1. Match the features of a plant cell listed in Column I with their corresponding examples in Column II.

   Column I

   i. Cell with cytoplasm and no nucleus

   ii. Cell lacking both cytoplasm and nucleus

   iii. Cell containing more than two nuclei

   iv. Haploid cell produced by mitosis

   Column II

   p. Pollen grain

   q. Synergid

   r. Tracheid

   s. Tapetum

   t. Mature sieve tube

   u. Phloem companion cell

   Choose the CORRECT combination from the options below.
   - A. i and t; ii and r; iii and s; iv and q
   - B. i and u; ii and r; iii and s; iv and p
   - C. i and u; ii and r; iii and q; iv and p
   - D. i and r; ii and t; iii and s; iv and q

2. Shown below are some of the reactions that occur in the metabolic pathway leading to complete oxidation of glucose during aerobic respiration.

   i.   Pyruvate $\longrightarrow$ Acetyl CoA

   ii. Dihydroxy acetone phosphate $\longrightarrow$ Glyceraldehyde-3-phosphate

   iii. Oxaloacetate $\longrightarrow$ Citrate

   iv. Fumarate $\longrightarrow$ Malate

   Choose the CORRECT sequence of reactions during the complete oxidation of glucose.
   - A. ii; i; iii; iv
   - B. i; iii; iv; ii
   - C. i; ii; iii; iv
   - D. ii; iii; i; iv

3. In a given species of flowering plant, the colour of the seeds is exclusively determined by the colour of its seed coat. Seed coat colour in this species is governed by a nuclear gene with two alleles. The *WHITE* (*W*) allele is dominant over *brown* (*w*) allele. If a plant with brown seeds (*ww*) is crossed as a female with pollen from a white seed (*WW*) plant, what will be the seed colour and the genotype of the embryo in the resultant seeds obtained from this cross?
   - A. Brown seeds with *Ww* embryo

B. White seeds with *Ww* embryo

C. Brown seeds with *ww* embryo

D. White seeds with *ww* embryo

4. During the CoVID-19 pandemic, SARS-CoV2 virus mutated multiple times giving rise to many variants. What is the genetic material of the SARS-CoV2 virus?

    A. Single stranded RNA

    B. Double stranded RNA

    C. Single stranded DNA

    D. Double stranded DNA

5. Lymph is an important body fluid. Choose the INCORRECT statement about the lymph.

    A. It remains as an interstitial fluid and is never put back into circulation.

    B. It is the interstitial fluid generated by the passage of liquid between the cells of the capillary.

    C. It is colourless and has similar mineral composition as of plasma.

    D. Fat digested in the intestine is absorbed through the lymph.

6. Interneurons play an important role in the execution of spinal cord-mediated reflex action. Where are these interneurons located?

    A. Gray matter

    B. White matter

    C. Dorsal root ganglion

    D. Muscle spindle

7. Osmoreceptors are sensitive to changes in ionic concentrations and volumes of body fluids. Which among the following best describes the function of these osmoreceptors?

    A. They stimulate hypothalamus to facilitate the release of the anti-diuretic hormone and increase water reabsorption.

    B. They stimulate pituitary gland to facilitate the secretion of mineralocorticoids to adjust the changes in mineral composition of the body fluid.

    C. They stimulate atrial wall to release atrial natriuretic factor to induce vasodilation and reduce blood pressure.

    D. They stimulate renin production to induce vasoconstriction and increase blood pressure.

8. A single point mutation in gene 'X' results in breathing difficulty, hypertension as well as partial sterility. Which among the following phenomenon best explains the observed phenotypes?

    A. Pleiotropy

    B. Incomplete dominance

    C. Linkage

    D. Partial dominance

9. In a cross between individuals of the genotypes PpQQRrSS and ppqqRrSS, what will be the expected number of progenies with the genotype ppQQRrSS in a population of 400 individuals, assuming independent assortment?

    A. 0

    B. 100

    C. 200

    D. 25

10. Organisms in which of the following phyla are triploblastic, acoelomate and have bilateral symmetry?

    A. Platyhelminthes

    B. Mollusca

    C. Arthropoda

    D. Hemichordata

11. Consider the following biomes: Tropical Rainforest (P); Tundra (Q); Desert (R) and Coastal zone (S). Choose the most probable descending order of Net Primary Productivity of these biomes.

    A. $P > S > Q > R$

    B. $P > Q > S > R$

    C. $Q > P > S > R$

    D. $R > Q > S > P$

12. Nine percent of a population cannot taste a certain food item because of a recessive allele of the gene IAT. Assuming the population is in Hardy-Weinberg equilibrium, what will be the frequency of dominant and recessive alleles, respectively?

    A. 0.7 and 0.3

    B. 0.9 and 0.1

    C. 0.3 and 0.7

    D. 0.1 and 0.9

13. As opposed to DNA replication within the cell, discontinuous synthesis of DNA does NOT occur in a polymerase chain reaction (PCR). Why?

    A. Denaturation step in PCR substitutes for the replication fork and Taq polymerase extends DNA only in the $5'$ to $3'$ direction.

    B. The replication fork is formed and Taq polymerase extends DNA in both $3'$ to $5'$ and $5'$ to $3'$ direction.

    C. Denaturation step in PCR substitutes for the replication fork and Taq polymerase extends DNA only in the $3'$ to $5'$ direction.

