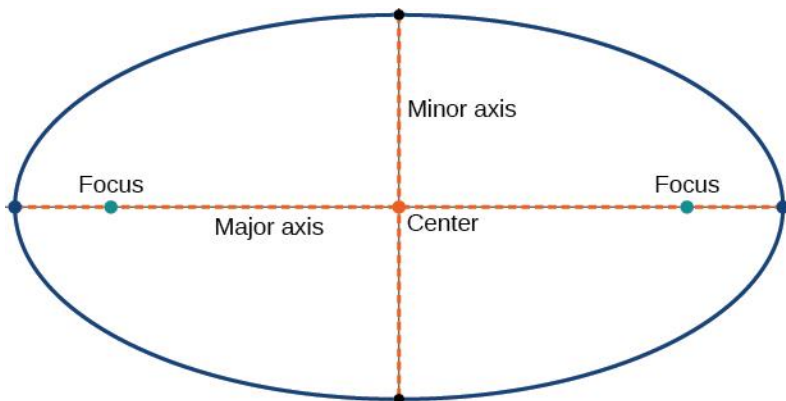


MCQ (30 Points)

Q.1.

In the past, astronomers used to think that planets have perfectly round orbits around the sun. Kepler proved that the orbits are actually ellipses. An ellipse is defined as the set of points that are in the same plane and for which the sum of the distances to two given points (called foci) is constant. The center of the ellipse is the middle of the segment determined by the foci. Ellipses have a semi-major axis (denoted by a) which is the maximum distance between the center of the ellipse and a point on the ellipse and a semi-minor axis (denoted by b) which is the minimum distance between the center of the ellipse and a point on the ellipse.

An ellipse also has an eccentricity which is given by the formula $e = \frac{a-b}{a+b}$



Kepler also proved that the ratio between the square of a planet's orbital period and the cube of its semi-major axis is a constant which is the same for every planet.

The speed of a planet on its orbit is given by the Vis-Viva equation:

$$v^2 = GM \left(\frac{2}{r} - \frac{1}{a} \right)$$

where v is the planet's speed, M is the mass of the central body, r is the distance between the planet and the central body, a is the semi-major axis of the orbit and $G = 6.67 \cdot 10^{-11} \frac{N \cdot m^2}{kg^2}$

Mercury's orbital period is 88 days and its semi-major axis is $58 \cdot 10^9 m$, Earth's orbital period is 365 days and its orbit's eccentricity is 0.0167.

Knowing the mass of the sun is $1.9 \cdot 10^{30} kg$ and that it is located in one of the foci, calculate the difference between Earth's maximum and minimum speed on the orbit.

- A.1** a. $0.225 \cdot 10^5 m/s$
b. $0.378 \cdot 10^5 m/s$
c. $0.153 \cdot 10^5 m/s$
d. $0.072 \cdot 10^5 m/s$

(1.0pt)

Q.2.

A photon's energy is $15.27 \cdot 10^{-33} J$. Using the table below and knowing the Planck constant $h = 6.62 \cdot 10^{-34} J \cdot s$, determine what spectrum of the light, the photon belongs to:

Type of waves	Wavelength (meters)
γ -rays	$< 10^{-16}$
x-rays	$10^{-11} - 10^{-8}$
Ultraviolet	$10^{-8} - 3.8 \cdot 10^{-7}$
Visible light	$3.8 \cdot 10^{-7} - 7.5 \cdot 10^{-7}$
Infrared	$7.5 \cdot 10^{-7} - 10^{-5}$
Microwaves	$10^{-5} - 1$
Short Radio Waves	1 - 1000
Long Radio Waves	> 1000

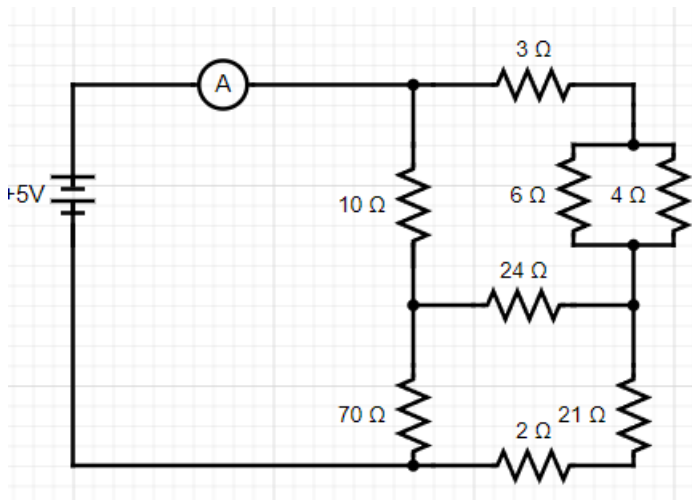
A.2

(1.0pt)

- a. x-rays
- b. Infrared
- c. Visible Light
- d. other

Q.3.

