Biology

1. Question 1

Match the entries in Column I with their functions described in Column II.

	Column I		Column II
P.	Squamous epithelium	(i)	The nucleus is at the basal side of the cell; also helps in movement of particles and mucous.
Q.	Cuboidal epithelium	(ii)	The nucleus is at the basal side of the cell; also helps in secretion and absorption.
R.	Columnar epithelium	(iii)	The nucleus is at the center of the cell; also helps in secretion and absorption.
S.	Ciliated epithelium	(iv)	It serves as a diffusion barrier.

Which one of the following combinations is correct?

(a) P - (iv); Q - (iii); R - (ii); S - (i)

(b) P - (iii); Q - (i); R - (iv); S - (ii)

(c) P - (ii); Q - (iv); R - (i); S - (iii)

(d) P - (i); Q - (ii); R - (iii); S - (iv)

2. Question 2

Which one of the following best describes peptones?

(a) Partially digested proteins

(b) Zymogen form of pepsin

(c) Activated form of pepsin

(d) An intestinal mixture of proteins, mucous and HCO_3^-

3. Question 3

Match the biomolecules given in Column I with their corresponding chemical nature given in Column II.

	Column I		Column II
P.	Insulin	(i)	Secondary metabolite
Q.	Inulin	(ii)	Homopolymer
R.	Lectin	(iii)	Quaternary ammonium derivative
S.	Lecithin	(iv)	Hetropolymer

Which one of the following combinations is correct?

(a) P - (iv); Q - (ii); R - (i); S - (iii)

(b) P - (ii); Q - (iv); R - (iii); S - (i)

(c) P - (iii); Q - (i); R - (iv); S - (ii)

(d) P - (i); Q - (iii); R - (ii); S - (iv)

4. Question 4

A mitotic drug inhibits microtubule formation. Which one of the following stages of karyokinesis will be the first to get affected by the drug?

(a) Metaphase

(b) Anaphase

(c) Prophase

(d) Telophase

5. Question 5

Which one of the following statements regarding seed structure is INCORRECT?

(a) In monocot seeds, the membraneous seed coat that is fused with the fruit wall is called the aleurone layer.

(b) The endosperm is not present in some of the mature dicot seeds.

(c) In dicots, the outer layer of the seed coat is called testa.

(d) Coleoptile and coleorhiza are found in monocotyledonous seeds.

6. Question 6

Which one of the following anatomical features of wood can be used to estimate the age of a tree growing in a temperate climate?

(a) Spring wood and late wood.

(b) Heart wood and sap wood.

(c) Spring wood and heart wood.

(d) Autumn wood and sap wood.

7. Question 7

Which one of the following statements is CORRECT about biological nitrogen fixation in plants?

(a) The catalytic redox center of Nitrogenase contains Mo and Fe as cofactors.

(b) Atmospheric nitrogen is fixed by Nitrogenase by converting N_2 to NO_3^-.

(c) Nitrogenase can function optimally only in the presence of molecular oxygen.

(d) The transport of important amides, like asparagine and glutamine, produced by transamination, to different parts of the plant body is mediated by phloem.

8. Question 8

Which one of the following is an example of genetic diversity?

(a) Variation in the potency and concentration of reserpine produced by *Rauwolfia vomitoria*.

(b) Higher diversity of amphibians in the Western Ghats than in the Eastern Ghats.

(c) Greater variation of ecosystems found in India than in Scandinavia.

(d) The greater diversity of plant species found in India compared to Central Asia.

9. Question 9

When the ribosome encounters a stop codon in the mRNA, during translation, which one of the followng binds to the stop codon?

(a) Release factor.

(b) Rho factor.

(c) Termination factor.

(d) Sigma factor.

10. Question 10

Match the terms in column I with their corresponding physiological roles given in Column II.

	Column I		Column II
P.	Sertoli cells	(i)	Secretion of chorionic gonadotropin
Q.	Follicle stimulating hormone	(ii)	Carries urine away from bladder
R.	Placenta	(iii)	Carries urine away from kidney
S.	Urethra	(iv)	Provides nutrition to developing spermatozoa
		(v)	Triggers ovulation

Which one of the following combinations is correct?