    D. The replication fork is formed and DNA ligase activity of the Taq polymerase joins the discontinuous fragments.

14. Which of the following figures CORRECTLY represents the chemiosmotic hypothesis of ATP synthesis occuring in a mitochondrion in a cell? (Keys for the figure; IMS: Intermembrane space, IMM: Inner mitochondrial membrane, MM: Mitochondrial matrix, ETC: Electron transport chain)

A.
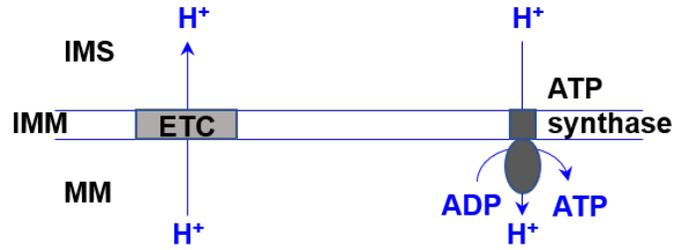
B.
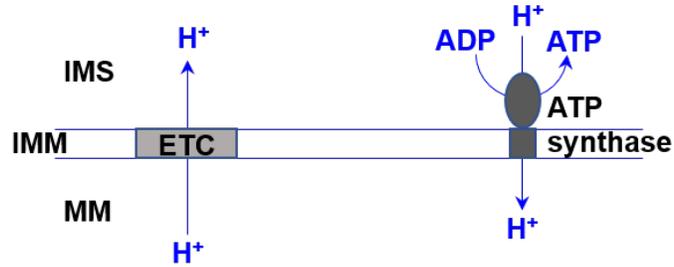
C.
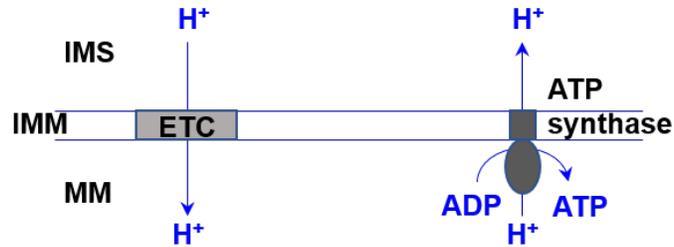
D.
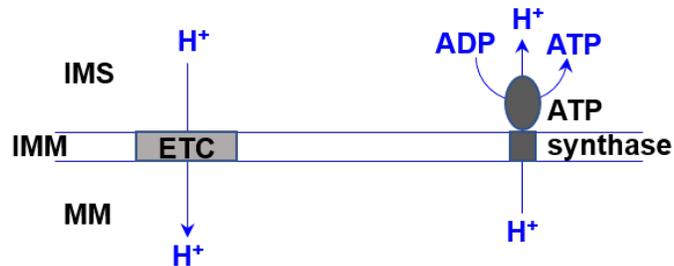
15. Let 'X' be the perpendicular distance from the centromere of each chromosome to the equatorial plane of a human cell. Which of the following stages of the cell cycle is most likely to have the HIGHEST average value of 'X'?

    A. Late anaphase

    B. Metaphase

    C. Early anaphase

    D. Early metaphase

1. The products of the reaction between aqueous solutions of $K_4[Fe(CN)_6]$ and $\frac{1}{2}$ H_2O_2 are

   A. $K_3[Fe(CN)_6]$ and KOH

   B. $K_3[Fe(CN)_6]$ and H_2O

   C. $K_3[Fe(CN)_6]$, H_2O and O_2

   D. $K_4[Fe(CN)_5(OH)]$ and HCN

2. For the colourless complex $[M(H_2O)_6]^{n+}$, where M is a $3d$ transition metal, the CORRECT ground state d-electron configuration of M is

   A. $(t_{2g})^6(e_g)^4$

   B. $(t_{2g})^3(e_g)^0$

   C. $(t_{2g})^6(e_g)^2$

   D. $(t_{2g})^4(e_g)^2$

3. Choose the correct statement about the structure of C_{60} fullerene.

   A. 5-membered rings are fused with 6-membered rings ONLY.

   B. 6-membered rings are fused with 5-membered rings ONLY.

   C. 6-membered rings are fused with 6-membered rings ONLY.

   D. 5-membered rings are fused with both 5-membered and 6-membered rings.

4. The first to fifth ionization energies (IE) of two p-block elements **X** and **Y** are given below.

|	IE_1 (eV)	IE_2 (eV)	IE_3 (eV)	IE_4 (eV)	IE_5 (eV)
X	6.0	18.8	28.4	120.0	153.7
Y	8.2	16.3	33.5	45.1	166.7

   The number of valence electrons in **X** and **Y** respectively are

   A. 3, 4

   B. 4, 5

   C. 3, 5

   D. 1, 4

5. Which of the following expressions represents the hydrogen atom wave function $\psi(r)$ shown in the figure below?
figure below?
(r is the distance of the electron from the nucleus and a_0 is a constant)

Radius, r/a_0
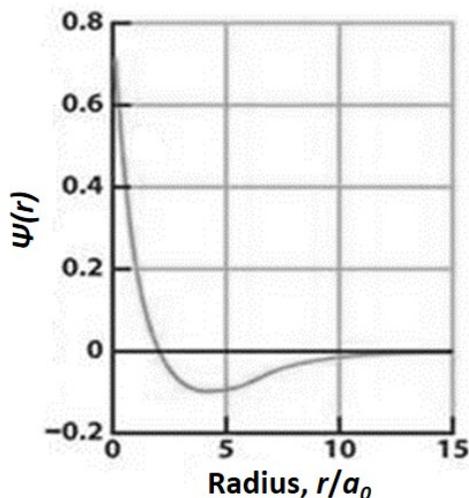
A. $\dfrac{1}{4\sqrt{2\pi}}\left(\dfrac{1}{a_0}\right)^{3/2}\left(2-\dfrac{r}{a_0}\right)e^{-r/2a_0}$