In the following circuit, the current indicated by the ammeter if the battery has 1Ω internal resistance?



*The 6Ω resistance is actually 12Ω .

A.3

(1.0pt)

- a. 0.68A
- b. 0.22A
- c. 1.23A
- b. 0.57A

Q.4.

A resistor with resistance 100Ω is connected to 9V battery with 1Ω internal resistance. The resistance is put in 100g of water (with heat capacity $4186 \frac{J}{kg \cdot K}$) at $10^\circ C$. After ten minutes, the temperature becomes $11^\circ C$.

If the water does not exchange any heat with the container or the air, determine the efficiency of the heating apparatus.

A.4

(1.0pt)

- a. 70.2%
- b. 90%
- c. 84.99%
- d. 93.7%

Q.5.

A body of mass m is hanged on a spring of elastic constant k and the elongation is Δl . The spring is cut into four equal parts and the body is hanged onto one of them. What will be the elongation?

A.5

(1.0pt)

- a. $4\Delta l$
- b. $4m\Delta l$
- c. $\Delta l/4$
- d. depends on the material

Q.6.

The Stefan-Boltzmann law is used to calculate the amount of energy per unit time per unit area radiated by a black body. Its equation is $P = A \cdot \sigma \cdot T^4$, where T is the temperature (in Kelvin), A is the surface area of the body, σ is the Stefan-Boltzmann constant and P is the power (the amount of energy radiated per unit time).

The Stefan-Boltzmann constant can be calculated with the formula $\frac{2\pi^{\alpha}}{15} \cdot k^{\beta} \cdot c^{\gamma} \cdot h^{\delta}$, where $k = 1.38 \cdot J \cdot K^{-1}$ and is called the Boltzmann constant, c is the speed of light in vacuum and is equal to $c = 3 \cdot 10^8 m \cdot s^{-1}$, $h = 6.62 \cdot 10^{-34} J \cdot s$ and is called the Planck constant and α , β , γ and δ are integer exponents.

A sphere of radius 1m (considered a black body) radiates 3450,681kJ of energy in 10 minutes at a temperature of 300K.

If $\pi=3.14$ and $\ln(\pi) = 1.144$, then what is the sum of α , β , γ and δ ?

A.6

- a. 0
- b. 14
- c. 10
- d. 4

(1.0pt)

Q.7.

A normal person can see objects at distances $d \in [0.2m; \infty]$. Matt has an eye problem and can only see objects between 0.5m and 2.5m. To solve his problem, he got 2 pairs of glasses, one for seeing close things and one for seeing far things. What is the difference between the power of the lens in the glasses for close vision and that of the lenses in the glasses for far vision?

A.7

- a. $3m^{-1}$
- b. $0.4m^{-1}$
- c. $3.4m^{-1}$
- d. $2.6m^{-1}$

Q.8.

An ambulance moves with a speed of $27 m/s$ and its siren emits sounds at a frequency of 700Hz. As the ambulance approaches a car, the driver of the car hears sound at a frequency of 729Hz. If the distance between the car and the ambulance is 25m and the speed of sound is $340 m/s$, after how much time does the ambulance pass the car?

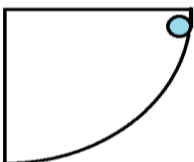
A.8

- a. 1.85s
- b. 2.3s
- c. 1.25s
- d. 0.76s

(1.0pt)

Q.9.

A ball of mass 1kg enters the bottom of a circular ramp of radius 2m with initial velocity of 7m/s. When the angle the ball moved relative to its initial position is equal to 90° , what is the normal force on the ramp (assume no friction)?



- A.9 a. 4.5N (1.0pt)
b. 0N
c. 24.5N
d. 36N

Q.10.

