%

24. The horizontal landing distance, Δx, can be expressed according to:
    A. $\left[\sqrt{\frac{k}{m}}x_{el}\right]\left[\sqrt{\frac{g}{2\Delta y}}\right]$
    B. $\left[\sqrt{\frac{m}{k}}x_{el}\right]\left[\sqrt{\frac{2\Delta y}{g}}\right]$
    C. $\left[\sqrt{\frac{k}{m}}x_{el}\right]\left[\sqrt{\frac{\Delta y}{2g}}\right]$
    D. $\left[\sqrt{\frac{k}{m}}x_{el}\right]\left[\sqrt{\frac{2\Delta y}{g}}\right]$

25. If the students pull the slingshot back to 10 cm, the horizontal landing distance, Δx_{ob}, they might expect to see is:
    A. 9.7 m
    B. 10.4 m
    C. 11.9 m
    D. 13.1 m

26. If the marble were doubled in mass, the effect on the horizontal landing distance would be:
    A. decrease by $\sqrt{2}$
    B. increase by $\sqrt{2}$
    C. decrease by 2
    D. no change

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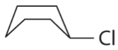
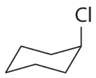
Question 27 is not associated with a passage.

27. Which of the following is the MOST stable conformation of chlorocyclohexane?

A. 

B. 

C. 

D. 

Questions 28–32 are based on the following passage.

Passage V

A standard imaging procedure in the investigation and evaluation of patients with cardiovascular disease is nuclear stress testing. Nuclear stress testing is often used to determine the extent of coronary artery blockage and assess the damage of heart muscle that arises as a result of a heart attack. In a typical nuclear stress test, the patient first walks on a treadmill to elevate the heart rate. Several minutes into the exercising period, a radiotracer or a drug tagged with a radioactive element known to target the heart is injected into the patient's vein and allowed to circulate. As the radiotracer circulates through the blood flow within the heart, the radioactive element decays, emitting gamma radiation that is collected by a gamma ray detector. If a part of the heart's muscle is damaged and not receiving blood flow, the amount of gamma rays detected from this area is less than normal regions of heart muscle. The collected gamma rays are used to produce images of the functional capacity of the heart, allowing the physician to identify any regions of the heart that are functioning below normal capacity.

A common radioactive element used in this testing procedure is thallium-201 (Tl-201). With a half-life of 73 hours, Tl-201 decays to mercury-201 (Hg-201) by electron capture according to:

$$^{201}_{81}\text{Tl} + {}^{0}_{-1}e \rightarrow {}^{201}_{80}\text{Hg} + {}^{0}_{0}\nu$$

The radioactive emissions from Tl-201 are primarily x-rays in the energy range 69–83 keV with gamma rays of energy 135 keV and 167 keV emitted less frequently.

28. In the radioactive decay process of Tl-201, which of the following is true?
   - **A.** A is constant; N increases; Z increases
   - **B.** A is constant; N increases; Z decreases
   - **C.** A increases; N increases; Z is constant
   - **D.** A increases; N is constant; Z is constant

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29. The wavelength of the 167 keV gamma ray emitted from Tl-201 is: (NOTE: $h = 4.15 \times 10^{-15}$ eV · sec; 1 angstrom (Å) = 1×10^{-10} m)
   A. 0.074 Å
   B. 0.183 Å
   C. 0.259 Å
   D. 0.362 Å
30. When compared to x-rays (68–83 keV), gamma rays (167 keV) have:
   A. lower frequency, shorter wavelength, but the same speed
   B. higher frequency, shorter wavelength, but the same speed
   C. lower frequency, longer wavelength, and greater speed
   D. higher frequency, shorter wavelength, and slower speed
31. In a typical nuclear stress test procedure, the percentage of the initial Tl-201 dose that would be present after 24 hours is:
   A. 40%
   B. 55%
   C. 67%
   D. 80%
32. The amount of time required for Tl-201 to decay to 10% of its original dosage is:
   A. 2 days
   B. 5 days
   C. 10 days
   D. 14 days

This is the end of the Unit I Minitest.