(a) P - (iv); Q - (v); R - (i); S - (ii)

(b) P - (v); Q - (i); R - (iv); S - (iii)

(c) P - (iii); Q - (ii); R - (v); S - (iv)

(d) P - (i); Q - (iv); R - (iii); S - (v)

11. Question 11

For which one of the following diseases does the causative agent require the splicing of their hnRNA to generate mature mRNA?

(a) Malaria

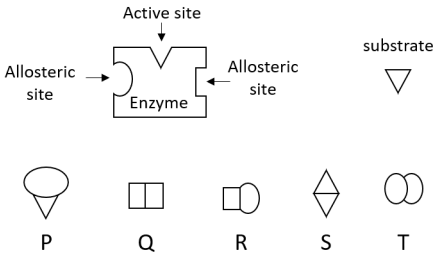
(b) Pertussis

(c) Typhoid

(d) Tuberculosis

12. Question 12

The diagram represents an enzyme, its substrate and potential inhibitors (P, Q, R, S, T).



Which one of the following combinations is the best pair of competitive inhibitors for the enzyme?

(a) P, S

(b) Q, R

(c) S, T

(d) R, T

13. Question 13

In an island with 10,000 individuals, four have sickle cell anemia, a recessive autosomal disease. Assuming that the locus is in Hardy-Weinberg equilibrium, how many individuals in that island are expected to be heterozygous for the disease allele?

(a) 392

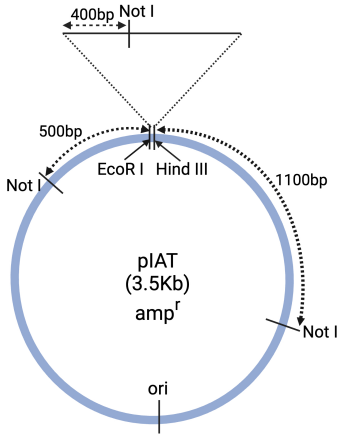
(b) 4

(c) 9996

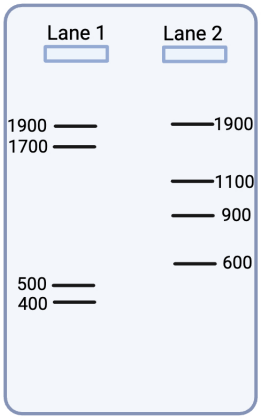
(d) 9608

14. Question 14

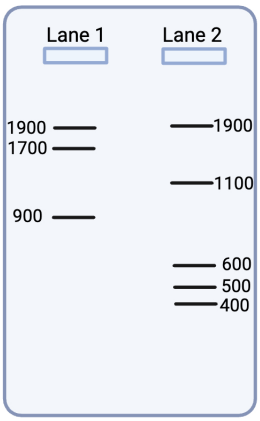
A 1000 base-pair DNA fragment was cloned between *Hind* III and *EcoR* I sites of the plasmid vector (pIAT) of size 3500 base-pair. The cloned fragment had a *Not* I site as shown in the figure. In order to confirm the presence of the insert, the recombinant plasmid was digested completely with (**a**) *Not* I and *EcoR* I, and (**b**)*Not* I and *Hind* III.



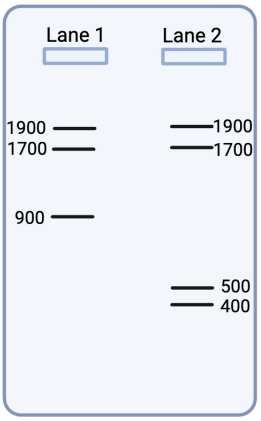
In lane 1 the products of the digestion by *Not* I and *EcoR* I was loaded. In lane 2 the products of the digestion by *Not* I and *Hind* III was loaded. Which one of the following correctly represents the agarose gel electrophoresis profile of the digested recombinant plasmid for (**a**) and (**b**), respectively?