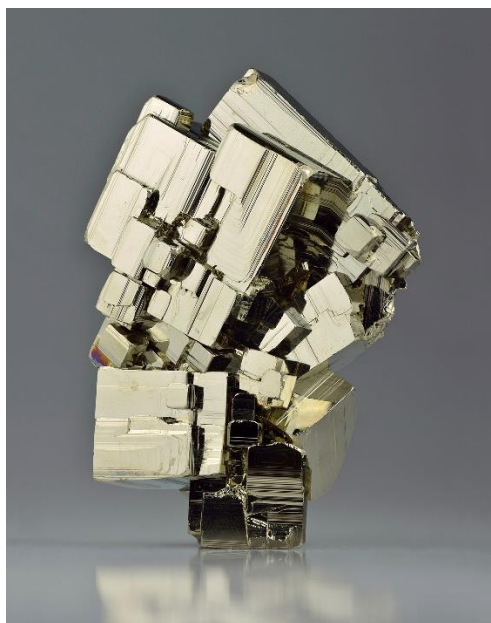
A voltmeter is connected to an electrochemical cell. If the concentration of the electrolyte in the cell's salt bridge increases, the value shown by the voltmeter:

- A.10 a. increases because the electromotive force is proportional to the concentrations of the electrolytes that make it up (1.0pt)
b. decreases because the ions in the salt bridge oppose the movement of electrons, so the internal resistance increases
c. increases because the ions in the salt bridge favor the transport of electrons so the internal resistance decreases
d. stays unchanged, because the salt bridge is not a part of the reaction, so its concentration has no relevance to the voltage of the electrochemical cell

Q.11.

Pyrite is a mineral with the formula FeS_2 (in which iron has oxidation number +2 and both sulfur atoms have the same oxidation number). A probe of pyrite with chalcopyrite impurities ($CuFeS_2$ – both metals have the same oxidation number) is treated with hydrochloric acid. After the reaction is done, a white precipitate forms and all of the gas released occupies 8.61L at 300K and 2atm.

Knowing that among all reactions taking place, only one is a redox reaction and, in the redox reaction, sulfur is both reduced and oxidized, calculate the purity of the probe (assume no other impurities)



- A.11 a. 76.5% (1.0pt)
b. 37.4%
c. 83.3%
d. 23.84%

Q.12.

Limestone is the insoluble chemical compound with the chemical formula CaCO_3 . Which of these processes don't yield soluble calcium salts?

- | | | |
|-------------|---|---------|
| A.12 | a. Bubbling CO_2 gas through water which barely covers CaCO_3
b. Adding HNO_3 over CaCO_3
c. Adding NaOH over CaCO_3
d. Adding HCl over CaCO_3 | (1.0pt) |
|-------------|---|---------|

Q.13.

How many chemical species are present in a phosphoric acid aqueous solution (phosphoric acid is a weak acid)?

- | | | |
|-------------|------------------------------|---------|
| A.13 | a. 5
b. 6
c. 7
d. 8 | (1.0pt) |
|-------------|------------------------------|---------|

Q.14.

Iron is a metal which can be both bivalent and trivalent, depending on the compound it is in. This, along with the fact that iron can form coordination complexes, gives this metal interesting chemical properties, making it act strange sometimes in reactions. Which of the following reaction is correct?

- | | | |
|-------------|--|---------|
| A.14 | a. $\text{Fe}(\text{OH})_3 + 3\text{KCN} \rightarrow \text{Fe}(\text{CN})_3 + 3\text{KOH}$
b. $\text{FeCl}_3 + 3\text{NaHCO}_3 \rightarrow \text{Fe}(\text{OH})_3 + 3\text{NaCl} + 3\text{CO}_2$
c. $2\text{FeCl}_3 + 3\text{Na}_2\text{CO}_3 \rightarrow \text{Fe}_2(\text{CO}_3)_3 + 6\text{NaCl}$
d. $2\text{Fe} + 6\text{HCl} \rightarrow 2\text{FeCl}_3 + 3\text{H}_2$ | (1.0pt) |
|-------------|--|---------|

Q.15.

A mixture of nitrogen, hydrogen and ammonia gases is at equilibrium. Knowing the standard enthalpy of formation for ammonia is 46 kJ/mol , which of the following statements is true:

- i. An increase in pressure, would shift the equilibrium towards the formation of ammonia
- ii. A decrease in temperature would shift the equilibrium towards the formation of ammonia
- iii. If more nitrogen is added to the system, the equilibrium would shift towards the decomposition of ammonia

- | | | |
|-------------|--|---------|
| A.15 | a. all statements
b. only i
c. i and ii
d. ii and iii | (1.0pt) |
|-------------|--|---------|

Q.16.