B. $\dfrac{1}{\sqrt{\pi}}\left(\dfrac{1}{a_0}\right)^{3/2}e^{-r/2a_0}$

C. $\dfrac{1}{\sqrt{6\pi}}\left(\dfrac{1}{a_0}\right)^{3/2}\left(\dfrac{r}{a_0}\right)e^{-r/2a_0}$

D. $\dfrac{1}{\sqrt{3\pi}}\left(\dfrac{1}{a_0}\right)^{3/2}\left(3-\dfrac{2r}{a_0}+\dfrac{2r^2}{9a_0^2}\right)e^{-r/3a_0}$

6. Which of the following molecules are aromatic?
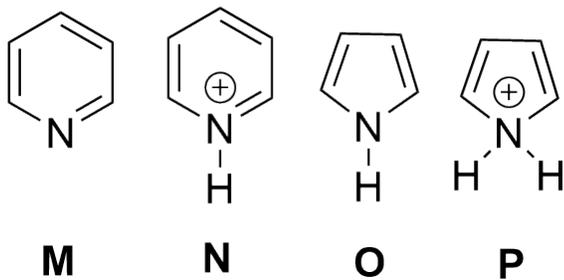
M   **N**   **O**   **P**

A. **M**, **N** and **O** only

B. **M**, **N**, **O**, and **P**

C. **M** and **O** only

D. **N** and **P** only

7. Which of the following are aryl bromides?
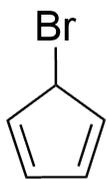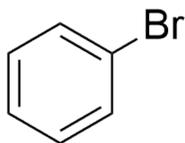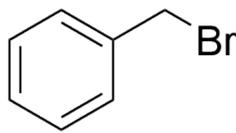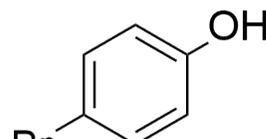
M   **N**   **O**   **P**

    A. **N** and **P** only

    B. **N**, **O** and **P** only

    C. **M**, **O** and **P** only

    D. **N** and **O** only

8. Benzamide is treated with Br_2 and NaOH(aq) to form the product X, which is then reacted with $NaNO_2$ and HCl(aq) at $0 - 5\,°C$ to form Y. Y is immediately treated with ethanol to give **Z**. What is **Z**?

A.

B.

OCH₂CH₃ labeled structure

C.

NH₂ labeled structure

D.

CH₂CH₃ labeled structure
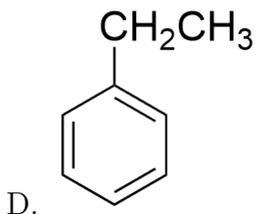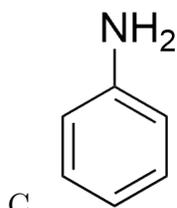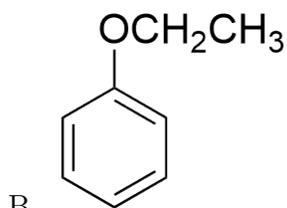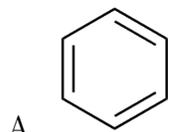
9. In the following reaction sequence, the major products **M**, **N**, and **O** respectively are

OH

(phenol) $\xrightarrow[\text{2. MeI}]{\text{1. NaOH}}$ **M** $\xrightarrow[\text{anhydrous AlCl}_3]{\text{CH}_3\text{COCl}}$ **N** $\xrightarrow{\text{NaOCl}}$ **O**

A.

OCH$_3$; OCH$_3$ (with COCH$_3$ para) ; OCH$_3$ (with C(=O)O$^-$ Na$^+$ para)

B.

OH (para-methyl) ; OH with COCH$_3$ (methyl para) ; OH with C(=O)O$^-$ Na$^+$ (methyl para)

C.

OCH$_3$; OCH$_3$ (with COCH$_3$ para) ; OCH$_3$ with Cl and COCH$_3$

D.

OCH$_3$; OCH$_3$ (ortho COCH$_3$) ; OH (ortho C(=O)O$^-$ Na$^+$)
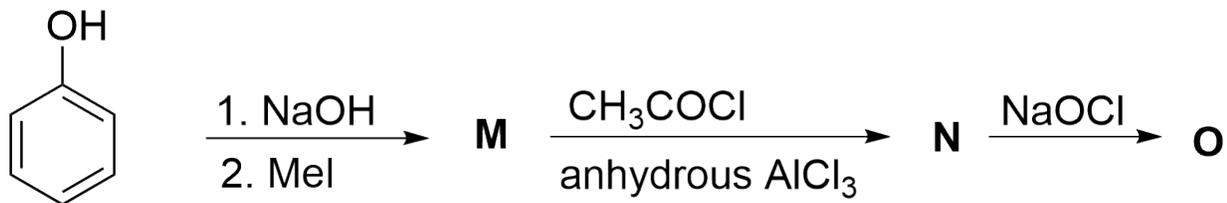
10. The major product **P** of the following reaction is

A.

B.

C.

D.
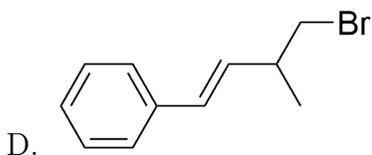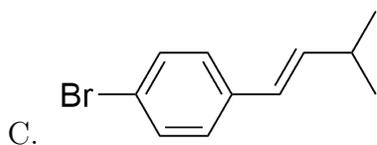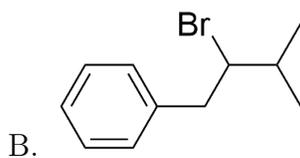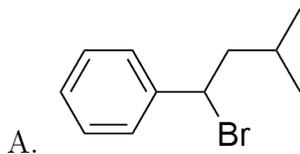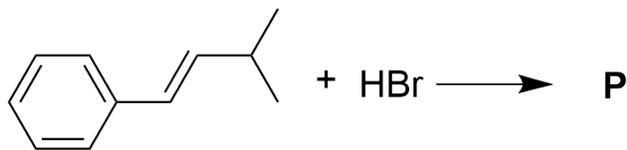
11. An aqueous solution contains 1.0 M of X^{2+} and 0.001 M of Y^{2+} ions at 25 °C. X^{2+} and Y^{2+} ions do not interact with each other. This solution is put in an electrolytic cell and the voltage is gradually increased till a current begins to flow through the cell. The voltage is maintained at this point and a deposit is observed on the cathode. What is the composition of the material deposited on the cathode?

