

**HOMI BHABHA CENTRE FOR SCIENCE EDUCATION**  
**TATA INSTITUTE OF FUNDAMENTAL RESEARCH**

**Entrance Test for Ph.D. Programme in Science Education - 2016**

**Section I:**  
**Multiple Choice Questions**

**Read the following instructions carefully:**

- This section of the question paper consists of 22 pages. There are a total of 90 questions distributed among the different subjects as follows:

**Q 1 to 30:** Scientific literacy, technical comprehension, and quantitative and logical reasoning.

**Q 31 to 50:** Social and cognitive sciences, and education.

**Q 51 to 90:** Ten questions *each* on biology (51 to 60), chemistry (61 to 70), mathematics (71 to 80), and physics (81 to 90)

- This section of the written test carries a maximum of **100 marks** and is of **2 hours** duration.
- All questions are of multiple choice type with four options, out of which **only one** option is correct. Each correct answer earns 2 marks. An unanswered question or a wrong answer earns no marks.
- You may answer **any 50 questions** from this section. In case more than 50 questions are attempted, the score obtained will be normalized to that corresponding to 50 questions.

$$\text{Normalized score} = \frac{\text{Score obtained}}{\text{No. of questions attempted}} \times 50$$

- Before you start answering, please check that you have written your Name and Roll Number on both sides of the Answer Sheet.
- You must indicate your answers only on the Answer Sheet provided, by putting a × in the appropriate box against the relevant question number, like this: .
- Use a dark ink **pen** to indicate your answers.
- Think and decide carefully on your answers before you indicate it on the Answer Sheet. In case you want to change your answer for a particular question after you have already put a × in a box, blacken out the entire box and put a × in the new box of your choice. In the example below, the initial choice of (B) has been changed to (C):

(A) (B) (C) (D)                      (A) (B) (C) (D)

   →   

- At the end of two hours, submit the Answer Sheet.

## Scientific Literacy, Technical Comprehension, Quantitative and Logical Reasoning

1. An accurate clock shows 9 o'clock in the morning. Through how many degrees will the hour hand rotate when the clock shows 4 o'clock in the afternoon?

- (A) 7                                      (B) 70                                      (C) 210                                      (D) 2520

2. Which of the following would be the value of the digit B so that the number 6B358 is divisible by 6?

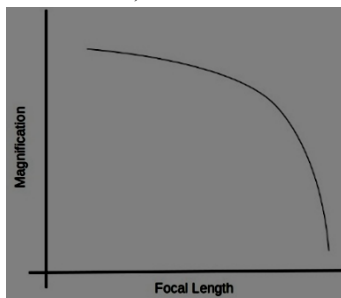
- (A) 1                                      (B) 6                                      (C) 7                                      (D) 8

3. In order to determine the right lens to be used for a microscope, a series of experiments was conducted to test which lens will give the maximum magnification. The result of the experiment is recorded in the following table.

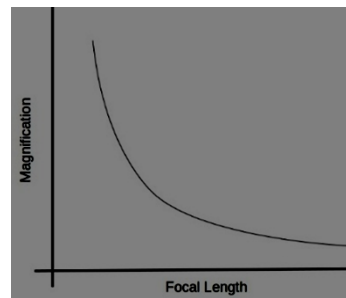
Focal Length	1	2	3	4	5	6	7	8
Magnification	8	4	2.6	2	1.6	1.3	1.1	1

Which of the following graph represent the data correctly? (Magnification shown on Y-axis and Focal length on X-axis.)

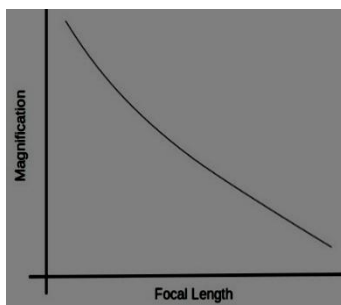
(A)



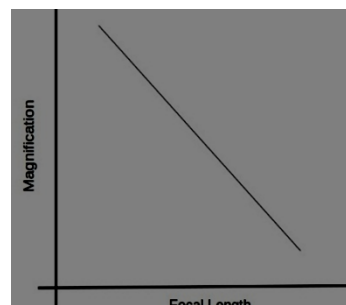
(B)



(C)



(D)



4. I am facing East. Turning to the right I go 20 m, then turning to the left I go 20 m and again turning to the right I go 20 m, then once again turning to the right I go 40 m and then again I go 40 m to the right. In which direction am I from my original position? (All turns are by 90 degrees.)

- (A) West                                      (B) North                                      (C) South                                      (D) East

*Answer questions 5 to 7 based on the Passage 1 below.*

### Passage 1

A seminar for providing scholarships to school students is being organized by an Education Council. For the seminar, 7 teachers from different schools have also been nominated (It is not necessary that all 7 teachers attend the seminar). Out of these P, Q and R are teachers of mathematics and S, T, U and V are teachers of science. At least 2 mathematics teachers should attend the seminar. Q and S cannot attend the

seminar together, R cannot attend the seminar with V and S and U cannot attend the seminar together.

5. If U is selected and Q is rejected, then which four teachers will attend the conference?

- (A) P, R, S and U (B) P, R, T and U  
(C) P, R, U and V (D) P, S, U and V

6. If R and S get selected, then which of the following two teachers will also attend the conference?

- (A) P and U (B) P and V  
(C) P and T (D) Q and T

7. If all the three mathematics teachers are selected, then how many combinations of four members can attend the conference?

- (A) One (B) Two (C) Three (D) Four

8. If P+Q means P is husband of Q, P/Q means P is the sister of Q, P\*Q means P is the son of Q. How is M related to N in M\*K+L/N?

- (A) Brother (B) Nephew (C) Niece (D) None of these

9. In a season, a kabaddi team played 60 games and won 30% of them. After this, the team had a phenomenal winning streak of continuous wins and raised its winning average to 50%. How many games must the team have won in a row to attain this average?

- (A) 24 (B) 30 (C) 26 (D) 32

10. Rs. 4800/- are divided among P, Q and R in such a way that the share of P is  $\frac{5}{11}$  of the combined share of Q and R. Thus, P gets:

- (A) Rs. 300/- (B) Rs. 3300/- (C) Rs. 1800/- (D) Rs. 1500/-

11. There are three different items that a person wants to buy for her birthday; Toffees, Marbles and Pens. Cost of Toffee is Rs. 1 for 1. Cost of Marble is Rs. 1 for 8, Cost of Pen is Rs. 10 for 1. She has only Rs. 90 to spend and the total number of items she wants to buy is 90. How much quantity of each item will she buy?