A Cu^{2+} ions solution is prepared by dissolving a mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in water, to make 100g grams of solution. 10g of the solution are put in a beaker and mixed with an excess of potassium iodide and starch. The mixture obtained is titrated with 0.1M $\text{Na}_2\text{S}_2\text{O}_3$ solution. If, after adding 100mL of thiosulfate solution, the mixture turns colorless, calculate the mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ dissolved initially in water:

A.16

- a. 25g
- b. 2.5g
- c. 16g
- d. 22g

(1.0pt)

Q.17.

Trinitrotoluene (TNT) is an organic liquid compound with the chemical formula $C_7H_5(NO_2)_3$. TNT is used as an explosive because the high amount of heat released when it is burnt in oxygen (to produce CO_2 , H_2O and nitrogen gas). the standard enthalpies of formation of TNT, carbon dioxide and water are -67 kJ/mol , -393.5 kJ/mol and -285.7 kJ/mol respectively. Given the density of trinitrotoluene is 1.65 g/cm^3 , what is the amount of heat released per liter of TNT burnt?

A.17

- a. 17.3 MJ/l
- b. 612.2 kJ/l
- c. 4.5 MJ/l
- d. 24.7 MJ/l

(1.0pt)

Q.18.

Chlorophyll a contains about 2.69% magnesium (by mass). If the chlorophyll molecule contains one Mg atom, what is the molar mass of magnesium?

A.18

- a. 892 g/mol
- b. 895 g/mol
- c. 2400 g/mol
- d. 64 g/mol

(1.0pt)

Q.19.

1L of HCl solution requires 40g of 10% $NaOH$ solution to be completely neutralized. What is the pH of the HCl solution?

A.19

- a. 1
- b. 2
- c. 10^{-1}
- d. 10^{-2}

(1.0pt)

Q.20.

Arrange the chemical species O^- , F , S^{2-} , Cl^- and N^{2-} in order of their increasing radius

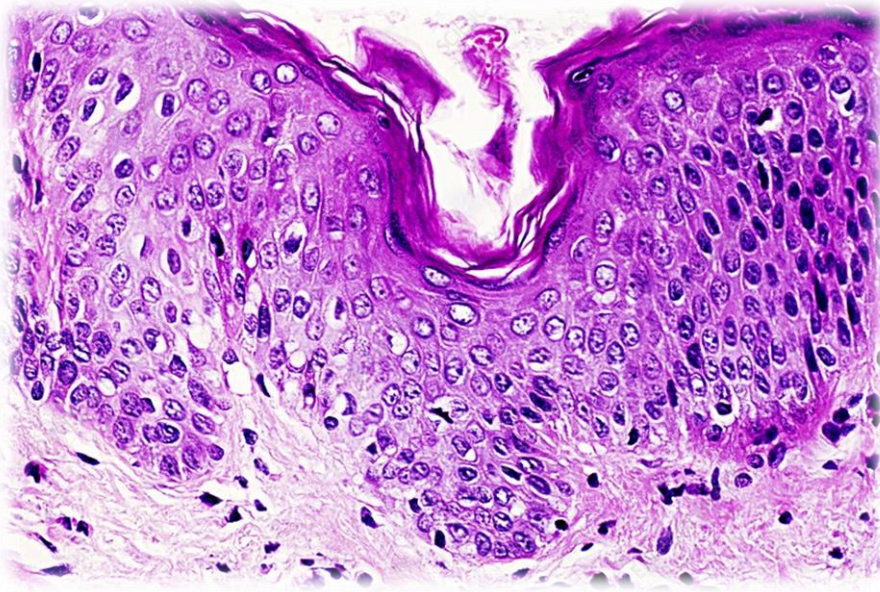
A.20

- a. $N^{2-} < O^- < F < S^{2-} < Cl^-$
- b. $Cl^- < S^{2-} < F < O^- < N^{2-}$
- c. $S^{2-} < Cl^- < N^{2-} < O^- < F$
- d. $F < O^- < N^{2-} < Cl^- < S^{2-}$

(1.0pt)

Q.21.

Which of the following parts of the body does the tissue bellow belong to?