(Given: Atomic weight of X is 63 and Y is 200.

$X^{2+} + 2e^- \rightarrow X$, $E^0 = 0.35$ V,

$Y^{2+} + 2e^- \rightarrow Y$, $E^0 = 0.40$ V,

E^0 is the standard reduction potential.)

    A. Only X

    B. 24% X and 76% Y by weight

    C. 98% X and 2% Y by weight

    D. Only Y

12. For the reaction involving ideal gases, $A(g) + 2B(g) \rightleftharpoons 2C(g) + 3D(g)$, which of the following plots is qualitatively correct? (K_p and K_c are the equilibrium constants in terms of pressure and concentration respectively. T is the absolute temperature.)

A.

B.

C.

D.
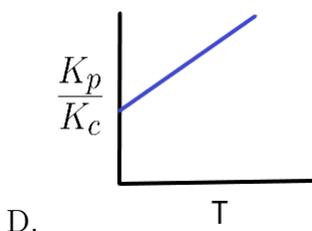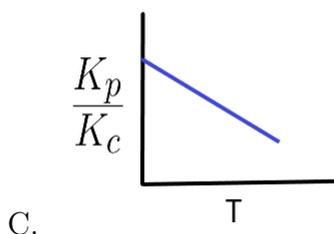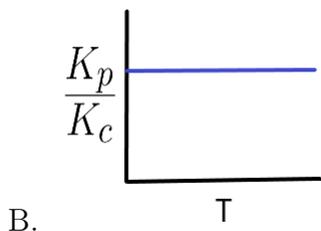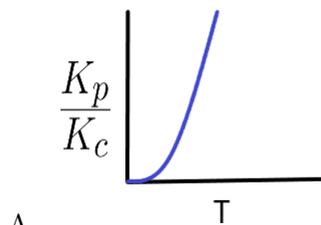
13. The van der Waals equation for a real gas is given by $\left(P + \dfrac{a}{V^2}\right)(V - b) = RT$. What is the dimension of $\left(\dfrac{a}{b}\right)$?

    A. ML^2T^{-2}

    B. $ML^{-1}T^{-2}$

    C. MLT^{-2}

    D. ML^2T^{-1}

14. 2 g of naphthoic acid (molecular weight $= 172$ g mol^{-1}) dissolved in 20 mL of benzene shows a freezing point depression of 2 K. For benzene, the freezing point depression constant, $K_f = 5$ K kg mol^{-1} and the density is 0.88 g mL^{-1}. What is the magnitude of the van't Hoff factor?

    A. 0.605

    B. 605.0

    C. 0.688

D. 688.0

15. Identify the correct order of the molecules with respect to the magnitude of their dipole moment:

A.

B.

C.

D.
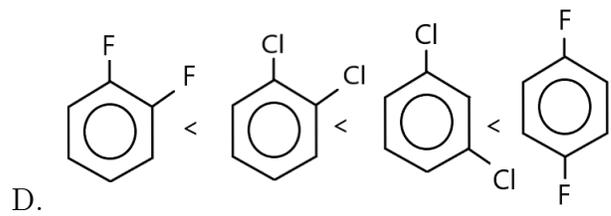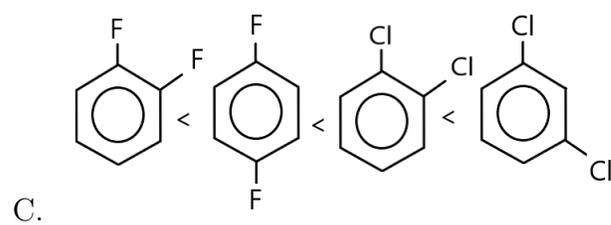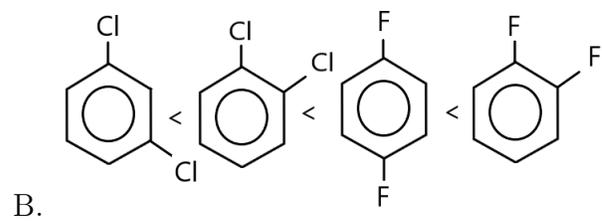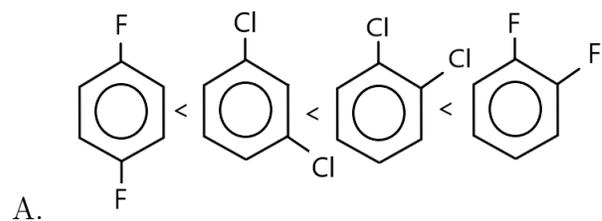
1. A randomly chosen card from a deck of 52 cards is given to be a black card (i.e. Spade or Club). What is the probability that it is either a face card (i.e. King, Queen or Jack) or a Spade?