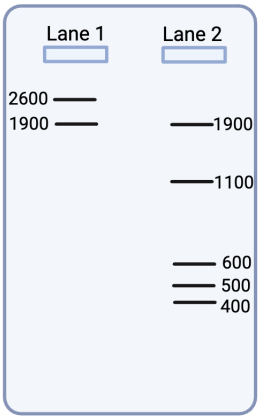
(a)


Lane 1
Lane 2
1900
1700
900
1900
1100
600
500
400

(b)


Lane 1
Lane 2
1900
1700
900
1900
1700
500
400

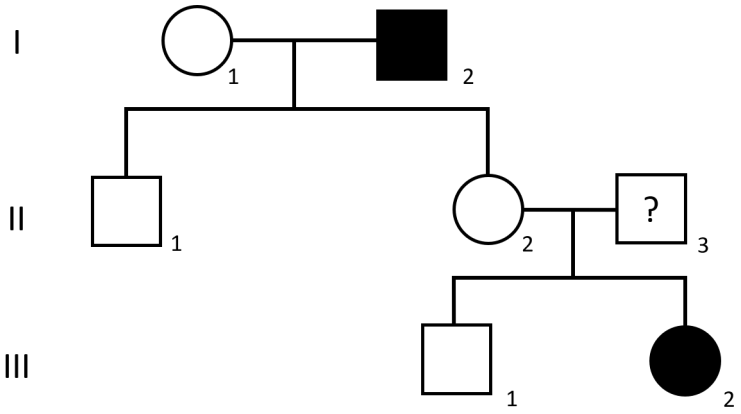
(c)



(d)

15. Question 15

The following pedigree chart shows the inheritance of a genetic disorder. I-2 and III-2 are the only affected individuals.



Which one of the following is the correct pattern of inheritance of the disorder, and the genotype of the II-3 individual?

(a) Autosomal recessive, heterozygous

(b) Autosomal dominant, homozygous for the normal allele

(c) X-linked recessive, heterozygous

(d) Autosomal recessive, homozygous for the normal allele

Chemistry

1. Question 1

   How many radial nodes does Ca^+ have in its 4s orbital?

   (a) 3

   (b) 0

   (c) 1

   (d) 2

2. Question 2

Amongst O_2, N_2, F_2, and B_2, which molecules will be attracted to an external magnetic field?

(a) O_2 and B_2

(b) F_2, N_2, and B_2

(c) O_2, B_2, and N_2

(d) O_2 and F_2

3. Question 3

What is the smallest P−P−P bond angle in the highly reactive allotrope of phosphorus?

(a) 60°

(b) 109°

(c) 45°

(d) 120°

4. Question 4

Which of the following is an ore of iron?

(a) Siderite

(b) Bauxite

(c) Malachite

(d) Quartz

5. Question 5

Which parameters are plotted in the Ellingham diagram?

(a) $\Delta_r G^\circ$ vs T

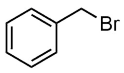
(b) $\Delta_r H^\circ$ vs T

(c) $\Delta_r S^\circ$ vs T

(d) $\Delta_r S^\circ$ vs P

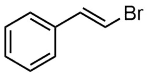
6. Question 6

Which of the following compounds will NOT undergo the Finkelstein reaction with NaI *via* $S_N 2$ pathway?

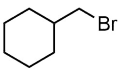


I

II



III



IV

(a) II and III

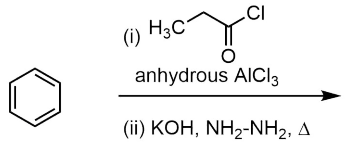
(b) I and III

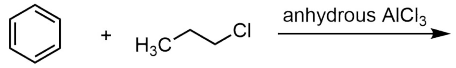
(c) II and IV

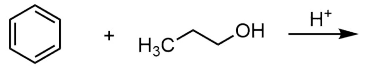
(d) I and IV

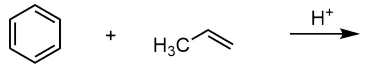
7. Question 7

Which one amongst the following is the most efficient way of synthesizing *n*-propyl benzene?

(I) 

(II) 

(III) 

(IV) 

(a) I

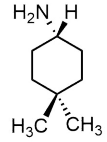
(b) II

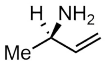
(c) III

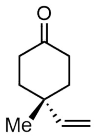
(d) IV

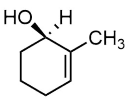
8. Question 8

Which amongst the following are chiral compounds?