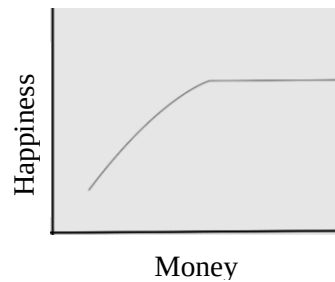
- (A) 11 Toffees, 72 Marbles, 7 Pens (B) 48 Toffees, 25 Marbles, 17 Pens  
(C) 13 Toffees, 70 Marbles, 7 Pens (D) 42 Toffees, 41 Marbles, 7 Pens

12. If the date February 11, 2003 is Tuesday, then the date March 11, 2004 would be on

- (A) Monday (B) Thursday (C) Wednesday (D) Tuesday

13. A group of scientists decided to find out if there is any relation between money and happiness. They

devised a way to measure happiness, conducted a survey of 20 lakh citizens with various income levels and represented the data collected as the following graph. Based on the graph, the relation between money and happiness that is always true is:



- (A) Increase in money is related to increase in happiness.  
 (B) There is no relation between money and happiness.  
 (C) Increase in happiness is related to decrease in money.  
 (D) Increase in money beyond a certain point does not affect happiness.
14. The following figure shows a shaded shape inside a square of unit side length. What is the area of the shaded region, if each of the four curves outlining it represents an arc of a circle with the centres at the four corners of the square?



- (A)  $0.125 \pi^2$                       (B)  $1 - 0.25 \pi$                       (C)  $0.125 \pi$                       (D)  $0.5 \pi - 1$
15. In a certain city, out of every 100 disposable plastic cups used to drink water, 27 land up in the city landfill. The rest are collected from the city waste by wastepickers, who eventually sell them for recycling. In an event organized in this city, 127 disposable plastic cups were used which were thrown in a trash bag that was closed and sent directly to the landfill. For a plastic cup that was used in the event, what is the probability that it was collected by a wastepicker?
- (A) 0.73                      (B) 0.27                      (C) 0.65                      (D) 0.00

**Read the following Passage 2 carefully and answer questions 16-20.**

**Passage 2**

Take the nest building behavior of some termites. A termite's building behavior involves modifying its local environment in response to the triggers provided by previous alterations to the environment, i.e. alterations made by other termites or by the same termite at an earlier time. Nest building is thus under the control of what are known as stigmergic algorithms.

A simple example of stigmergy is the construction of arches (a basic feature of termite nests) from mudballs. Here is how it works: All the termites make mud balls, which at first they deposit at random. But each ball carries a chemical trace added by the termite. Termites prefer to drop their mudballs where the chemical trace is strongest. It thus becomes likely that new mudballs will be deposited on top of old ones, which then generate an even stronger attractive force. Columns thus form. When two columns are fairly proximal,

the drift of chemical attractants from the neighboring column influences the dropping behavior by inclining the insects to preferentially add to the side of each column that faces the other. This process continues until the tops of the columns incline together and an arch is formed. A host of other stigmergic effects eventually yield a complex structure of cells, chambers, and tunnels. At no point in this extended process is a plan of the nest represented or followed. No termite acts as a construction leader. No termite "knows" anything beyond how to respond when confronted with a specific patterning of its local environment. The termites do not talk to one another in any way, except through the environmental products of their own activity. Such environment-based coordination requires no linguistic encoding or decoding and places no load on memory, and the "signals" persist even if the originating individual goes away to do something else.

To sum up: We learn important lessons from even simple cases of emergent collective phenomena. Such phenomena can come about in either direct or highly environmentally mediated ways. They can support complex adaptive behaviors without the need for leaders, blueprints, or central planners. And they can display characteristic features quite different in kind from those of the individuals whose activity they reflect.

*Adapted from:* Clark, A. (1998). *Being there: Putting brain, body, and world together again*. MIT press.

16. What is stigmergy?

- (i) A termite behavior.
- (ii) A mechanism of indirect communication & coordination.
- (iii) Interaction with the environment through cue traces.
- (iv) Nest building activity.

- (A) (i) and (iv)                      (B) (ii) and (iii)                      (C) (i) only                      (D) (iv) only

17. The order that best describes Stigmergy is:

- (A) Random Individual Action → Environmental Modifications → Cues from Modifications → Response to cues by same / another individual
- (B) Environment Modifications → Random Individual Action → Cues from Modifications → Response to cues by same / another individual
- (C) Cues from Modifications → Environmental Modifications → Random Individual Action → Response to cues by same / another individual
- (D) Environment Modifications → Cues from Modifications → Random Individual Action → Response to cues by same / another individual

18. A characteristic feature of Stigmergy is

- (A) no communication.
- (B) can be exhibited only by termites.
- (C) decentralized co-ordinating network.
- (D) initial efforts "Stic" individually then "merge" later.

19. The term “Algorithm” refers to
- (A) a sequence of well-defined procedures. (B) an emergent phenomenon.  
(C) a rhythmic phenomena. (D) a complex structure.
20. Select an appropriate title for the passage.
- (A) Termites: the finest engineers  
(B) Termites: the prolific architects  
(C) Termites: the synergistic arthropods  
(D) Termites: Social creatures beyond individual capacities

**Read the following Passage 3 carefully and answer questions 21-25.**

**Passage 3**

It is difficult to think of a set of issues more important now to the welfare of us as human beings than those concerning the environment. Problems of climate change, pollution, and the depletion of natural resources are now only too familiar—as is the putative remedy of ‘sustainable development’. And the curricula of many national education systems, at least in their rhetoric, are attempting to address this area of concern, particularly, but not exclusively, those nations that were signatory to Agenda 21 of the 1992 Rio Earth Summit, United Nations Conference on Environment and Development. Although there is considerable variation in detail of the curricular approaches taken to environmental education, it remains the case that ‘sustainable development’ is a key orientating idea.

The essence of my argument is that our environmental predicament is a crisis not simply of our physical survival, but of our spiritual survival—that is, our understanding of what we are and how we should relate to the world around us. This is a crisis that is as much of human feeling as it is of the intellect. Having said that, Environmental Education must have two agendas: (a) a short-term pragmatic agenda of damage limitation that would focus on the cautious but imaginative use of science and technology to monitor and help ameliorate undesirable outcomes of the impact of human behaviour on nature. This agenda is now widely being addressed. (b) A long-term agenda of developing a sense of a right relationship with nature – this gradually, but increasingly, informing and orientating the more immediate agenda above. This, the most important agenda, is constantly peripheralized and subverted by the dominant metaphysics of our time that can only permit it as a façade, a public relations exercise.

Environmental education is essentially concerned with an understanding and appreciation of the environment and the significance of the natural order, including our place in it. At the heart of this will be an attempt to characterize, and develop in life, what should count as a right relationship with nature and thus a fuller understanding of what truly should count as human flourishing. Human well-being remains a central concern, but its interpretation is not restricted to the economic, and its achievement is understood as involving an understanding of our own nature and an appreciation of nature’s value that truly transcends the instrumental.

**Adapted from:** Michael Bonnett (2007). *Journal of Curriculum Studies*, 39(6), 707–721.

21. What does the author mean by “putative” remedy?
- (A) A crucial remedy (B) The obvious remedy  
(C) A well-proven remedy (D) The supposed remedy

22. Which of the following does **not** reflect the authors' thoughts?
- (i) Many national education systems have tried to address the environmental concern, but only superficially.
  - (ii) The guiding theme for most of the curricular realignment has been sustainable development.
  - (iii) Many national education systems have successfully aligned their curricula to the goals of Rio Earth Summit.
  - (iv) Many nations who are trying to realign their curricula with current environmental problems are signatories to Agenda 21 of the 1992 Rio Earth Summit, UNCED 1992.

