

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2019

Section I:

Multiple Choice Questions

Read the following instructions carefully.

- This section of the written test carries **100 marks** and is of **two hours** duration.
- 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: Quantitative reasoning, scientific literacy and technical comprehension.

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).

- 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 mark.
- You may answer **any 50 questions** from this section. In case more than 50 questions are attempted, the score obtained will be normalised to that corresponding to 50 questions, using the following formula.

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

- Before you start answering, please check that you have written your Roll Number on both sides of the Answer Sheet.
- You must indicate your answers **only on the Answer Sheet provided**, by putting a \times 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 answer 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 \times in a certain box, blacken out the entire box and put a \times 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)
 \rightarrow

- At the end of two hours, please submit this question paper along with the Answer Sheet.

Quantitative Reasoning, Scientific Literacy and Technical Comprehension

1. Anand is now 3 times as old as Jafar. After 4 years, Anand is going to be twice as old as Jafar. What is the age of Jafar at present?
(A) 4 (B) 6 (C) 9 (D) 12
2. An elderly man was distributing laddus to houses in his locality as part of Gandhi Jayanti celebration. After he distributed the laddus equally to 25 houses, he was left with 8 laddus. However, if he had distributed laddus equally to 28 houses, he would have been left with 22 laddus. What was the total number of laddus he started with?
(A) 258 (B) 308 (C) 358 (D) 408
3. Anju is jogging in a circular ground. After initial warm up, she jogs at a constant speed of 3 km/hr and is able to complete 4 rounds in 20 minutes. What is the approximate radius of the ground?
(A) 35m (B) 40m (C) 45m (D) 50m

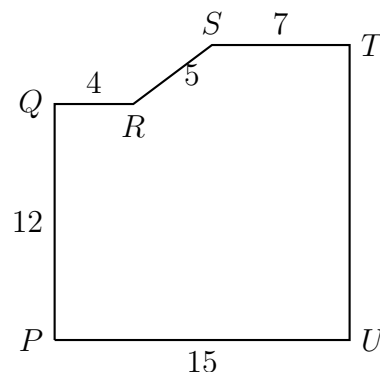
4. From an unknown language, researchers have deciphered few phrases as given below:

Taching Fat Kulu – He is tall
Making Fox Kuto – Chief was brave
Making Fat Koho – She is brave
Hoka Fita Kulu – He will be fat
Sita Fox Koho – She was kind

Based on this, translate the sentence “Chief will be kind”.

- (A) Sita Fita Kuto
(B) Making Fita Koho
(C) Hoka Fox Kuto
(D) Making Fox Koho
5. The number 6544AB is a perfect square, where A and B are digits. Its square root can be
(A) 803 (B) 805 (C) 807 (D) 809
6. I noticed position of hands of a clock at a certain time. After another 166 minutes, the positions of minute hand and hour hand were exchanged. What was the time when I first saw the clock?
(A) 02:12 (B) 02:26 (C) 05:12 (D) 05:26
7. Shagufta bought a new laptop and got a discount of 20% on the price of the laptop. She paid the shopkeeper Rs. P , including an 8% sales tax on the discounted price. Which of the following represents the original price of the laptop?
(A) $0.88P$ (B) $\frac{P}{0.88}$ (C) $(0.8 \times 1.08)P$ (D) $\frac{P}{(1.08 \times 0.8)}$

8. In the given figure, $l(PQ) = 12$ units, $l(QR) = 4$ units, $l(RS) = 5$ units, $l(ST) = 5$ units and $l(PU) = 15$ units. Find the total area of the figure.



- (A) 201 sq. units
 (B) 207 sq. units
 (C) 213 sq. units
 (D) 225 sq. units

9. The equation given below shows how temperature (F), measured in degrees Fahrenheit, relates to a temperature (C), measured in degrees Celsius.

$$C = \frac{5}{9}(F - 32)$$

Based on this equation, which of the following must be true?

1. A temperature increase of 1 degree Fahrenheit will correspond to more than 0.5 degree Celsius increase in temperature.
2. A temperature increase of 1 degree Celsius will correspond to 1 degree Fahrenheit increase in temperature.
3. A temperature increase of 1 degree Celsius will correspond to more than 2 degree Fahrenheit increase in temperature.