   A. 8/13

   B. 9/13

   C. 19/26

   D. 7/13

2. Let ω be a complex root of the quadratic polynomial $x^2 + x + 1$. The value of

$$\left(\omega + \frac{1}{\omega}\right) \cdot \left(\omega^2 + \frac{1}{\omega^2}\right) \cdots \left(\omega^{100} + \frac{1}{\omega^{100}}\right)$$

is

   A. -2^{33}

   B. -2^{31}

   C. 2^{33}

   D. 2^{31}

3. Let $f(x) = a_n x^n + a_{n-1} x^{n-1} + \cdots + a_1 x + a_0$ be a polynomial. Suppose that

$$f(0) = 0, \quad \frac{df}{dx}\bigg]_{x=0} = 1, \quad \frac{d^2 f}{dx^2}\bigg]_{x=0} = 4 \text{ and } \frac{d^3 f}{dx^3} = \frac{d^5 f}{dx^5}.$$

   Then $f(5) =$

   A. 55

   B. 25

   C. 35

   D. 105

4. Let S be the set of all unit vectors in the XY-plane. Then the set S has

   A. Infinitely many elements

   B. 2 elements

   C. 4 elements

   D. 8 elements

5. A lab reports that the global average temperature in the year 2020 was 14.9°C and predicts that the global average temperature will increase at the rate of 1% per year. What will be the global average temperature in the year 2035?

   A. 17.298°C

   B. 15.049°C

   C. 17.135°C

   D. 17.471°C

6. Let X be the set of all 2×2 matrices with real entries and $R \subset X \times X$ be the relation

$$R = \{(A, B) : AB = BA\}.$$

Which of the following statements is true?

   A. R is reflexive and symmetric but not transitive

   B. R is reflexive and transitive but not symmetric

   C. R is symmetric and transitive but not reflexive

   D. R is an equivalance relation

7. For a natural number n, let C_n be the curve in the XY-plane given by $y = x^n$, where $0 \leq x \leq 1$. Let A_n denote the area of the region bounded between C_n and C_{n+1}. Then the largest value of A_n is

   A. $\dfrac{1}{6}$

   B. $\dfrac{1}{2}$

   C. $\dfrac{1}{3}$

   D. $\dfrac{1}{12}$

8. Let f be a continuous function on $[0, 1]$ and F be its antiderivative. If $F(0) = 1$ and $\int_0^1 f(x) \, dx = 1$, then $F(1)$ is

   A. 2

   B. 0

   C. 1

   D. $\dfrac{1}{2}$

9. Let a be a nonzero real number and $f : \mathbf{R} \to \mathbf{R}$ be a continuous function such that $f'(x) > 0$ for all $x \in \mathbf{R}$. Consider $g(x) = f(2a^2 x - ax^2)$. Then g has

   A. Local maxima at $x = a$ if $a > 0$

   B. Local maxima at $x = a$ if $a < 0$

   C. Local minima at $x = a$ if $a > 0$

   D. A point of inflection at $x = a$

10. Let A be the matrix
$$\begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 1 & 1 & 1 \\ \sin\theta & 0 & \cos\theta \end{bmatrix}.$$

For any natural number k, the determinant of A^k is

   A. 1

   B. -1

   C. $(-1)^k$

D. 0

11. Consider the vectors

$$\vec{a} = \hat{i} + x\hat{j} + 2\hat{k},$$
$$\vec{b} = \hat{i} + 2\hat{j} + x\hat{k},$$
$$\vec{c} = 2\hat{i} + \hat{j} + 3\hat{k}.$$

The values of x for which there is at least one nonzero vector perpendicular to the vectors $\vec{a}, \vec{b}$ and $\vec{c}$ are

    A. 0, 2

    B. -2, 2

    C. 7/2, 0

    D. 4, -2

12. Consider the tangent lines to the circle $x^2 + y^2 = 1$ at points $P = (1,0)$ and $Q = (\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}})$. If R is the point of intersection of these two tangent lines, then $\angle PRQ$ is:

    A. $\frac{3\pi}{4}$

    B. $\frac{\pi}{4}$

    C. $\frac{5\pi}{6}$

    D. $\frac{\pi}{6}$

13. The function given by $f(x) = 2x^3 - 15x^2 + 36x - 5$ is

    A. Increasing on the interval $(0, 2)$

    B. Decreasing on the interval $(-3, 0)$

    C. Increasing on the interval $(2, 3)$

    D. Decreasing on the interval $(3, \infty)$

14. The value of the integral

$$\int_1^{100} \frac{[x]}{x} \, dx,$$

where $[x]$ is the greatest integer less than or equal to x for any real number x, is

    A. $\log\left(\dfrac{100^{99}}{99!}\right)$

    B. $\log\left(\dfrac{100^{99}}{98!}\right)$

    C. $\log\left(\dfrac{100^{98}}{99!}\right)$

    D. $\log\left(\dfrac{100^{98}}{98!}\right)$

15. For arbitrary constants α, β, the differential equation representing the family of curves $y = (\alpha x + \beta)e^x$ is

A. $y'' - 2y' + y = 0$

B. $y'' - y' + y = 0$

C. $y'' - 2y' - y = 0$

D. $y'' - y' - y = 0$

Physics: Set A

1. A particle experiences an acceleration $\vec{a} = \alpha\vec{v}$, where $\vec{v}$ is the velocity of the particle and α is a constant. If the distances traveled by the particle in the time intervals $t_2 - t_1$ and $t_3 - t_1$ are S_{12} and S_{13}, respectively, which of the following relations is true?