(I) 

(II) 

(III) 

(IV) 

(a) II and IV

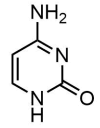
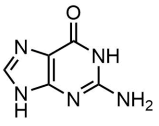
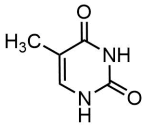
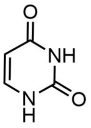
(b) I and IV

(c) II and III

(d) I and II

9. Question 9

Which one amongst the following bases is NOT present in RNA?

(I)  (II)  (III)  (IV) 

(a) III

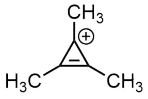
(b) I

(c) II

(d) IV

10. Question 10

Which amongst the following are aromatic?

(I) 

(II) 

(III) 

(IV) 

(a) I and II

(b) III and IV

(c) II and IV

(d) I and III

11. Question 11

Why is it harder to compress liquids and solids relative to gases?

(a) Molecules are closer to each other in solids and liquids.

(b) Due to the presence of electron-nuclear attraction in solids and liquids.

(c) Due to the absence of electron-nuclear attraction in solids and liquids.

(d) Solids and liquids have definite volume.

12. Question 12

Related to the Freundlich adsorption isotherm, which one of the following statements is NOT correct?

(a) It holds good over a wide range of pressures.

(b) The value of $\frac{1}{n}$ is between 0 and 1.

(c) The Freundlich adsorption isotherm equation is an empirical equation.

(d) It is used for the adsorption of both gases and solutions.

13. Question 13

Consider the following reaction:
$CH_4(g) \rightarrow C(g) + 4H(g)$; $\Delta_a H^0 = 1665$ kJ mol^{-1}
Which of the statements is FALSE?

(a) $\Delta_a H^0$ is the mean bond enthalpy of a C-H bond.

(b) All four C-H bonds in CH_4 are identical in bond length and energy.

(c) The energy required to break individual C-H bonds in successive steps is different.

(d) Mean C-H bond enthalpies differ slightly from compound to compound.

14. Question 14

In two solutions X (hexane and benzene) and Y (water and HCl), what types of deviations from Raoult's law are observed?

(a) No deviation (ideal behaviour) and negative deviation, respectively.

(b) Negative deviation and positive deviation, respectively.

(c) Positive deviation and negative deviation, respectively.

(d) Positive deviation and no deviation (ideal behaviour), respectively.

15. Question 15

In aqueous solution, the hydronium ion gets further hydrated to give which of the following species?

(a) $H_9O_4^+$

(b) $H_7O_4^+$

(c) $H_3O_2^+$

(d) $H_5O_3^+$

Mathematics

1. Question 1

   Let $f : \mathbf{R} \to (0, \infty)$ be a continuous decreasing function. Suppose $f(0), f(1), \ldots, f(10)$ are in a geometric progression with common ratio $\frac{1}{5}$. In which of the following intervals does the value of $\int_0^{10} f(x)dx$ lie?

   (a) $(0, 2f(0))$

   (b) $(4f(0), 6f(0))$

   (c) $(8f(0), 10f(0))$

   (d) $(12f(0), 14f(0))$

2. Question 2

Let M be a 3×3 matrix with real entries such that

$$\left\{ \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} : M \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \right\} = \left\{ \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} : x_1 + x_2 = 0 = x_2 + x_3 \right\}.$$

What is the value of the determinant of M?

(a) 0

(b) 1

(c) 2

(d) 3

3. Question 3

What is the locus of the center of circles passing through the origin $(0, 0)$ with fixed radius?

(a) Circle

(b) Hyperbola

(c) Parabola

(d) Line

4. Question 4

Let α be a real number. What is the total number of distinct point(s) of intersection between the parabola $y = x^2 + 4x \sin \alpha + 6$ and the pair of lines $y^2 = 1$?

(a) Zero

(b) One

(c) Two

(d) Four

5. Question 5

Let L be a straight line passing through the origin, and it makes angles α, β and γ with the positive X, Y and Z-axes, respectively. What is the value of $\cos 2\alpha + \cos 2\beta + \cos 2\gamma$?

(a) -1

(b) 3

(c) 1

(d) -3

6. Question 6

What is the total number of distinct divisors of $2^9 \times 3^{19}$?