- (A) 1 only (B) 2 only (C) 3 only (D) 1 and 3 only

10. If $5x - 2y = 12$, then the value of $\frac{32^x}{4^y}$

- (A) will be less than 1000.
 (B) will be more than 1000 but less than 4000.
 (C) will be more than 4000.
 (D) cannot be determined from the information given.

11. If $6 < |x - 3|$, which of the following can be a possible range of values for x ?

- (A) $x < 9$ (B) $0 < x < 6$ (C) $-3 < x < 0$ (D) $x < -3$

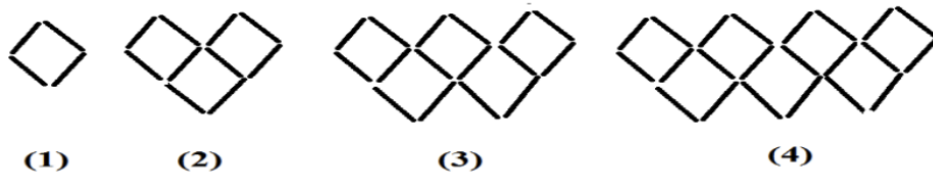
12. If x is the average (arithmetic mean) of s and 9, y is the average of $2s$ and 15 and z is the average of $3s$ and 18, what is the average of x and y in terms of z ?

- (A) $z + 3$ (B) $\frac{(z + 3)}{2}$ (C) $z - 3$ (D) $\frac{(z - 3)}{2}$

13. If a is any odd integer and b is any even integer, which of the following is an odd integer?

- (A) $3b$ (B) $a + 3$ (C) $a + 2b$ (D) $2a + b$

14. How many matchsticks would we need for the 36th pattern in the series?



- (A) 212 (B) 213 (C) 214 (D) 215

15. Consider the statement of the form “p implies q”, where p = “If Tausif is Parveena’s father, then Parveena is Shafiq’s sister” and q = “Shafiq is Tausif’s son.” Which of the following statements is equivalent to this statement?

- (A) Shafiq is Tausif’s son, implies if Tausif is Parveena’s father then Parveena is not Shafiq’s sister.
(B) Shafiq is not Tausif’s son, implies if Tausif is Parveena’s father then Parveena is not Shafiq’s sister.
(C) Shafiq is not Tausif’s son, implies Tausif is Parveena’s father or Parveena is Shafiq’s sister.
(D) Shafiq is Tausif’s son, implies Tausif is Parveena’s father and Parveena is Shafiq’s sister.

Read the following passage carefully and answer questions 16 to 20.

Policies may have enabled the historically disadvantaged groups of women and dalits to enter the higher education classrooms but their voices remain hidden and unheard in the classroom. Even sociologists who are expected to investigate caste, gender and ethnicity seem reluctant to take on the caste identity discourse in the classroom. To understand this, one might need to take a closer look at how caste identities are assumed as neutral in academic practice, having no bearing on the content of sociology. The challenges in the classroom are posited as an issue of language, merit and so on.

The hierarchies of caste are hidden in the distinctions among central and state universities with English as the medium of teaching and research in the central universities and regional languages in the state institutions. Further, work carried out in English is deemed superior while that in regional languages as lesser and “down to earth”. Sociologists put these issues into a paradoxical position when they bemoan the lack of “our own theories” and at the same time, express fear of decline in standards if teaching is no longer done in English. As the classroom becomes metropolitan with the entry of dalit and women scholars, sociologists turn the blame of the decline of intellectual merit on this diversity, labeling the difficulties brought on by language as lack of knowledge itself. Further, sociologists seem afraid of addressing caste identities in the classroom for fear of accusations of feminizing theory or contributing to decline of merit. Keeping women, dalit and ethnic minorities away from mainstream discourse also helps in subverting the challenges posed by dalit or feminist knowledges. Sociological discourse limits the definitions in “good sociology” to binaries such as theoretical

brahmin/empirical shudra, objectivism/subjectivism, social/political, etc. Sociologists also deem this as the only and superior way of understanding identities. They seek to remedy gaps in the classroom through remedial classes or translation of books. Indigenists and nativists, alternately, hold English as incapable of understanding “our” culture and propose teaching-learning in native languages as “cultural duty”. Both groups may have missed seeing the cultural and symbolic effects of language and the links between language and power.