   A. $\dfrac{S_{13}}{S_{12}} = \dfrac{\exp[\alpha(t_3 - t_1)] - 1}{\exp[\alpha(t_2 - t_1)] - 1}$

   B. $\dfrac{S_{13}}{S_{12}} = \dfrac{\exp[\alpha(t_3 - t_1)]}{\exp[\alpha(t_2 - t_1)]}$

   C. $\dfrac{S_{13}}{S_{12}} = \dfrac{\log[\alpha(t_3 - t_1)]}{\log[\alpha(t_2 - t_1)]}$

   D. $\dfrac{S_{13}}{S_{12}} = \dfrac{\log[\alpha(t_3 - t_1)] - 1}{\log[\alpha(t_2 - t_1)] - 1}$

2. A point mass m attached to a massless string is undergoing circular motion in a vertical plane. The length of the string is R and the acceleration due to gravity is g. If the minimum value of the tension in the string is $2mg$, the maximum speed of this circular motion of the point mass is

    A. $\sqrt{7gR}$.

    B. $\sqrt{\dfrac{7gR}{2}}$.

    C. $\sqrt{6gR}$.

    D. $4\sqrt{gR}$.

3. An object is released from rest from the inner edge of a hemispherical bowl, and it falls under gravity. The coefficient of kinetic friction between the object and the bowl is μ. If the object covers an angular displacement θ with respect to the center of the hemisphere when it stops for the first time, which of the following expressions is correct?

        A. $\mu = \cot(\theta/2)$

        B. $\mu = \cot(\theta)$

        C. $\mu = \tan(\theta)$

        D. $\mu = \tan(\theta/2)$

4. As shown in the figure a block is resting on a frictionless floor and is attached to the free end of a spring. The right edge of the block in equilibrium is at a distance d from the wall. When the spring is compressed by a distance $d/2$ and released, the time-period of the motion is T. Similarly, when compressed by a distance $2d$ and released, the time-period is T_0. Considering elastic collision between the block and the wall, what is the value of the quantity T_0/T?
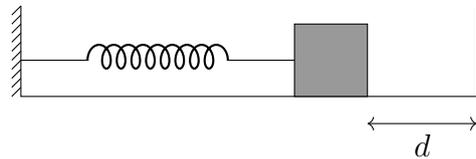

A. 2/3

B. 1

C. 3/4

D. 1/4

5. A liquid of density ρ in a container weighs W. A cubic block of side L and density $\rho_b < \rho$ is pushed by a stick to completely submerge the block in the liquid without touching the bottom. If g is the acceleration due to the gravity and liquid displaced by the stick is negligible, what is the new weight of the container as registered by the weighing machine below?
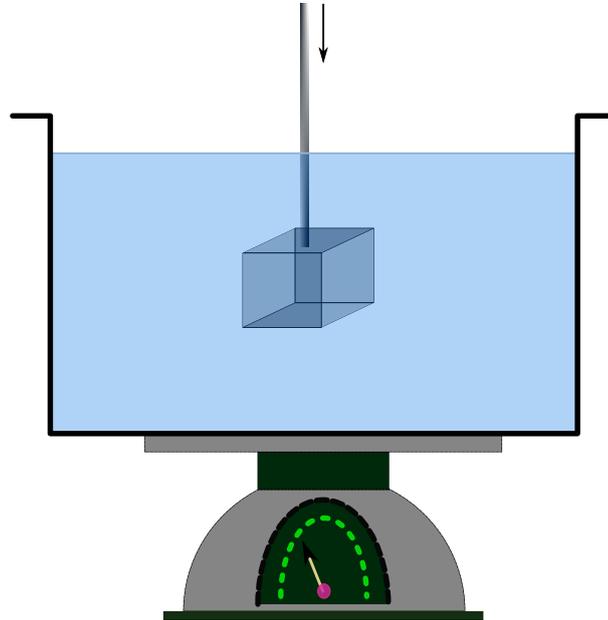

A. $W + \rho g L^3$

B. $W + \rho_b g L^3$

C. $W + (\rho - \rho_b)g L^3$

D. $W + (\rho_b - \rho)g L^3$

6. A monoatomic ideal gas at pressure P and volume V is first adiabatically compressed to volume $\dfrac{V}{8}$ and then is allowed to expand isothermally back to its original volume. What is the final pressure of the gas?

    A. $4P$

   B. $2P$

    C. P

    D. $\dfrac{P}{2}$

7. A uniform taut string with two point charges q and $-q$ attached to its ends passes over two massless pullies kept L distance apart as shown in the figure. If f is the fundamental frequency of the part of the string over pullies, which of the following statements is correct?
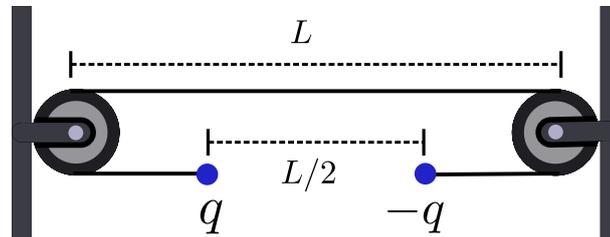

A. $f \propto L^{-2}$

B. $f \propto L^{-1}$

C. $f \propto L$

D. $f \propto L^2$

8. Two uniformly charged concentric thin spherical shells of radii r_1 and r_2 have charges $+Q$ and $-Q$, respectively. How does the electrostatic potential vary with distance from the center of the shells?

A.

B.

C.