(a) 200

(b) 30

(c) 435

(d) 100

7. Question 7

Suppose the mean and the standard deviation of the data $\{x_1, x_2, \cdots, x_9\}$ are μ and $\sigma(\neq 0)$, respectively. After including one more data value x_{10}, the mean of the data $\{x_1, x_2, \cdots, x_9, x_{10}\}$ remains μ. What is the standard deviation of the data $\{x_1, x_2, \cdots, x_9, x_{10}\}$?

(a) $\dfrac{3}{\sqrt{10}}\,\sigma$

(b) $\dfrac{\sqrt{10}}{3}\,\sigma$

(c) $\dfrac{10}{9}\,\sigma$

(d) $\dfrac{9}{10}\,\sigma$

8. Question 8

Consider three biased coins. Let the probability of getting head be $\frac{1}{3}$ and the probability of getting tail be $\frac{2}{3}$ in each of the coins. Consider the experiment of tossing the three coins one by one, and the following events:

E : "at least two heads show up"
F : "first coin shows tail".

What is the conditional probability of E given that F has already occured?

(a) $\frac{1}{9}$

(b) $\frac{2}{9}$

(c) $\frac{1}{4}$

(d) $\frac{4}{9}$

9. Question 9

Which of the following differential equations has $y = e^x$ as one of its particular solutions?

(a) $$y\frac{d^2y}{dx^2} - e^x\frac{dy}{dx} + y^2 = e^{2x}$$

(b) $$y\frac{d^2y}{dx^2} + e^x\frac{dy}{dx} + y^2 = e^{2x}$$

(c) $$y\frac{d^2y}{dx^2} - e^x\frac{dy}{dx} + y^2 = e^x$$

(d) $$y\frac{d^2y}{dx^2} + e^x\frac{dy}{dx} + y^2 = e^x$$

10. Question 10

What is the area of the region

$$\left\{(x, y) : 0 \leq y \leq xe^{x^2}, 0 \leq x \leq 1\right\}?$$

(a) $\frac{1}{2}(e-1)$

(b) $\frac{1}{2}e$

(c) $e-1$

(d) $e-2$

11. Question 11

Consider the objective function

$$Z = x - y$$

subject to the constraints:

$$\begin{aligned} x + 2y &\leq 10 \\ x + y &\geq 2 \\ x \geq 0, y &\geq 0. \end{aligned}$$

What is the minimum value of Z subject to the above constraints?

(a) -5

(b) -2

(c) 2

(d) -10

12. Question 12

Let $p(x) = x^2 + bx + c$ be a quadratic polynomial with real coefficients b and c. Suppose $p(1) = 5$ and $p(-1) = 3$. What is the product of the roots of $p(x) = 0$?

(a) 3

(b) -1

(c) 2

(d) 1

13. Question 13

Let $f : (-1, 2) \to \mathbf{R}$ be a differentiable function such that

$$f'(x) = \frac{2}{x^2 - 5} \quad \text{and} \quad f(0) = 0.$$

Then in which of the following intervals does $f(1)$ lie?

(a) $(-\infty, 0)$

(b) $(0, 2)$

(c) $(2, 4)$

(d) $(4, \infty)$

14. Question 14

Let $f(x) = \sin(3x),\ x \in \left[0, \frac{\pi}{2}\right]$. Which of the following statements is true?

(a) f is decreasing on $\left(\frac{\pi}{4}, \frac{\pi}{2}\right)$.

(b) f is increasing on $\left(\frac{\pi}{4}, \frac{\pi}{2}\right)$.

(c) f is increasing on $\left(\frac{\pi}{4}, \frac{\pi}{3}\right)$ and decreasing on $\left(\frac{\pi}{3}, \frac{\pi}{2}\right)$.

(d) f is decreasing on $\left(\frac{\pi}{4}, \frac{\pi}{3}\right)$ and increasing on $\left(\frac{\pi}{3}, \frac{\pi}{2}\right)$.

15. Question 15

Which one of the following functions is differentiable at $x = 0$?