Unit I Minitest Answers and Explanations

1. **The correct answer is B.** Terminal velocity occurs when the drag force exerted on the skydiver becomes equal in magnitude and opposite in direction to the weight of the skydiver. The drag force develops as the air molecules interact with the surface area of the falling skydiver. The greater the surface area of the skydiver that acts perpendicular to the direction of the skydiver's fall, the greater force will be exerted on the skydiver, resulting in a smaller terminal velocity. To the contrary, the smaller the surface area of the skydiver that acts perpendicular to the direction of the skydiver's fall, the smaller force will be exerted on the skydiver, resulting in a larger terminal velocity. From the orientations presented in the options, the one orientation that translates to the smallest surface area and hence the greatest terminal velocity is given by choice B.
2. **The correct answer is C.** Using the relationship

$$\text{density} = \frac{\text{mass}}{\text{volume}},$$

you can determine the mass of the helium used to inflate the balloon from

$$\text{mass} = (\text{density}) \times (\text{volume})$$

where density $= 0.1785\ \text{g/cm}^3$ and volume $= 8.5 \times 10^8$ mL or since 1 mL $= 1\ \text{cm}^3$, volume $= 8.5 \times 10^8\ \text{cm}^3$. Thus,

$$\begin{aligned}\text{mass} &= \left(0.1785\ \frac{\text{g}}{\text{cm}^3}\right) \times \left(8.5 \times 10^8\ \text{cm}^3\right)\\ &= 1.52 \times 10^8\ \text{g}\\ &= 1.52 \times 10^5\ \text{kg}\end{aligned}$$

The weight of the helium used to inflate the balloon can be determined from

$$\begin{aligned}\text{weight} &= (\text{mass}) \times (\text{acceleration due to gravity})\\ &= (1.52 \times 10^5\ \text{kg}) \times (9.8\ \text{m/s}^2)\\ &= 14.9 \times 10^5\ \text{N}\\ &= 1.49 \times 10^6\ \text{N} \approx 1.5 \times 10^6\ \text{N}\end{aligned}$$

given by choice C.

3. **The correct answer is D.** The initial velocity (v_i) of Mr. Baumgartner in the vertical direction is 0, his final velocity (v_f) is 373 m/s, and the acceleration due to gravity is 9.8 (although in reality it is probably slightly lower because of the significantly large jumping altitude). The equation of motion that can be used to determine the distance traversed by Mr. Baumgartner is:

$$\begin{aligned}\text{displacement} &= \frac{(\text{final velocity})^2 - (\text{initial velocity})^2}{2 \times (\text{acceleration due to gravity})}\\ &= \frac{\left(373\,\frac{\text{m}}{\text{s}}\right)^2 - \left(0\,\frac{\text{m}}{\text{s}}\right)^2}{19.6\,\frac{\text{m}}{\text{s}^2}}\\ &= \frac{139,129\,\frac{\text{m}^2}{\text{s}^2} - 0}{19.6\,\frac{\text{m}}{\text{s}^2}}\\ &= 7098\,\text{m}\end{aligned}$$

4. **The correct answer is A.** When an object in free fall reaches terminal velocity, it is in equilibrium. In other words, the drag force acting upward becomes equal in magnitude yet opposite in direction to the object's weight or:

$$\begin{aligned}F_d &= F_g\\ Cv_t^2 &= \text{mg}\\ C &= \frac{\text{mg}}{v_t^2} = \frac{1,156\,\text{N}}{\left(373\,\frac{\text{m}}{\text{s}}\right)^2} = \frac{1,156\,\text{N}}{139,129\,\frac{\text{m}^2}{\text{s}^2}} = 0.008\,\frac{\text{kg}}{\text{m}}\end{aligned}$$

5. **The correct answer is C.** Terminal velocity occurs for a free-falling object when the drag force (F_d) becomes equal in magnitude yet opposite in direction to the object's weight or force due to gravity (F_g). This is depicted by the free body diagram with the two forces, F_d and F_g, drawn as arrows of equal size in opposite directions, given by choice C.
6. **The correct answer is A.** The longest wavelength will have the lowest frequency and the lowest energy. This lowest energy occurs from the transition from $n = 3$ to $n = 2$. The relationship can be found in the equation $E = \frac{hc}{\lambda}$. The energy, E, of a photon is equal to Planck's constant times the speed of light, divided by the wavelength. As the wavelength increases, the value of the denominator increases, decreasing the value of E.

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7. **The correct answer is B.** The density of a solution can be determined from:

$$\rho = \frac{m}{V}$$

where ρ is the density of the solution (in units of $\frac{\text{g}}{\text{cm}^3}$), m is the mass of the solution (in units of g), and V is the volume of the solution (in units of cm^3). The mass of the solution, m_{sol}, is the total mass of the solution and the syringe, m_{tot}, minus the mass of the syringe, m_{syr}, or:

$$m_{\text{tot}} = m_{\text{sol}} + m_{\text{syr}}$$
$$m_{\text{sol}} = m_{\text{tot}} - m_{\text{syr}} = 80\text{ g} - 5\text{ g} = 75\text{ g}$$