**A.21**

- a. Skin
- b. Lung
- c. Stomach
- d. Artery

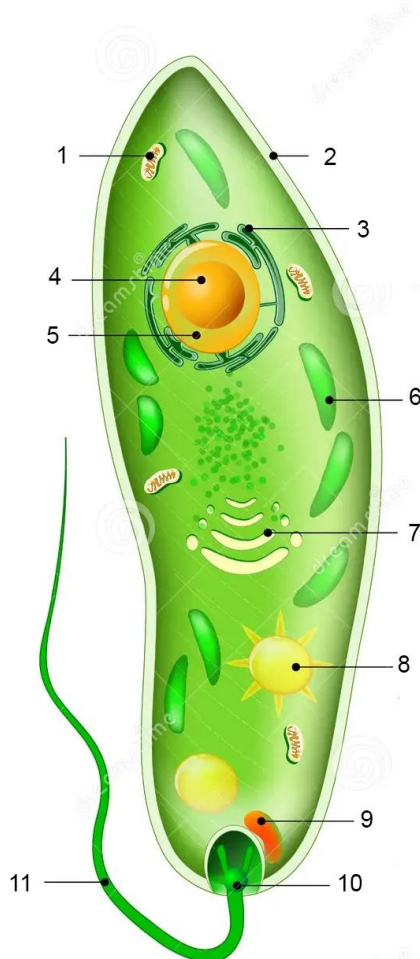
(1.0pt)

Q.22.

Which of the following tables about the labeled organelles in the picture of the euglena is correct?

A.22

(1.0pt)

**A.**

Organelle	Name	Role
6	Chloroplast	Photosynthesis
11	Flagellum	Excretion
5	Nucleus	Contains DNA material

B.

1	Ribosome	Produces energy
4	Nucleolus	Helps in mitosis
2	Membrane	Protects the euglena

C.

11	Flagellum	Movement
9	Ribosome	Protein synthesis
3	Endoplasmic reticulum	Protein synthesis

D.

11	Flagellum	Movement
9	Stigma	Guidance
1	Mitochondria	Intracellular respiration

Q.23.

Duchenne muscular dystrophy (DMD) is an X-linked recessive genetic disorder. It affects muscle evolution and, after some time leads to muscle loss. It is deadly because it can also affect the muscle of the heart. If Stephen's daughter has DMD and his father is healthy, knowing that his mom does not show any symptoms, what is Stephen's mom's and Stephen's wife's genotype (X^d means mutated X gene)

A.23	<u>MOM</u>	<u>WIFE</u>	(1.0pt)
a.	XX	XX	
b.	X^dX	XX	
c.	X^dX	X^dX^d	
d.	X^dX	XX	

The following information is required for questions 24 and 25:

Hemoglobin has a quaternary structure, meaning it's made up of four subunits. Hemoglobin A is the most common hemoglobin type in the human body (almost 97%). It is made up of two α subunits and two β subunits.

Hemoglobin subunits are proteins, meaning they are made up by amino acids.

Proteins are synthesized inside the ribosome, using RNA which contains instructions on what amino acids to synthesize. Each amino acid is encoded by three nitrogenous bases (adenine, uracil, cytosine and guanine). The groups of three nitrogenous bases are called codons.

Making RNA begins inside the nucleus. The nucleus contains DNA which has two strands, called the 3'-5' strand and the 5'-3' strand. An enzyme called RNA-polymerase breaks the hydrogen bonds between the two strands. Then, RNA polymerase creates an RNA strand which is complementary to the 3'-5' strand of DNA (called the template strand) and reattaches the two DNA strands. After the RNA is made, it goes inside a ribosome, where it is read and, for each codon, an amino acid is created.

The first six amino acids in the β subunit of Hemoglobin A are valine, histidine, leucine, threonine, proline and glutamic acid.

Sickle cell anemia is a disease caused by a mutation of the sixth codon in the gene encoding the β subunit (so a different sixth amino acid on the β subunit). The first 18 nitrogenous bases on the 3'-5' strand of the gene used to make hemoglobin β subunits are: CACGTGGACTGAGGACAC.

A mutation in the sixth codon is the only mutation that occurs in sickle cell anemia.

Q.24.

Which of the following correspondences between an amino acid and its RNA codon is correct?

A.24	a. Valine – GCG b. Proline – CCU c. Threonine – AGU d. Histidine - CAG	(1.0pt)
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Q.25.

What is the sixth amino acid in the mutated β subunit?

A.25	a. Valine b. Glutamic acid c. Histidine d. Leucine	(1.0pt)
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Q.26.