(a) $\cos|x|$

(b) $\sin|x|$

(c) $|x|^{\frac{1}{2}}$

(d) $|x|$

Physics

1. Question 1

   A ball is thrown vertically upwards with an initial speed u from a height h above the ground. The ball eventually hits the ground with a speed v. The acceleration due to gravity is g and the air resistance is negligible. What is the average speed of the ball over its entire trajectory?

   (a) $\dfrac{u^2+v^2}{2(u+v)}$

   (b) $\dfrac{v+u}{2}$

   (c) $\dfrac{gh}{2(u+v)}$

   (d) $\dfrac{u^2+gh}{2(u+v)}$

2. Question 2

Two cubes A and B of same dimensions are made of different materials with densities ρ_{A} and ρ_{B}, respectively. Cube A floats in water with a fraction η of its volume immersed. When cube B is placed on top of cube A, it is found that cube A is just entirely immersed, while cube B is entirely above the surface of the water. What is the ratio $\rho_{\mathrm{B}}/\rho_{\mathrm{A}}$?

(a) $(1-\eta)/\eta$

(b) $\eta/(1-\eta)$

(c) η

(d) $1/\eta$

3. Question 3

An object is placed in front of a convex lens. A real inverted image of double its size is formed. When the object is moved closer to the lens by a distance d, the image shifts away from the lens by a distance $8d$ from its previous position. What is the magnitude of the magnification in the final setup?

(a) 4

(b) 1/2

(c) 8

(d) 16

4. Question 4

The frequency of the whistle of a train moving with a constant speed is observed by a stationary detector on the platform to be ν_1. The frequency of the same whistle is detected to be ν_2 inside another train moving on a parallel track, at a speed v towards the first train. If the speed of sound in air is taken to be v_{sound}, what is the ratio v/v_{sound}?

(a) $\dfrac{\nu_2 - \nu_1}{\nu_1}$

(b) $\dfrac{\nu_2 - \nu_1}{\nu_2}$

(c) $\dfrac{\nu_2}{\nu_1}$

(d) $\dfrac{\nu_1}{\nu_2}$

5. Question 5

A current I flows through a cylindrical cable of length L and uniform cross-sectional area A. The power dissipated due to the current is P_1. The cable is cut into two equal halves. If the cross-sectional area and the current flowing through the two halves remain unchanged and the power dissipated in each half is P_2, which of the following options is correct?

(a) $P_2 = P_1/2$

(b) $P_2 = 2P_1$

(c) $P_2 = P_1$

(d) $P_2 = P_1/4$

6. Question 6

Particle A with charge Q and particle B with charge $2Q$ are fixed at positions $\vec{r}_{\mathrm{A}}$ and $\vec{r}_{\mathrm{B}}$, respectively. The force on A due to B is $\vec{F}_{\mathrm{BA}}$, and that on B due to A is $\vec{F}_{\mathrm{AB}}$. Which of the following options is correct?

(a) $\vec{F}_{\mathrm{AB}} = -\vec{F}_{\mathrm{BA}}$

(b) $\vec{F}_{\mathrm{AB}} = \vec{F}_{\mathrm{BA}}$

(c) $\vec{F}_{\mathrm{AB}} = 2\vec{F}_{\mathrm{BA}}$

(d) $\vec{F}_{\mathrm{AB}} = -2\vec{F}_{\mathrm{BA}}$

7. Question 7

The magnetic flux $\phi_B(t)$ through a coil at a time t is given by $\phi_B(t) = \phi_0 \cos \omega t$, where $0 \leq \omega t \leq \pi$ and ϕ_0 is a non-zero constant. At what time is the magnitude of the induced emf a maximum?

(a) $\dfrac{\pi}{2\omega}$

(b) $\dfrac{\pi}{\omega}$

(c) $\dfrac{\pi}{4\omega}$

(d) 0

8. Question 8

The intrinsic electron and hole concentrations of a Si-based intrinsic semiconductor are $n_e^{(0)}$ and $n_h^{(0)}$, respectively. Upon doping with trivalent impurities the respective carrier concentrations become n_e and n_h. Which of the following options is true?

(a) $n_h > n_h^{(0)}$

(b) $n_e > n_e^{(0)}$

(c) $n_e = n_h$

(d) $n_e^{(0)}$ and $n_h^{(0)}$ are independent of temperature.