- (A) Statements (i) and (iii)
- (B) Statement (iii)
- (C) Statements (ii) and (iii)
- (D) Statements (i), (iii) and (iv)

23. In the author's vision, environment education's most important agenda requires

- (A) human beings to work towards sustainable development.
- (B) human beings to use science and technology to tackle environmental problems.
- (C) human beings to work on their relationship with nature.
- (D) realigning curricula to goals of the Rio Earth Summit.

24. Which of the following reflects the authors' thoughts?

- (i) Developing a sense of a right relationship with nature has been undermined constantly.
- (ii) Our environmental crisis is a matter of our physical and spiritual survival.
- (iii) Using science and technology cautiously but imaginatively will solve all our environmental problems.
- (iv) Building the right relationship with nature can lead to a richer understanding of 'humans flourishing'.

- (A) Statements (i), (ii) and (iv)
- (B) Statements (i), (ii) and (iii)
- (C) Statements (i), (iii) and (iv)
- (D) Statements (ii) and (iv)

25. Which of the following words **cannot** replace "ameliorate" in the above passage?

- (A) Alleviate
- (B) Mitigate
- (C) Mollify
- (D) Upgrade

***Read the following Passage 4 carefully and answer questions 26-30.***

**Passage 4**

We believe that the history of life is dominated by punctuational changes, i.e., the evolution is concentrated in very rapid events of speciation that are geologically instantaneous, and which may be taking place almost continuously in ecological time. Most species, during their geological history, either do not change in any appreciable way, or else they fluctuate mildly in morphology with no apparent direction. Phyletic gradualism is very rare and too slow to produce the major events of evolution. Evolutionary trends are not

the product of slow, directional transformation within lineages; they represent the differential success of certain species within a clade, wherein speciation may be random with respect to the direction of a trend.

As an a priori bias, phyletic gradualism has prevented any fair assessment of evolutionary tempos and modes. It could not be refuted by empirical catalogues constructed within its framework because it excluded contrary information as the artificial result of an imperfect fossil record. With the model of punctuated equilibria, an unbiased distribution of evolutionary tempos can be established by treating the periods of no significant changes as data and by recording the pattern of change for all species in an assemblage. This distribution of tempos can lead to strong inferences about modes of evolution. If as we predict, the punctuational tempo is prevalent, then speciation – not phyletic evolution – must be the dominant mode of evolution.

We argue that virtually none of the examples that was brought forward to refute our model can stand as support for phyletic gradualism. Many of these examples are so weak and ambiguous that they only reflect the persistent bias for gradualism still deeply embedded in the field of paleontology. Of the few stronger cases, we concentrate on Gingerich's study of the small condylarth *Hyopsodus* in the Big Horn Basin rocks of northwestern Wyoming and argue that it provides an excellent example of species selection under our model. The record of human evolution seems to provide a particularly good example as no gradualism has been detected within any hominid taxon, and many changes are long-ranging; the trend to larger brains arises from differential success of essentially static taxa. Molecular genetics data supports our assumption that large genetic changes often accompany the process of speciation.

Phyletic gradualism was an a priori assertion from the start – it was never "seen" in the rocks; it expressed the cultural and political biases of 19th century liberalism. Huxley advised Darwin to refrain from it as an "unnecessary difficulty." We think that it has now become an empirical fallacy. A punctuational view of change may have wide validity at all levels of evolutionary processes. At the very least, it deserves consideration as an alternate way of interpreting the history of life.

**Compiled from:** Stephen Jay Gould and Niles Eldredge articles.

### **Meanings**

*Speciation:* the evolutionary process by which reproductively isolated biological populations evolve to become distinct species.

*Phyletic:* of or relating to evolutionary change in a single line of descent without branching.

*Clade:* a group of organisms that consists of a common ancestor and all its lineal descendants, and represents a single "branch" on the "tree of life".

26. The authors in the passage claim that:

- (A) Phyletic gradualism is one of possible pathways of evolution which may get suppressed in species where multiple branching is often observed in lineages.
- (B) Darwin did not agree to the idea of phyletic gradualism but Huxley strongly supported it.
- (C) Phyletic gradualism has an important educational value as an alternate theory for understanding evolution of life.
- (D) Phyletic gradualism emerged out of socio-cultural ideologies rather than empirical evidence.

27. According to the authors, in evolution, species formation is a

- (A) slow, gradual processes.
- (B) rapid and discontinuous process.
- (C) static non-directional process.
- (D) none of above.



28. The salient features of the theory is
- i) it is antithetical to evolution being a gradual process.
  - ii) it held that under “Phyletic gradualism”, there would be a need for unbroken fossil series linking two forms.
  - iii) the evolutionary process is based on patterns of first appearances and subsequent histories of species in the fossil record.
  - iv) speciation – not phyletic evolution – is the dominant mode of evolution.

(A) (i), (ii), (iii), and (iv)

(B) (ii), (iii), and (iv)

(C) (i), (iii), and (iv)

(D) (i), (ii), and (iv)

29. The theory holds that species

- (A) originate too rapidly resembling “punctuation”, and then persist unchanged through geological time in stasis referred to as “equilibrium”.
- (B) originate too rapidly resembling “equilibrium”, and then persist unchanged through geological time in stasis referred to as “punctuation”.
- (C) originate gradually resembling “punctuation”, and then persist unchanged through geological time in stasis referred to as “equilibrium”.
- (D) originate gradually resembling “equilibrium”, and then persist unchanged through geological time referred to as “punctuation”.

30. Select an appropriate title for the paragraph.

(A) Genetics and Evolution

(B) Speciation and Natural Selection

(C) Phyletic Gradualism

(D) Punctuated equilibrium

### **Social and Cognitive Sciences and Education**

31. Ideally, 'inclusive education' would mean

- (A) having an ‘alternative system of education’ like the National Institute of Open Schooling and the Non-formal Education programs.
- (B) schools creating separate units for admitting children with disabilities.
- (C) schools implementing practices that profit all children and not just those with special needs.
- (D) including children with disabilities into the mainstream education system with restricted participation in educational and co-curricular activities.

32. Which of the following statements are true for “Operation Blackboard”?

Statement 1: It was an outcome of NPE 1986.

Statement 2: It was an outcome of Kothari Commission 1966.

Statement 3: It has provisions for minimum essential facilities to all primary schools in the country.

Statement 4: It has provision for additional teachers for schools with enrollment of more than 100 students.

(A) Statements 1 and 4

(B) Statements 2 and 3

(C) Statements 1, 3 and 4

(D) Statements 1 and 3

33. Which of the following Education Policies in India featured a 'limit on pupil teacher ratio'?

(A) The 42<sup>nd</sup> Constitutional Amendment (1976)

(B) The National Policy on Education (1986)

(C) The 86<sup>th</sup> Constitutional Amendment (2002)

(D) The Right to Education Act (2009)

34. YouTube (a global video sharing website) shows videos where children as young as two sing classical music. Given such videos, which of the following statement is true?