The image bellow shows an arctic fox:

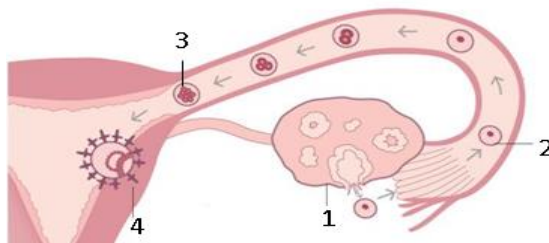


Which of the following statement-reasoning pairs about the arctic fox is correct?

- A.26** (1.0pt)
- a. S: The arctic fox has white fur
R: It scares the predators
 - b. S: The arctic fox has small ears
R: It minimizes heat loss through extremities
 - c. S: The arctic fox lives in a white environment
R: It has white fur
 - d. S: The arctic fox has its eyes positioned in front of her face
R: It gives it a wider field of view

Q.27.

The image bellow shows the evolution of a fertilized egg until it fixates in the uterus.



Which of the following statements is true?

- A.27** (1.0pt)
- a. Number 2 is called an embryo
 - b. The process that occurs at number 4 is called "nidation"
 - c. Number 3 is a haploid cell
 - d. Number 3 is called a spermatozoid

Q.28.

Which of the following organs does not produce enzymes?

A.28

(1.0pt)

- a. The Stomach
- b. The Salivary glands
- c. The Liver
- d. The Small Intestine

Q.29.

Which of the following statements about the innermost layer of the eye is true?

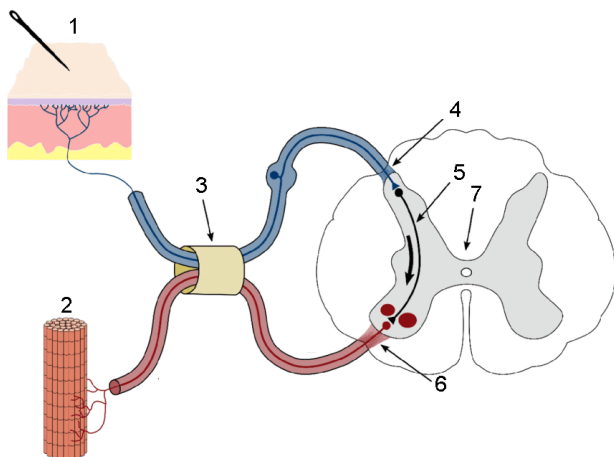
A.29

(1.0pt)

- a. Rod cells are less sensitive to light than cone cells
- b. The crystalline becomes more convergent when seeing closer objects
- c. The places where the optic nerve leaves the eye is known as the "blind spot"
- d. Touching the cornea triggers the lacrimal glands.

Q.30.

The image below is the representation of a reflex.



Which of the following statements are true?

- i. The tissue at number 2 is smooth muscular tissue
- ii. If nerve in number 6 were damaged, the person would still feel the pain sensation, but wouldn't have the reflex to pull the part which was stung with the needle.
- iii. In area number 4 the pain sensation is formed.
- iv. Number 7 contains cerebrospinal fluid
- v. Number 4 is the posterior horn of the spinal cord.

Choose the option with correct combination of inferences cited above:

A.30

(1.0pt)

- a. i, ii and iv
- b. all
- c. ii, iv and v
- d. ii, iii and v

MCQ

MCQ Answers (30 Points)

Number	Options			
Answer No 1	A	B	C	D
Answer No 2	A	B	C	D
Answer No 3	A	B	C	D
Answer No 4	A	B	C	D
Answer No 5	A	B	C	D
Answer No 6	A	B	C	D
Answer No 7	A	B	C	D
Answer No 8	A	B	C	D
Answer No 9	A	B	C	D
Answer No 10	A	B	C	D
Answer No 11	A	B	C	D
Answer No 12	A	B	C	D
Answer No 13	A	B	C	D
Answer No 14	A	B	C	D
Answer No 15	A	B	C	D
Answer No 16	A	B	C	D
Answer No 17	A	B	C	D
Answer No 18	A	B	C	D
Answer No 19	A	B	C	D
Answer No 20	A	B	C	D
Answer No 21	A	B	C	D
Answer No 22	A	B	C	D
Answer No 23	A	B	C	D
Answer No 24	A	B	C	D
Answer No 25	A	B	C	D
Answer No 26	A	B	C	D
Answer No 27	A	B	C	D
Answer No 28	A	B	C	D
Answer No 29	A	B	C	D
Answer No 30	A	B	C	D