9. Question 9

The velocity $v(t)$ of a particle moving in one dimension is given by:

$$v(t) = \begin{cases} \alpha t, & 0 \le t \le T/3 \\ \alpha T/3, & T/3 \le t \le 2T/3 \\ \alpha\left(T - t\right), & 2T/3 \le t \le T, \end{cases}$$

where α ($\neq 0$) is a constant. What is the total displacement of the particle from time $t = 0$ to $t = T$?

(a) $\dfrac{2\alpha T^2}{9}$

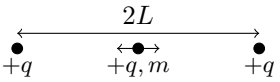
(b) $\dfrac{4\alpha T^2}{9}$

(c) $\dfrac{8\alpha T^2}{9}$

(d) $\dfrac{7\alpha T^2}{9}$

10. Question 10

Two fixed point particles, each of charge $+q$, are separated by a distance $2L$. Another point charge $+q$ of mass m is oscillating about its equilibrium position as indicated in the figure below. The time period of oscillation is given by $T = 2\pi^{3/2}\alpha\sqrt{m}/q$. Given that ϵ_0 is the permittivity of free space, which of the following options is the dimensionally correct expression for α in SI units?



(a) $\epsilon_0^{1/2} L^{3/2}$

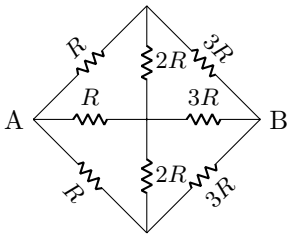
(b) $\epsilon_0^{1/2} L$

(c) $\epsilon_0^{3/2} L^{1/2}$

(d) $\epsilon_0^{3/2} L$

11. Question 11

What is the effective resistance between A and B in the circuit shown below?



(a) $\frac{4R}{3}$

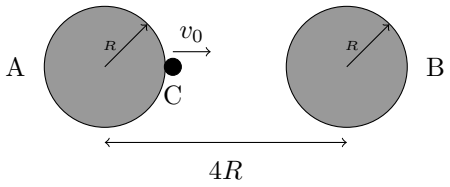
(b) $\frac{R}{3}$

(c) $\frac{2R}{3}$

(d) $\frac{R}{6}$

12. Question 12

Two spherical bodies A and B each of mass M and radius R are located such that their centers are apart by a distance of $4R$ as shown in the figure. An object C of mass m is thrown from the surface of A directly towards the center of B with a speed $v_0 = 2v_{min}$, where v_{min} is the minimum speed needed for C to reach the surface of B. Given that G is the universal gravitational constant, how does the speed $v(x)$ of C change as a function of its distance x from the center of A?



(a) $v(x) = \dfrac{2\sqrt{2GMR}}{x^{1/2}(4R-x)^{1/2}}$

(b) $v(x) = \dfrac{2R\sqrt{2GMR}}{x(4R-x)}$

(c) $v(x) = \dfrac{\sqrt{GMR}}{x^{1/2}(4R-x)^{1/2}}$

(d) $v(x) = \dfrac{6R^2\sqrt{2GMR}}{x^{3/2}(4R-x)^{3/2}}$

13. Question 13

Consider the Bohr model of an atom where an electron of charge $-e$ revolves around a nucleus of charge $+e$ in an orbit of radius r. The electron has an orbital angular momentum $2\hbar$. If the nucleus had charge $+2e$, what would have been the radius of the orbit of the electron with the same principal quantum number?

(a) $r/2$

(b) $2r$

(c) r

(d) $\sqrt{2}r$

14. Question 14

A quantity has been measured to have a value of 0.00230 in some units. How many significant figures does the measured value have?

(a) 3

(b) 5

(c) 4

(d) 2

15. Question 15

Consider a Carnot heat engine operating between a heat reservoir at temperature 600 K, and an external atmosphere at temperature 300 K. In one cycle, 1000 kJ of heat is extracted from the heat reservoir, and the associated work is input to a reversible refrigerator that operates between 200 K and the same external atmosphere at 300 K. The refrigerator completes one cycle and releases heat into the atmosphere. How much heat is released into the atmosphere at the end of one cycle of the combined system?

(a) 2000 kJ

(b) 2500 kJ

(c) 1000 kJ

(d) 500 kJ