Excerpted and adapted from: Rege, S. (2010). Education as “Trutiya Ratna”: Towards Phule-Ambedkarite Feminist Pedagogical Practice. Economic and Political Weekly, 45(44-45), p88-98.

16. Sociologists seem to stay away from the discourse of identities in the classroom because
- (A) they are unsure about what is the discourse of identities.
 - (B) they do not wish to challenge what is held as knowledge.
 - (C) they are unsure about the diverse identities in the classroom.
 - (D) they are upper caste elites.
17. Which, among the following, is closest in meaning to “down to earth” with reference to its use in the passage?
- (A) high practical value
 - (B) high emotional value
 - (C) low social rank
 - (D) low self-esteem
18. What does “feminizing” refer to in the paragraph?
- (A) including conflicting discourse is seen as fashionable and hence adopted by women.
 - (B) inclusion of and caring for the marginalized.
 - (C) making something appear gentle to the marginalized.
 - (D) most sociologists are women and what they say is “feminine”.
19. What is meant by “theoretical brahmin/empirical shudra”
- (A) terms used to maintain simple understanding.
 - (B) people’s work is related to caste.
 - (C) people with theoretical ideas are deemed superior and those with experiences as lowly.
 - (D) terms used to maintain what is known and understood.
20. What might be the link between “language and power” implied in the paragraph?
- (A) Language stabilises power by reifying distinctions.
 - (B) Language is powerful only when spoken by the right people.
 - (C) Language stabilises power with differences in grammar.
 - (D) Language used through the power of speech, as in ability to talk.

Read the following passage carefully and answer questions 21 to 25.

Terri Bollinger, principal at the Ridge Central elementary school, has noticed a troubling trend. Her third graders are doing incredibly well. Most of them meet or exceed Illinois state reading standards. But her fifth graders aren't showing the same kind of improvement. Principals and teachers around the country are growing increasingly concerned with what they call the fourth-grade slump. The malaise, which can strike children any time between the end of the second and the middle of fifth grade, is marked by a declining interest in reading and a gradual disengagement from school. What's causing it? Some say fourth graders get distracted by videogames, organized sports and after-school activities. Others worry that kids are burning out. "We kill them with tests in third grade. By fourth grade, they're tired," says Gina Defalco, a fourth-grade teacher in Fredericksburg, Va. The slump was first noted in the 1960s, but with schools under pressure to show that kids in all grades are improving, administrators are taking a fresh look at the problem.

For a lot of kids, fourth grade is a turning point. According to the National Assessment of Education Progress, American kids' reading scores are improving in the early years of elementary school. After fourth grade, test scores are flat. Kids read less as they get older, too. In a 2006 survey by Scholastic Inc., 40 percent of kids between the ages of 5 and 8 read every day. At fourth grade, though, that rate declined to 29 percent. Testing may be contributing to the slump in subtle, curricular ways. At every level of schooling, a reading expert says "kids need to use a wide range of reading materials—nonfiction and expository writing—and lots of vocabulary words." But in an effort to "teach to the test," many schools are replacing social studies and science with reading instruction in the early years, and that hurts kids. Without this critical base, many kids aren't equipped to do the abstract thinking and learning required of them as they move on.

Between third and fourth grade, kids go from learning to read to reading to learn. Textbooks get more difficult—instead of reading about Dot and Spot, fourth graders read about the solar system. To keep up, 9-year-olds have to be able to decode words, comprehend sentences and make inferences about what paragraphs mean. Elise Holston, principal of the Kempton Elementary School, found that her school's fourth-grade slump started in third grade. On statewide tests, 26 percent of Kempton's second graders were proficient or advanced in reading. A year later, that rate dropped to 15 percent. So this year, Holston's third and fourth graders adopted a new reading program. Kids learn about the Everglades from a textbook, but there's also a short video so kids who were struggling can keep up. Back at Ridge Central, Bollinger has her own slump-busting strategy, and it looks a little like a bribe. Six hundred minutes of reading equals a free trip to a local amusement park.