(A) Such child prodigies exist in all arts and sciences and only they can do well in related professions.

(B) The cases of such children strongly suggest that your success in life is fully dependent on your genes.

(C) The fact that such children exist says very little about the nature of learning or professional success.

(D) This ability comes from rigorous training in childhood, and such training in early childhood is required for success in these professions.

35. "Glass ceiling" is a metaphor widely used to depict

(A) false goals set by women.

(B) a form of barrier hindering advancement of women.

(C) wall between men and women.

(D) unachievable limits set for women.

36. Which of these details is most important for evaluating the validity of a scientific claim?

(A) The Principle Investigator and her collaborators all have doctorate degrees.

(B) Research was peer reviewed by scientists in the concerned field.

(C) The scientists are associated with a university and not a private company.

(D) The study supports the accepted ideas in the concerned field.

37. "Scientific theories cannot be proven to be true, but they are potentially falsifiable." This view of science is associated with

(A) Karl Popper.

(B) Albert Einstein.

(C) Thomas Kuhn.

(D) Paul Feyerabend.

38. Identify the myths from the following statements.

Statement 1: Science also requires art and creativity.

Statement 2: In time, science can solve all problems in society.

Statement 3: Technology can precede science.

Statement 4: Universal Scientific Method does exist.

(A) Statements 2 and 3

(B) Statements 1 and 4

(C) Statements 2 and 4

(D) Statements 1, 2 and 4

39. Scientific theories

(A) are formulated only prior to research.

(B) are always based on pre-existing facts.

(C) are never issue driven.

(D) are usually testable.

40. Karl Marx emphasized which of the following as a major factor in shaping social life?

(A) Social-psychology

(B) Economics

(C) Politics

(D) Communism

41. The interpretation of "texts" is central to what intellectual tradition?

(A) Enlightenment philosophy

(B) Symbolic interactionism

(C) Phenomenology

(D) Hermeneutics

42. Which among the following is the most mechanistic explanation?

(A) The rat eats because it is hungry.

(B) The rat eats because it needs certain nutrients.

(C) The rat eats because of a change in blood sugar level.

(D) The rat eats because it is aware of its nutritional needs.

43. What is Greenwashing?

(A) Transforming products to be more ecological.

(B) Making a product appear more ecological than it really is.

(C) Converting the company to green production methods.

(D) Convincing customers to buy eco-friendly products.

44. What is a research design?

(A) A way of conducting research that is not grounded in theory.

(B) The choice between using qualitative or quantitative methods.

(C) The style in which you present your research findings, e.g. a graph.

(D) A framework for every stage of the collection and analysis of data.

45. A researcher showed films depicting violence to two groups of children. One group was then allowed to play with kittens while the other group sat for a test of English. The researcher then assessed the cooperativeness of each group of students. The independent variable in this study is
- (A) the level of cooperativeness. (B) the level of violence in subjects.  
(C) the type of activity following the film. (D) the film shown.

46. A recent study showed that the gestures made by blind people when they talk are similar to the gestures made by native speakers of the language. This would indicate that
- (A) gestures are innate.  
(B) gestures are random movements not related to language.  
(C) gestures are generated by language elements.  
(D) gestures are part of personality.

47. In cognitive psychology, a go-nogo task is used to test “executive control”. For example, in one such task you need to start tapping your finger when a green light is shown (the go condition) and stop tapping when you see a red light (the nogo condition). Often in these cases, stopping is difficult, particularly when you have done many taps, or when you are tired. A similar “executive control” situation is involved in a multiple choice exam with negative marking, where you have to choose not to attempt some questions, based on your perceived ability to correctly answer the questions.

Now, assume that all candidates in a multiple choice exam with negative marking have similar level of knowledge and training. In this case, the candidates who do well in the exam succeed because of their capacity to not attempt questions where they may not do well, and thus avoid negative marking.

In this case, candidates are selected for:

- a) Knowledge, as the candidates who stop do so because of better knowledge.  
b) Executive control, as candidates who stop do so because of better executive control  
c) Strategy, as candidates do so because of better strategy (such as identifying difficult questions as soon as they get the question paper, and thus avoiding the stopping problem).  
d) Chance, as candidates who stop do so because they are attentive and not tired (this depends on many external factors, such as how much sleep they had, traffic jams, life circumstances, etc.)

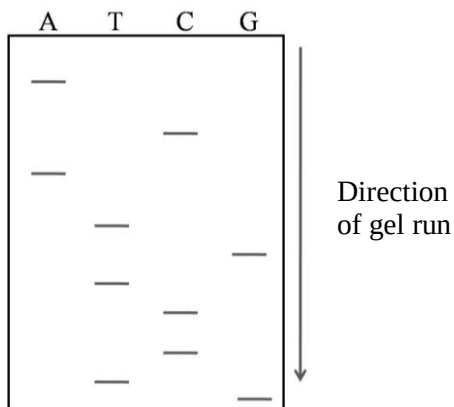
- (A) More b, c, and a than d (B) More a, c, and d than b  
(C) More b, c, and d than a (D) More a, b, and d than c

48. Recent research shows that counting below 10, even in adults, is influenced by the way the culture uses fingers while teaching counting. This suggests that
- (A) it is not possible to teach numbers without using fingers.  
(B) people who use their hands more are better at working with numbers.  
(C) people without fingers will not do well in mathematics.  
(D) the physical media used to teach numbers is stored in the mind along with the numbers.

49. Thirteen year old Rehan's father did not need to be told that his son had failed his exams. He could guess by the look on Rehan's face what his result was. This is an example of
- (A) gesturing. (B) non-verbal communication.  
 (C) effective communication. (D) extra sensory perception (ESP).
50. Three year old Jessica has recurrent allergies and must receive injections to counteract them. She became fearful and cried whenever she got her injections but now just the sight of a nurse makes her fearful and tearful. What is the conditioned stimulus in this example?
- (A) Nurse (B) Injections (C) Doctors (D) Allergies

### Biology

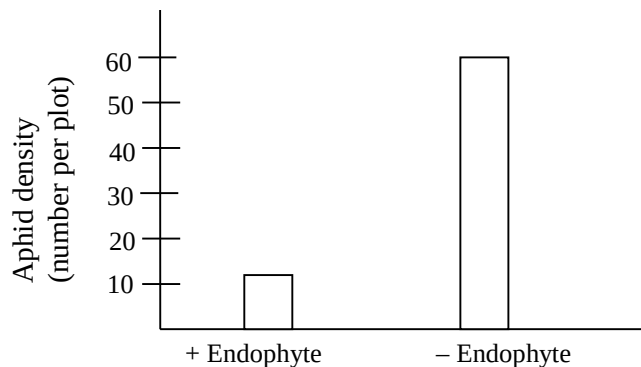
51. Priya went to a hill station during her vacation and found some light-green coloured, branched leaf-like structures growing on rock patches. She collected the sample and studied it in her college laboratory after she returned back. After observing the anatomical and morphological features, she realized that it is not a variety of Bryophyte but a Lichen. Which one of the following observations would have confirmed her decision?
- (A) Absence of vascular tissue  
 (B) Dorsiventrally flattened branched body  
 (C) Absence of reproductive structures  
 (D) Algal cells embedded in fungal hyphae
52. An oligonucleotide was being sequenced by a DNA sequencing method called the dideoxy method or the Sanger sequencing method. The autoradiogram obtained is shown below.