The volume of the solution in the syringe is $V_{\text{syr}} = 30\text{ mL} = 30\text{ cm}^3$. The density of the solution is:

$$\rho = \frac{m}{V} = \frac{75\text{ g}}{30\text{ cm}^3} = 2.5\,\frac{\text{g}}{\text{cm}^3}$$

8. **The correct answer is B.** Realizing that the atomic mass is almost at the midpoint value of the two isotopes, you can conclude that the approximate abundance is about 50% for each isotope. This comes closest to choice B. To check, take the relative abundance for each isotope and multiply by the mass number for that isotope. Doing so gives the following: $(0.507)(79)+(0.493)(81) = 40.053 + 39.933 = 79.986$. Considering that there will always be some error in analysis, this is the closest choice to the atomic mass of bromine.
9. **The correct answer is D.** There are four combinations for the bromine atoms: Br-79 and Br-79 (=158), Br-79 and Br-81 (=160), Br-81 and Br-79 (=160), and Br-81 and Br-81 (=162). An m/z ratio of 160 will be detected 50% of the time while the other two m/z ratios occur 25% of the time each.
10. **The correct answer is A.** The electron configuration for bromine is $1s^22s^22p^6 3s^23p^64s^23d^{10}4p^5$. While a bromine atom has an unpaired electron, Br_2 does not. Because there are no unpaired electrons, it will be diamagnetic. Br_2 will not be polar as it is diatomic and both atoms have the same electronegativity. Finally, looking at the trend down the halogen family, F_2 will be a gas as will Cl_2 because of their low atomic masses and low dispersion force attractions. Because I_2 has the greater mass, its dispersion forces allow it to be a solid at room temperature. As per the passage, bromine is a liquid and will be less dense than iodine.
11. **The correct answer is C.** The general trend is that Z_{eff} will increase moving down a family and from left to right across a period. However, because the number of core electrons remains constant while one goes from left to right in a period, the nuclear charge will increase and have a greater effect on the valence electrons. The impact of effective nuclear charge will be greater when moving left to right than from top to bottom on the periodic table.

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12. **The correct answer is B.** When $^{80}_{35}\text{Br}$ undergoes positron decay, the result is $^{0}_{+1}e +$ $^{80}_{34}$ Se. In order to achieve $^{80}_{36}\text{Kr}$, two more modes of beta decay need to occur as per the following:

$$^{80}_{34}\text{Se} \rightarrow {}^{0}_{-1}e + {}^{80}_{35}\text{Br} \quad \text{and} \quad {}^{80}_{35}\text{Br} \rightarrow {}^{0}_{-1}e + {}^{80}_{36}\text{Kr}$$

13. **The correct answer is B.** This problem can be solved by substituting the results of each scenario into Poiseuille's law and searching for the smallest value. Choice A yields a 8-fold increase in flow. Choice B results in a 32-fold decrease in flow. Choice C yields a 32-fold increase in flow, while choice D results in a 8-fold decrease in flow.
14. **The correct answer is A.** By definition of the two types of lenses, a concave lens increases the focal length of an image, while a convex lens reduces the focal length of an image. Therefore, choices B and C are incorrect and can be immediately excluded. Since myopia results in image formation in front of the retina, the appropriate corrective lens would be a concave lens which increases the focal length of the image, causing the image to focus past this point and on the retina. Choice A is the correct response. Choice D represents the corrective approach for hyperopia or farsightedness.
15. **The correct answer is D.** The electrostatic force can be calculated using Coulomb's law:

$$F = k\frac{q_e q_p}{r_{\text{ep}}^2} = \left(9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right) \frac{(-1.6 \times 10^{-19}\,\text{C})(+1.6 \times 10^{-19}\,\text{C})}{(5.3 \times 10^{-11}\text{m})^2}$$

$$= -8.2 \times 10^{-8}\,\text{N}$$

represented by choice D.
16. **The correct answer is A.** In single-slit diffraction, light (electromagnetic radiation) passes through a small slit within a diffraction grating and moves toward a screen as wavefronts. As the wavefronts strike the screen, points within the wavefronts will either amplify as a result of constructive interference or cancel each other as a result of destructive interference. The alternating patterns of constructive and destructive interference will result in a pattern of bright and dark fringes on the screen. This observation is indicative of the wavelike behavior of light. Compton scattering involves a two-dimensional elastic collision that can take place only if particles are involved. An electron is a particle and thus in order to observe the Compton effect, light (electromagnetic radiation) must also behave as a particle as well.