D.
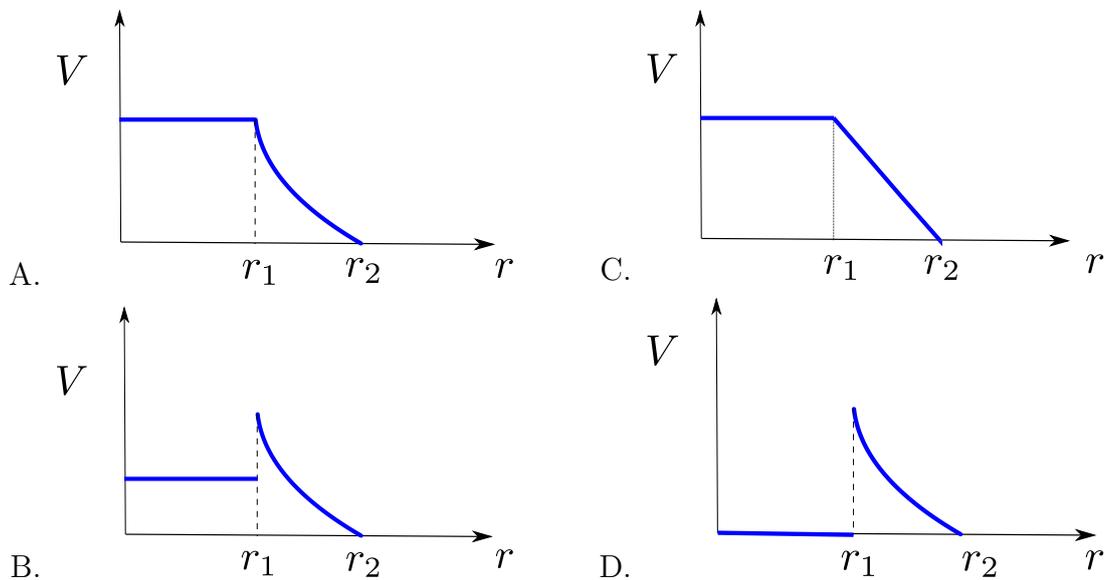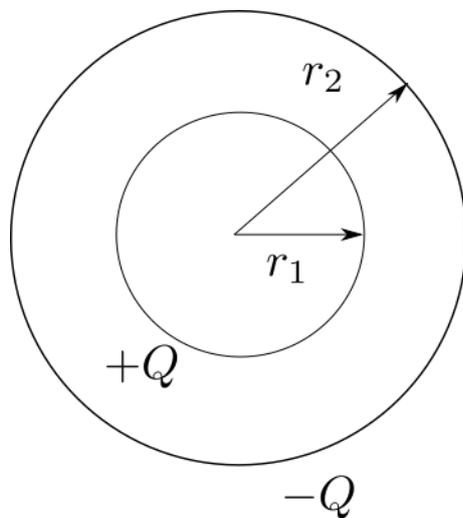
9. Consider a very long cylinder of radius a having a uniform positive charge density ρ. A sphere of radius a has been carved out (see figure), leaving no charge in that region. The distance radially outward to the cylinder, as measured from the center of the sphere is x. At what value of x will the electric field be maximum?
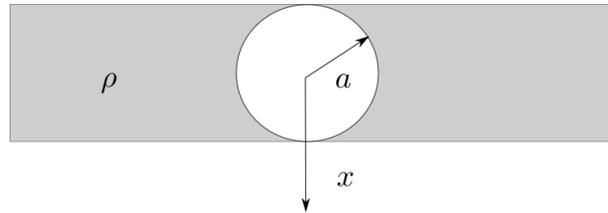

A. $\dfrac{4}{3}a$

B. $\dfrac{2}{3}a$

C. $\dfrac{3}{2}a$

D. a

10. In the given circuit, the box B either contains a capacitor, or an inductor or a resistor. The current I versus time t plots for three cases (a_1, a_2, a_3) are shown in figures. The switch S is closed at time $t = 0$. Which of the following is correct?
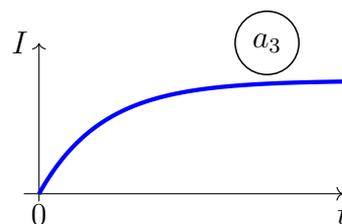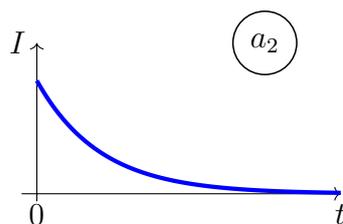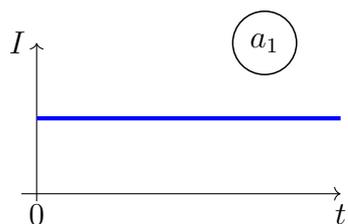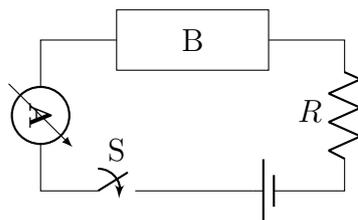

A. a_1 corresponds to a resistor, a_2 corresponds to a capacitor, a_3 corresponds to an inductor.

B. a_1 corresponds to a resistor, a_2 corresponds to an inductor, a_3 corresponds to a capacitor.

C. a_1 corresponds to an inductor, a_2 corresponds to a resistor, a_3 corresponds to a capacitor.

D. a_1 corresponds to an inductor, a_2 corresponds to a capacitor, a_3 corresponds to a resistor.

11. In the given circuit each of the resistors is of 1 kΩ resistance and each of the capacitors has 4 μF capacitance. What is the charge in the capacitor between the points B and F?