The sequence of the oligonucleotide strand that is being sequenced is:

- (A) 3'GTCCTGTACA5' (B) 5'GTCCTGTACA3'  
 (C) 3'ACATTGCCTG5' (D) 3'CAGGACATGT5'
53. Endophytic fungi live inside plants, generally in the intercellular spaces. An experiment with a plant *Lolium multiflorum* was conducted by growing plots of these plants with and without an endophytic

fungi *Neotyphodium* (equal number of plants were grown in each plot). The number of aphids feeding on these plants over the next few days was monitored and the data is given below.



The results obtained indicate that the association between the plant and the fungus is

- (A) parasitism.                      (B) pathogenic.                      (C) antagonistic.                      (D) mutualistic.

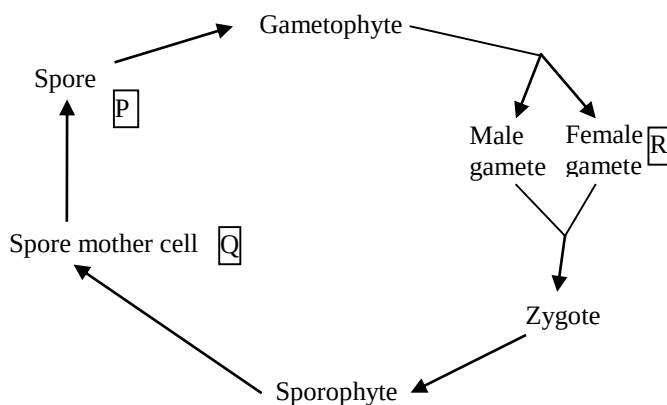
54. A student was working with some digestive enzymes (X, Y and Z) in the lab. She wanted to ascertain the source of these enzymes. To do so, she used some substrates and observed the following:

- X acted on proteins to break them down to short peptides.
- Y acted on triglycerides to give monoglycerides.
- Z acted on starch to give disaccharides.

The most likely predominant sources of X, Y and Z could be:

- (A) X: salivary glands              Y: stomach              Z: pancreas  
 (B) X: stomach                      Y: pancreas              Z: salivary glands  
 (C) X: salivary glands              Y: pancreas              Z: stomach  
 (D) X: gall bladder                  Y: stomach              Z: salivary glands

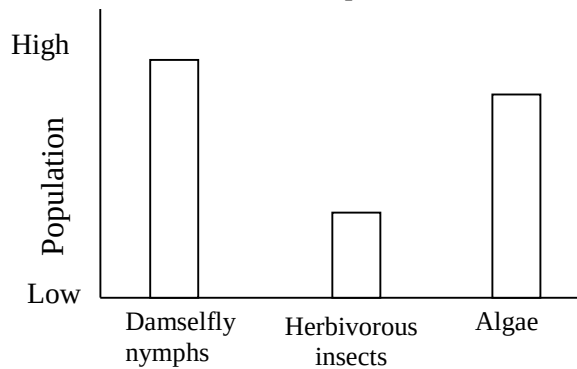
55. Alternation of generation is a characteristic feature of the plant life cycle. The plant passes through haploid (n) and diploid (2n) phases and both the stages are distinct from each other in lower plants. A diagram representing the life cycle of a plant is depicted below.



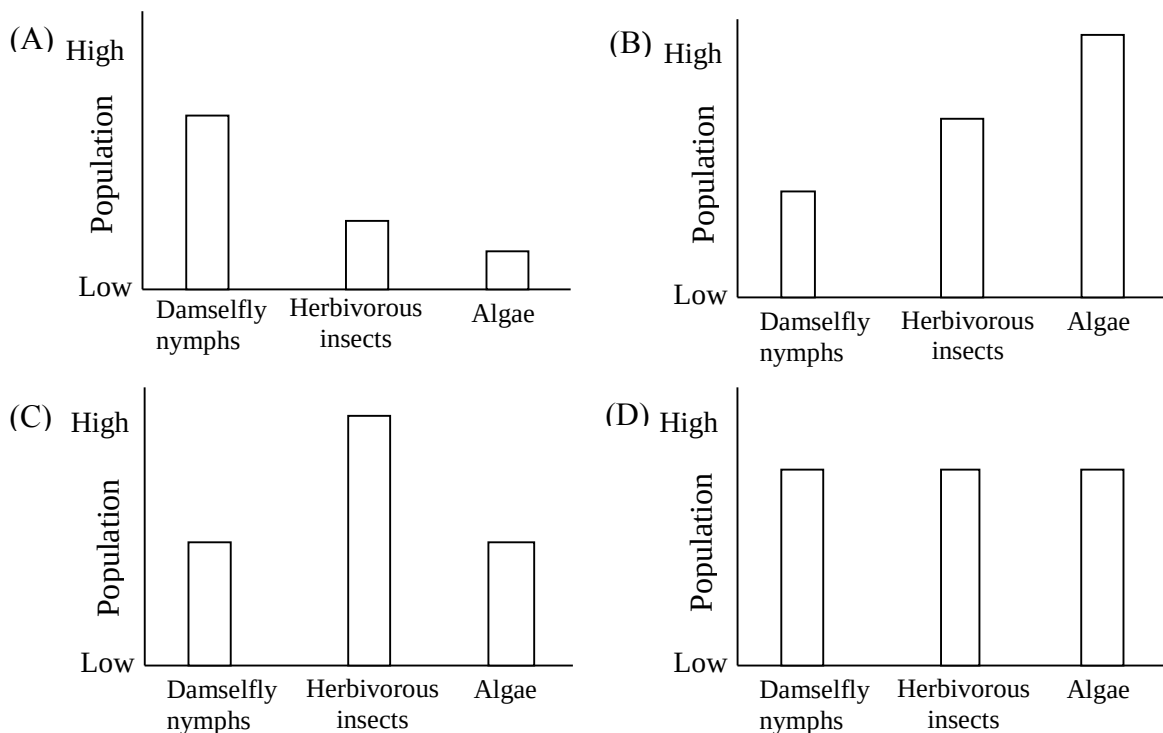
In the given diagram, the ploidy levels at phases P, Q and R, respectively, will be:

- (A) 2n, n, and 2n                      (B) n, n, and 2n  
 (C) n, 2n, and n                      (D) 2n, n, and n

56. An ecologist was studying a stream ecosystem comprising of algae, small herbivorous insects and damselfly nymphs feeding on these insects. In a cross sectional study, she estimated the population sizes of these three communities. The data obtained is represented in the bar diagram below.