17. **The correct answer is A.** The interference pattern described in Fraunhofer single-slit diffraction is based on the fact that light behaves as waves. Wavefronts passing through the slit move toward the screen and, depending on the position of the wavefronts, an interference pattern consisting of alternating maxima and minima will result. If the source were composed of particles, the resultant image will depict a linear array of points, consistent with the geometrical constraints of the slit, as illustrated in Option A.
18. **The correct answer is D.** In Compton scattering, a two-dimensional elastic collision occurs between a photon with an incident energy, E_{ph}, and an electron at rest. As the photon collides with the electron, it scatters at some angle θ after transferring a portion of its energy to the electron, which in turn causes it to scatter with an energy, E_{el}, at some angle ϕ. The energy of the scattered photon, E'_{ph}, is less than the original energy of the photon. From the relation

$$E = hv = h\frac{c}{\lambda},$$

you can see that a reduced energy implies a lower frequency (because energy is directly proportional to frequency) and a longer wavelength (because energy is inversely proportional to wavelength).
19. **The correct answer is A.** This problem requires the application of the conservation of energy:

$$(\text{total energy})_{\text{before collision}} = (\text{total energy})_{\text{after collision}}$$
$$(E_{ph} + E_{el})_{\text{before collision}} = (E'_{ph} + E'_{el})_{\text{after collision}}$$

Although the collision is two-dimensional, only the conservation of energy in the x-direction allows one to develop a relationship between the energy of the Compton-scattered electron and the energy of the incident and scattered photon:

$$(E_{ph} + 0)_{\text{before collision}} = (E'_{ph}\cos(-\theta) + E'_{el}\cos(\phi))_{\text{after collision}}$$

$E_{el} = 0$ because the electron before the collision is at rest. Because cosine is an even function, $\cos(-\theta) = \cos(\theta)$. Therefore,

$$E_{ph} = E'_{ph}\cos(\theta) + E'_{el}\cos(\phi)$$

Solving for E'_{el} yields

$$E_{el} = \frac{\left[E_{ph} - E'_{ph}\cos(\theta)\right]}{\cos(\phi)}$$

20. **The correct answer is A.** This problem can be solved through the use of unit analysis. The units for Planck's constant, h, are J · s, wavelength, λ, is m, and frequency, v, is $\frac{1}{\text{s}}$. The question is which combination of these units will yield the units of momentum $\left(\frac{\text{kg} \cdot \text{m}}{\text{s}}\right)$. The term that has units of momentum is $\frac{h}{\lambda}$.

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21. **The correct answer is A.** The spring constant, k, which is a constant unique to an elastic object that describes the amount of force required to stretch or compress the elastic object by a known distance, can be determined from the data displayed in the first table. Plotting the data with the elastic force, F_{el}, on the y-axis and stretching distance, x_{el}, on the x-axis, the spring constant can be found by taking the slope of the graph. Since the data indicate a linear graph, the slope and thus the spring constant can be found by using the endpoints:

$$k = \text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta F_{el}}{\Delta x_{el}} = \frac{5N - 2N}{0.3m - 0.14m} = \frac{3N}{0.16m} = 18.75\frac{N}{m}$$

22. **The correct answer is D.** The work done in pulling back the slingshot is stored as elastic potential energy, which in turn is transferred to kinetic energy of the moving projectile. Applying the work-kinetic energy theorem:

$$\text{Work} = \text{Elastic Potential Energy} = \text{Change in Kinetic Energy}$$
$$= \frac{1}{2}kx_{el}^2 = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$$
$$v_f^2 = \frac{k}{m}x_{el}^2 \qquad v_f = \sqrt{\frac{k}{m}}x_{el}$$

23. **The correct answer is C.** The percent error can be found from the following equation and substituting in the appropriate values:

$$\%\text{Error} = \left[\frac{\text{Predicted Value} - \text{Observed Value}}{\text{Predicted Value}}\right] \times 100\%$$
$$= \left[\frac{3.94\text{m} - 2.64\text{m}}{3.94\text{m}}\right] \times 100\% = 32.9\% \approx 33\%$$

24. **The correct answer is D.** The horizontal landing distance, Δx, can be determined from the equation:

$$\Delta x = v_x \,\Delta t$$

From the response to Question 21, the horizontal velocity that the marble leaves the tabletop with is given by:

$$v_f = v_x = \sqrt{\frac{k}{m}}x_{el}$$

The time can be found using the equation for displacement in the y-direction for accelerated motion:

$$\Delta y = \frac{1}{2}g\Delta t^2$$

Solving for Δt yields:

$$\Delta t = \sqrt{\frac{2\Delta y}{g}}$$

Substituting into the expression above for the horizontal landing distance gives:

$$\Delta x = v_x \,\Delta t = \left[\sqrt{\frac{k}{m}}x_{el}\right]\left[\sqrt{\frac{2\Delta y}{g}}\right]$$