A. 10 μC
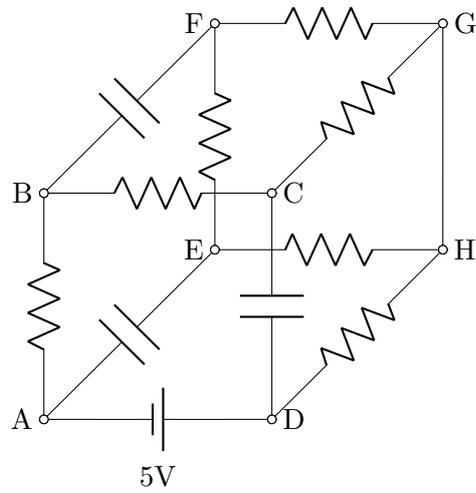
B. 15 μC

C. $\dfrac{40}{7}\mu$C

D. $\dfrac{60}{7}\mu$C

12. A thin lens made of material of refractive index n_l forms the image at the position I of a point object held at O on the central axis of the lens, as is shown in the ray diagram below. Consider that the refractive index of the medium is n_m and $n_l > n_m$ for the figure given. Where does the image form when $n_l < n_m$?
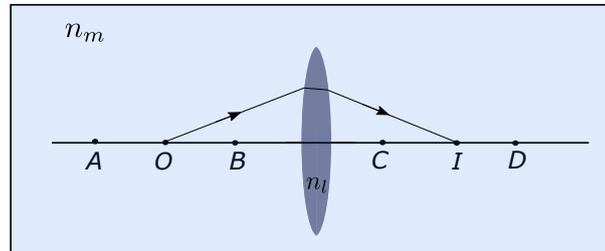
A. At point B

B. At point A

C. At point C

D. At point D

13. A conducting sphere of radius a initially contains a uniform volume charge density ρ. What is the electric flux Φ through a spherical surface of radius $2a$ centered at a point on the surface of the charged sphere (see figure) at a later time t? (ϵ_0 is the permittivity of free space.)
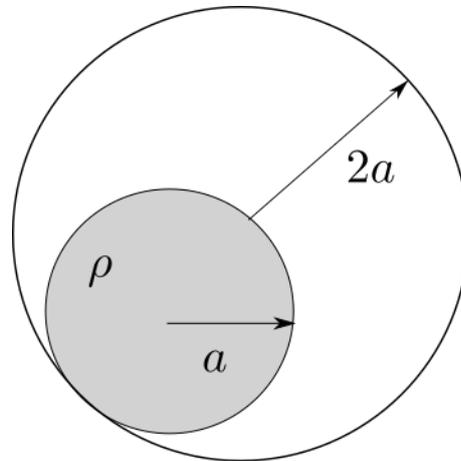

A. $\Phi = \dfrac{4}{3\epsilon_0}\pi a^3 \rho$

B. $\Phi = \dfrac{32}{3\epsilon_0}\pi a^3 \rho$

C. $\Phi = \dfrac{16}{\epsilon_0}\pi a^2 \rho$

D. $\Phi = \dfrac{4}{\epsilon_0}\pi a^2 \rho$

14. The figures in the options show the photocurrent J of a photoelectric material versus the frequency f of an incident light beam. The light beam can have three different intensities I_1, I_2, I_3, with $I_3 > I_2 > I_1$. Which of the options is correct?

A.

B.

C.

D.
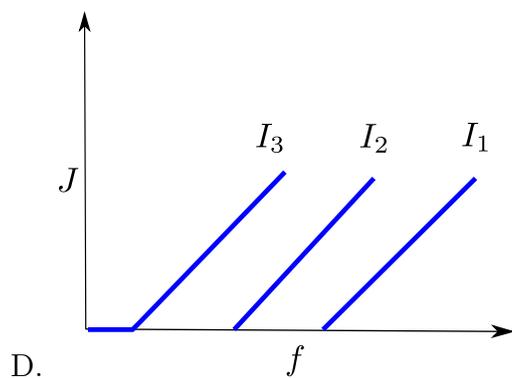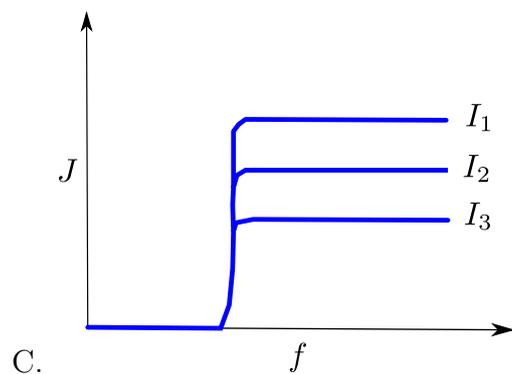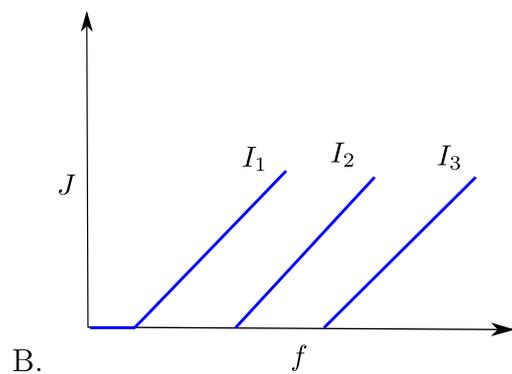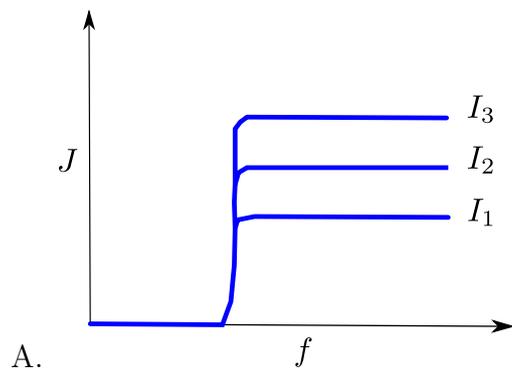
15. Consider that in a fission of a single Plutonium (Pu^{239}) atom 207 MeV energy is released. Assuming all atoms of Plutonium undergo fission, which of the following options is the closest estimate of the amount of Plutonium required for a 20,000 units of TNT explosion?

(1 unit of TNT= 4.184×10^9 J, 1 eV= 1.6×10^{-19} J)

    A. 1 kg.

    B. 10 kg.

    C. 60.0 g.

    D. 0.5 kg.