She then introduced large carnivorous fish into the stream. What would be the most likely effect of this on the three populations? Mark the correct figure.



57. Sexually-transmitted disease gonorrhea is becoming difficult to treat because the causative bacteria are evolving resistance to antibiotics. For example, in Hawaii between 1997 and 1999, resistance of gonorrhea causative bacteria to fluoroquinolones increased from 1.4% to 9.5%. Scientists attribute this to natural selection. What does natural selection mean in this context?

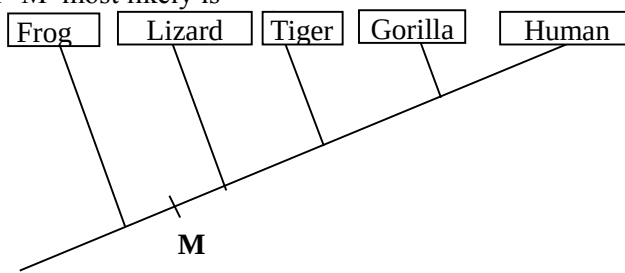
- (A) The bacteria have learned to avoid that particular class of antibiotic.
- (B) The antibiotic has changed the genetic structure of the bacteria allowing them to become antibiotic-resistant.
- (C) The antibiotic created an environment in which bacteria harboring antibiotic-resistant genes could survive.
- (D) The mutation rate for antibiotic-resistance increased during the time period.

58. During the breeding season, male stickleback fish develop bright red coloration on their undersides. This coloration acts as a sign stimulus for territorial males who react aggressively when another red-bellied male approaches it.

Niko Tinbergen, an ethologist, observed that a male stickleback fish in the laboratory aquarium displayed aggressive behavior when a red coloured vehicle passed by. This is an example of

- (A) habituation. (B) conditional learning.  
(C) fixed action pattern. (D) artificial selection.

59. The evolutionary relationships between animals can be represented using branching tree-like diagrams called cladograms. A cladogram representing the evolution of a few animals is shown below. The evolutionary character 'M' most likely is



- (A) amniotic egg. (B) hair. (C) lungs. (D) jaws.

60. In a patient suffering from diarrhea, the best way to replenish energy by the intravenous route is by injecting an isotonic solution of

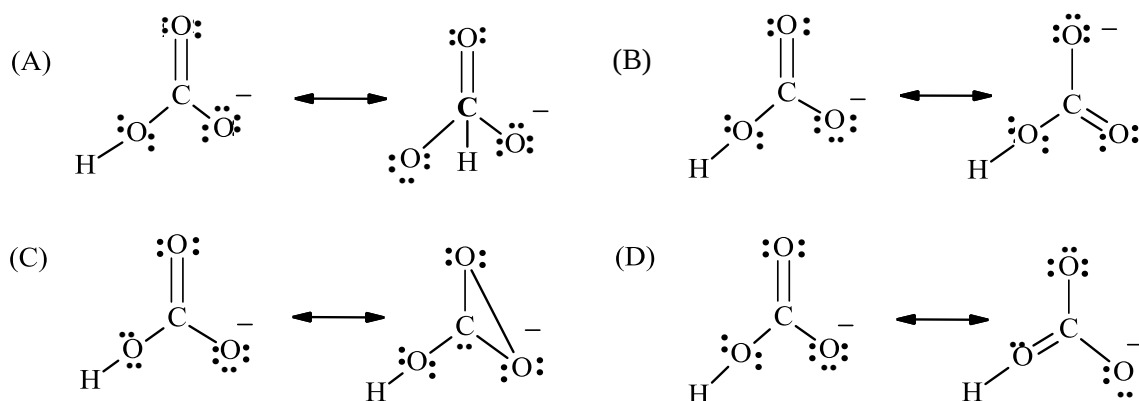
- (A) glucose. (B) glucose with sodium salts.  
(C) glucose-6-phosphate. (D) glucose with calcium salts.

## Chemistry

61. A compound contains, by mass, 40.0% carbon, 6.71% hydrogen, and 53.3% oxygen. A 0.320 mole sample of this compound weighs 28.8 g. The molecular formula of this compound is (atomic masses of H, C, and O are 1, 12, and 16 g mol<sup>-1</sup>, respectively)

- (A) C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>. (B) C<sub>3</sub>H<sub>6</sub>O<sub>3</sub>. (C) C<sub>2</sub>H<sub>4</sub>O. (D) CH<sub>2</sub>O.

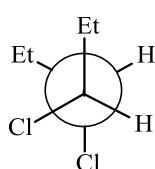
62. The appropriate resonance structures for bicarbonate ion, HCO<sub>3</sub><sup>-</sup>, are



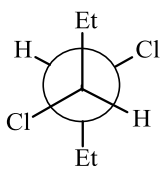


63. A sealed conical flask is filled with HCl gas at 298 K and 1 atm. If this gas is now replaced with methane at same temperature and pressure, the statement that is true is:
- (A) The number of moles for both gases in the flask will be different.  
 (B) Both the gases in the flask will have same number of molecules.  
 (C) The mass of both gases in the flask will be identical.  
 (D) The density of both the gases in the flask will be same.

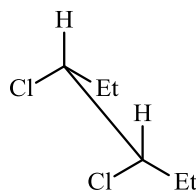
64. The formulae I to III represent different



I



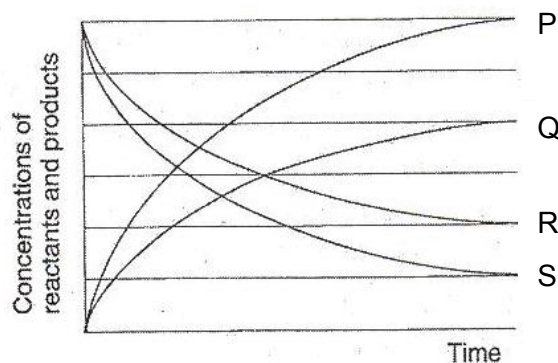
II



III

- (A) conformations.      (B) compounds.      (C) diastereomers.      (D) configurations.

65. The gas phase reaction  $4\text{NH}_3 + 5\text{O}_2 \rightleftharpoons 4\text{NO}_2 + 6\text{H}_2\text{O}$  was carried out with equal concentrations of the reactants. The plots of variation in the concentrations of reactants and products are as given below.

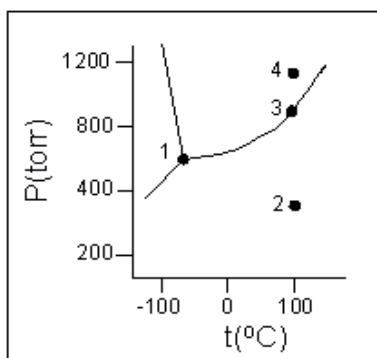


Which of the following correctly represents the experimental results?