25. **The correct answer is A.** The students are being asked to extrapolate from the data points already collected and displayed in the second table. Performing simple linear regression analysis, the graphed data reveal the following graph of a line:

$$y = 88.3x + 0.895$$

Substituting the value of 10 cm or 0.1 m into the regression line for x, the y-value or the observed value the students should expect to see when the slingshot is pulled back to 10 cm is:

$$y = 88.3\ (0.10) + 0.895 = 9.73\ \text{m}$$

26. **The correct answer is A.** Using the expression for the horizontal landing distance:

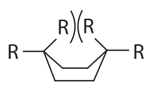
$$\Delta x = v_x\,\Delta t = \left[\sqrt{\frac{k}{m}}x_{\text{el}}\right]\left[\sqrt{\frac{2\Delta y}{g}}\right]$$

If the mass of the marble were doubled,

$$\Delta x = v_x\,\Delta t = \left[\sqrt{\frac{k}{2m}}x_{\text{el}}\right]\left[\sqrt{\frac{2\Delta y}{g}}\right]$$

So, in comparison to the original mass of the marble, the horizontal landing distance would decrease by $\sqrt{2}$.

27. **The correct answer is C.** The answer choices are best considered as two sets of two: two boat conformations and two chair conformations. Boat conformations in general are almost always of higher energy owing to the so-called flagpole interactions shown here:



The distinguishing characteristic between the two chair conformations is that one (choice C) places the chlorine substituent in an equatorial attitude, whereas the other (choice D) forces the substituent to occupy an axial position. An equatorial orientation is almost always energetically preferable.

28. **The correct answer is B.** In the decay process of Thallium-201, given in the passage as ${}^{201}_{81}\text{Tl} + {}^{0}_{-1}e \rightarrow {}^{201}_{80}\text{Hg} + {}^{0}_{0}\nu$, it can be seen that the mass number of Tl-201 ($A = 201$) is identical to the mass number of Hg-201 ($A = 201$); the atomic number of Tl-201 ($Z = 81$) is greater than the atomic number of Hg-201 ($Z = 80$); and the neutron number of Tl-201 ($N = 201 - 81 = 120$) is smaller than the neutron number of Hg-201 ($N = 201 - 80 = 121$). Thus, A remains constant, N increases by one and Z decreases by one. Choice B is the correct choice.

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29. **The correct answer is A.** The wavelength of the gamma ray is equal to its energy by the relation:

$$E = h\frac{c}{\lambda}$$

where E is the energy of the electromagnetic radiation (in units of eV), h is Planck's constant $(= 4.15 \times 10^{-15}\ \text{eV} \cdot \text{sec})$, c is the speed of light in vacuum $(= 3.0 \times 10^{8}\ \text{m/s})$, and 1 is the wavelength.

$$\lambda = h\frac{c}{E} = (4.15 \times 10^{-15}\ eV \cdot s)\frac{\left(3.0 \times 10^{8}\ \text{m/s}\right)}{(167 \times 10^{3}\ eV)} = 0.074 \times 10^{-10}\ m = 0.074\,\text{Å}$$

30. **The correct answer is B.** The energy, wavelength, frequency, and speed are related by:

$$E = h\nu = h\frac{c}{\lambda}$$

Because gamma rays have higher energy than x-rays and frequency is linearly proportional to the energy, the frequency is larger as well. Because the wavelength is inversely proportional to energy, the wavelength decreases as the energy increases. The speed of the x-rays, which is the same speed for the gamma ray, is the speed of light in a vacuum and is constant. Thus, choice B is the correct answer.

31. **The correct answer is D.** This problem is solved using the radioactive decay equation:

$$N = N_o e^{-\left(\frac{0.693}{T_{1/2}}\right)\cdot t}$$

$$\frac{N}{N_o} = e^{-\left(\frac{0.693}{73hr}\right)\cdot 24\ hr} = e^{-0.22} = 0.80$$

Expressed in percentage, the fraction $\frac{N}{N_o}$ is 80%.

32. **The correct answer is C.** This problem is solved using the radioactive decay equation:

$$N = N_o e^{-\left(\frac{0.693}{T_{1/2}}\right)\cdot t}$$

$$\frac{N}{N_o} = 0.10 = e^{-\left(\frac{0.693}{73hr}\right)\cdot t} = e^{-(0.0095/hr)\cdot t}$$

Taking the natural logarithm of both sides yields:

$$-2.3 = -(0.0095/\text{hr}) \cdot t$$

$$t = \frac{2.3}{0.0095/\text{hr}} = 242\ \text{hr} \approx 10.1\ \text{days}$$