- |     | P                    | Q             | R             | S                    |
|-----|----------------------|---------------|---------------|----------------------|
| (A) | $\text{NH}_3$        | $\text{O}_2$  | $\text{NO}_2$ | $\text{H}_2\text{O}$ |
| (B) | $\text{H}_2\text{O}$ | $\text{NO}_2$ | $\text{O}_2$  | $\text{NH}_3$        |
| (C) | $\text{H}_2\text{O}$ | $\text{NO}_2$ | $\text{NH}_3$ | $\text{O}_2$         |
| (D) | $\text{H}_2\text{O}$ | $\text{NH}_3$ | $\text{O}_2$  | $\text{NO}_2$        |

66. Increased  $\text{CO}_2$  concentration in air increases the concentration of dissolved  $\text{CO}_2$  in water bodies. For a river flowing through calcium carbonate rocks, increase in  $\text{CO}_2$  concentration in surrounding air would
- (A) promote the dissolution of carbonate rocks in river water.  
 (B) prevent dissolution of carbonate rocks in river water.  
 (C) promote frothing in the river water.  
 (D) promote recrystallization of calcium carbonate.

67. The (pressure versus temperature) phase diagram for compound Y is given below.



The statement that is correct for compound Y is

- (A) at point 4, Y(g) will spontaneously convert to Y(l).
- (B) at point 1, Y(s) will spontaneously convert to Y(g) and no Y(l) is possible.
- (C) at point 3, Y(s) is in equilibrium with Y(g).
- (D) at point 2, Y(l) is in equilibrium with Y(g).

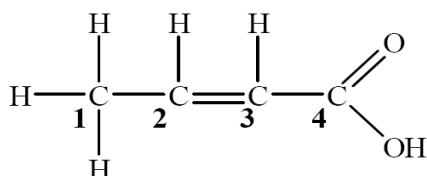
68. The volume of 0.50 M KOH (in mL) that would be required to neutralize completely 500 mL of 0.25 M H<sub>3</sub>PO<sub>4</sub> solution is

- (A) 250.
- (B) 166.
- (C) 333.
- (D) 750.

69. The IUPAC name of the compound HCOOCH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub> is

- (A) butanoic acid.
- (B) butanal.
- (C) methyl propanoate
- (D) propyl methanoate.

70. Identify the hybridization of carbon atoms (marked from 1 - 4) in this molecule.



	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
(A)	sp <sup>3</sup>	sp <sup>2</sup>	sp <sup>2</sup>	sp <sup>2</sup>
(B)	sp <sup>2</sup>	sp <sup>2</sup>	sp <sup>2</sup>	sp
(C)	sp <sup>3</sup>	sp	sp <sup>2</sup>	sp
(D)	sp	sp <sup>2</sup>	sp	sp <sup>2</sup>

### Mathematics

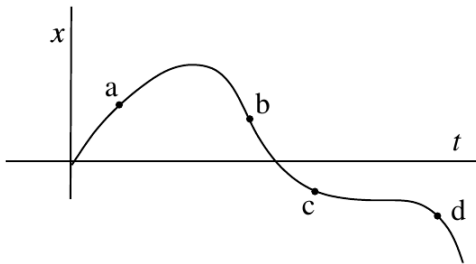
71. The locus of the centres of the circles of unit radius that pass through the origin is a

- (A) straight line.
- (B) circle.
- (C) parabola.
- (D) ellipse.

72. Let  $P(x)$  be a non-constant polynomial with real coefficients. If  $0$ ,  $1$ , and  $3i$  are roots of  $P(x)$ , where  $i = \sqrt{-1}$ , then the smallest possible value of degree of  $P(x)$  is  
 (A) 3 (B) 4 (C) 5 (D) 6
73.  $\lim_{x \rightarrow \infty} (\sin x + \cos x)$   
 (A) does not exist (B) is equal to  $\sqrt{2}$  (C) is equal to  $\frac{1}{2}$  (D) is equal to 1
74. Let  $\mathbb{Z}$  denote the set of all integers and let  $\mathbb{R}$  denote the set of all real numbers. For any real number  $x$ , let  $[x]$  denote the greatest integer not exceeding  $x$ . The domain of definition of the function  $f(x) = \frac{1}{[x](x-[x])}$  is  
 (A)  $\mathbb{R} - (\mathbb{Z} \cup (0, 1))$  (B)  $(\mathbb{R} - \mathbb{Z}) \cup (\mathbb{R} - (0, 1))$   
 (C)  $\mathbb{Z} \cup (\mathbb{R} - (0, 1))$  (D)  $(\mathbb{R} - \mathbb{Z}) \cup (0, 1)$
75. Let  $O$  be the center of the circle  $\Omega$ . Let  $A$  and  $B$  be two points on  $\Omega$  such that  $\angle AOB = 120^\circ$ . Let  $C$  be the circumcentre of triangle  $AOB$ . Then magnitude of  $\angle ACB$  is  
 (A)  $60^\circ$  (B)  $90^\circ$  (C)  $120^\circ$  (D)  $150^\circ$
76. Let  $f: [0, 1] \rightarrow \mathbb{R}$  satisfy  $f(x) + f(1-x) = 2$  for all  $x$ . Then  $\int_0^1 f(x) dx$  is  
 (A) 1 (B)  $\frac{3}{2}$  (C) 2 (D) 4
77. Let  $P(x)$  be a polynomial of degree 2 with real coefficients. The equation  $P(x) = 0$  does not have real roots. The graph of  $y = P(x)$   
 (A) intersects the  $x$ -axis at two distinct points  
 (B) is tangent to the  $x$ -axis  
 (C) does not intersect the  $x$ -axis  
 (D) does not intersect the  $y$ -axis
78. The number of real solutions of  $x \cos x = 1$  is  
 (A) 0 (B) 1 (C) 2 (D) not finite
79. The total number of squares on an  $8 \times 8$  chessboard is  
 (A) 64 (B) 128 (C) 144 (D) 204
80. Let  $i = \sqrt{-1}$  and  $f(n) = 1 + i + i^2 + i^3 + \dots + i^n$  for any positive integer  $n \geq 1$ . The smallest value of  $n$  for which  $f(n)$  is a real number is  
 (A) 1 (B) 2 (C) 3 (D) 4

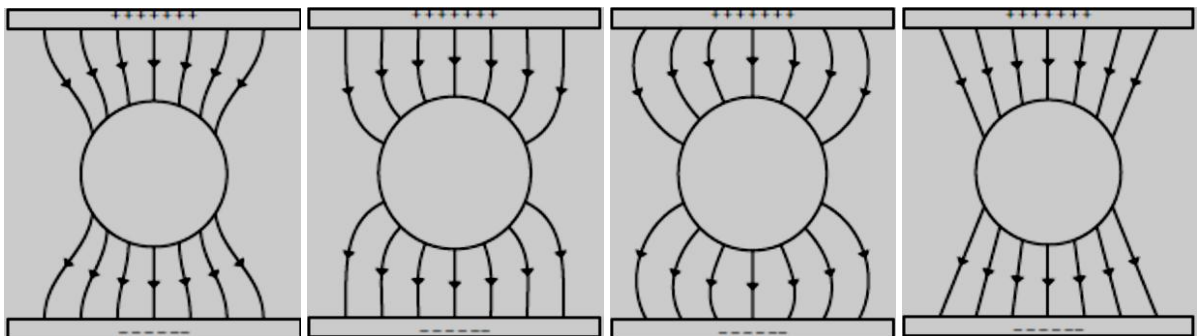
## Physics

81. The figure below shows a displacement vs time ( $x$  vs  $t$ ) graph for an object in motion. At which of the lettered point on the graph is the object speeding up?



- (A) a                      (B) b                      (C) c                      (D) d
82. The following can easily penetrate bone matter:
- (A) violet light              (B) ultraviolet light              (C) x-rays                      (D) gamma rays
83. The international space station is maintained in a nearly circular orbit with a mean altitude of 330 km and a maximum of 410 km. An astronaut is floating in the space station's cabin. Let  $g$  represent the acceleration due to gravity at the Earth's surface. The acceleration of the astronaut as measured from the earth is
- (A) zero.  
 (B) nearly zero and directed toward the earth.  
 (C) nearly  $g$  and directed toward the earth.  
 (D) nearly  $g$  and directed along the line of travel of the station.
84. In a thermally isolated system, two boxes filled with an ideal gas are connected by a valve. When the valve is in closed position, the states of the box 1 and 2 respectively are (1.0 atm,  $V$ ,  $T$ ) and (0.5 atm,  $4V$ ,  $T$ ). When the valve is opened, such that there is no heat lost to the surroundings, the final pressure of the system is close to
- (A) 0.50 atm.                      (B) 0.60 atm.                      (C) 0.75 atm.                      (D) 1.0 atm.

85. A metallic sphere is kept in between two charged plates. The most appropriate representation of the field lines is



- (A)                      (B)                      (C)                      (D)

86. Surface tension  $\sigma$  of pure liquid water in contact with its water vapour has been given by the expression

$$\sigma = B \left[ \frac{T_c - T}{T_c} \right]^\mu \left[ 1 - \frac{5}{8} \left( \frac{T_c - T}{T_c} \right) \right]$$

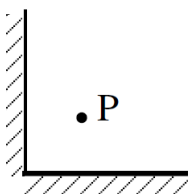
Here  $T$  is the temperature and  $\{B, \mu, T_c\}$  are positive constants. A student has collected data for the variation in surface tension with respect to the temperature. In order to get the value of  $\mu$  from the slope of the graph, she will plot

- (A)  $\log \sigma$  on  $y$ -axis and  $\log \left( \frac{T_c - T}{T_c} \right)$  on  $x$ -axis
- (B)  $\log \sigma$  on  $y$ -axis and  $\log T$  on  $x$ -axis
- (C)  $\log \left[ \sigma \left\{ 1 - \frac{5}{8} \left( \frac{T_c - T}{T_c} \right) \right\} \right]$  on  $y$ -axis and  $\log \left( \frac{T_c - T}{T_c} \right)$  on  $x$ -axis
- (D)  $\log \left[ \frac{\sigma}{1 - \frac{5}{8} \left( \frac{T_c - T}{T_c} \right)} \right]$  on  $y$ -axis and  $\log \left( \frac{T_c - T}{T_c} \right)$  on  $x$ -axis

87. Which of the following statement is true in the case of adiabatic compression of an ideal gas?

- (A) The work done on the system will be zero as the system is not allowed to exchange heat with the surrounding.
- (B) The pressure of the system decreases as the work is done by the surrounding on the system.
- (C) The temperature of the system remains constant as there is no heat flow between the system and the surrounding.
- (D) The internal energy of the system increases as there is no heat flow between the system and the surrounding.

88. Two plane mirrors are placed together on one of their edges so as to form a right angle as shown. A point object (**P**) is placed equidistant from each mirror. The total number of images of the object that can be formed using this setup is

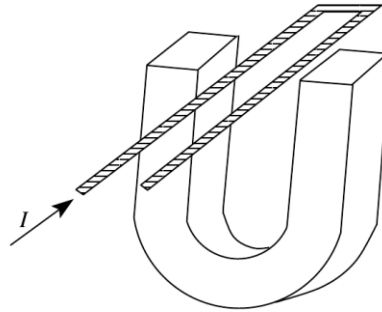
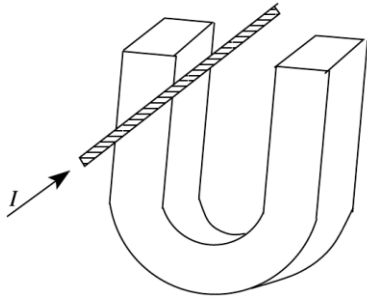


- (A) two.
- (B) three.
- (C) four.
- (D) infinite.

89. A plano-concave lens is

- (A) converging when the surrounding medium is optically denser and diverging when it is rarer.
- (B) always converging.
- (C) converging when the surrounding medium is optically rarer and diverging when it is denser.
- (D) always diverging.

90. A wire is placed in between a “U” shaped magnet as shown in the figure to the left. When a current flows in the direction shown in the figure as seen from front, the wire moves downwards. The wire is now made to form a loop and placed horizontally keeping the direction of current same as shown in the figure to the right.



The loop will now

(A) move upward.

(B) move downward.

(C) remain stationary.

(D) rotate anticlockwise.

**HOMI BHABHA CENTRE FOR SCIENCE EDUCATION**  
**TATA INSTITUTE OF FUNDAMENTAL RESEARCH**

**Entrance Test for Ph.D. Programme in Science Education - 2016**

**Section II: Critical Reasoning**

Read the following instructions carefully.

- This section of the written test carries **50 marks** and is of **one hour** duration.
- This section of the question paper consists of 7 pages. It has three main questions of varying marks.
- The answers must be given on this question paper itself, in the space provided after each question. Do not exceed the space provided.
- Before you start answering, please check that you have written your Name and Roll Number in the space provided at the bottom of this page.
- At the end of one hour, please submit this question paper.

**Name:** \_\_\_\_\_

**Roll Number:**

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*(Do not write anything below the line)*

91	92	93	Total
15	15	20	50

**91. (15 marks) Describe briefly any research topic of your interest in:- science education, mathematics education or design and technology education. Provide arguments for why that research is important, and outline the possible educational outcomes of the research you have described. Please restrict your answer to 300 words or less.**

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**92. (15 marks) Describe your response (in 300 words or less) to any one of the given issues in education.**

- (a) Information may be a click away, but it takes a teacher to evolve it into knowledge.
- (b) Often students with good content knowledge in science are unable to assess socio-scientific issues.
- (c) Being educated is not a matter of degrees, it is a quality of mind.
- (d) Science education cannot be a value neutral (objective) process.

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**93. (20 marks) Write short notes (about 150 words) on any two of the following:**

- (a) Measures to improve teacher status in India.
- (b) Science is not an opinion based subject, it is a fact based subject.
- (c) Virtual classrooms may make physical classroom teaching unnecessary in the near future.
- (d) Girls' schools are essential for promoting education of the girl child.
- (e) Criteria to evaluate the effectiveness of the mid-day meal scheme.
- (f) Measures to make the textbook and classroom interaction culturally sensitive.

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