Adapted from the article "Fourth-Grade Slump", by Karen Springen originally published in the Newsweek on 2/18/07

21. In the context of this passage, what could the word 'malaise' be best replaced by
(A) malpractice (B) problem (C) disease (D) side-effect
22. Which of the following statement is TRUE in relation to the above passage?
As kids go from learning to read to reading to learn ...

- (A) They should be proficient in reading as well as writing.
- (B) They should have developed the ability to communicate what they have read.
- (C) They should be able to understand sentences and draw conclusions.
- (D) They should be able to perform well in reading at the statewide tests.

23. In the sentence, “Without this critical base, many kids...”, what is the critical base that the author is referring to?

- (A) Reading and comprehension skills.
- (B) Problem-solving skills.
- (C) Reading instruction and passages.
- (D) Exposure to multiple subjects and methods.

24. As per the passage provided, what are the most common reasons/ factors observed for the fourth grade slump?

- (i) children are distracted by videogames, organized sports and after-school activities
- (ii) lack of books and reading material
- (iii) focus on testing
- (iv) kids read less as they get older
- (v) textbooks get more difficult

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

25. Why does Terri Bollinger, the principal at the Ridge Central elementary school call her own (slump-busting) strategy, a bribe?

- (A) The motivation is extrinsic in nature.
- (B) Children get an intrinsic motivation to perform a task.
- (C) The strategy to improve the slump is in the interest of teachers.
- (D) The strategy to improve the slump is in the interest of students.

Read the following passage carefully and answer questions 26 to 30.

The seemingly basic life cycle of butterflies: eggs hatch into caterpillars, caterpillars turn into cocoons and cocoons hatch was once hotly debated. It was a pioneering naturalist, Maria Sibylla Merian, whose meticulous observations conclusively linked caterpillars to butterflies, laying the groundwork for the fields of entomology, animal behaviour and ecology.

Maria Sibylla Merian was born in 1647 in Frankfurt and was trained as an artist. Merian is arguably one of the first true field ecologists. She studied the behaviour and interactions of living things at a time when taxonomy and systematics (naming and cataloguing) were the main pursuit of naturalists. Like most modern entomologists, Merian’s passion for insects started early. At 13, she began collecting and raising caterpillars as subjects for her paintings. She often painted by candlelight, awaiting the moment when a caterpillar formed its cocoon or a newly formed butterfly later emerged from it.

In 1699, with her youngest daughter in tow, she embarked on one of the first purely scientific expeditions in history. Her goal was to illustrate new species of insects in

Surinam, a South American country (now, Suriname) only recently colonised by the Dutch. Surrounded by new species, Merian was itching to collect and paint everything she could get her hands on. She immediately ran into problems, however, as the Dutch planters of the island were unwilling to help two unaccompanied women collect insects from the forest, a mission they believed to be frivolous.

So Merian forged relationships with enslaved Africans and Indigenous people who agreed to bring her specimens and who shared with her the medicinal and culinary uses of many plants. For example, Merian writes that enslaved Amerindian women used the seeds from particular plants to abort fetuses in order to spare them from the cruelty of slavery. It is a stark reminder of the unmitigated horrors of 1600s colonialism. Merian died in 1717. After her death, inaccuracies began to creep into the hand-painted copies of Merian's books. New plates with imaginary insects were added. Others were recoloured to be more aesthetically pleasing. The careful attention to detail that made Merian's work so incredible was gradually eroded. In the 1830s, naturalist Lansdowne Guilding wrote a scathing critique of Merian's work in a book. In one place he accuses Merian of ignoring facts "every boy entomologist would know." Guilding attacks Merian for relying too heavily on the knowledge of African slaves and Amerindians, people he regarded as unreliable.

However, Karl Linnaeus, famous for developing a system for classifying life, referred heavily to her illustrations in his species descriptions. The grandfather of Charles Darwin, Erasmus Darwin, cites Merian's work in his book *The Botanic Garden*. Certain claims made by Merian which attracted scepticism then, are now found to be true.

Adapted from Hidden women of history: Maria Sibylla Merian, 17th-century entomologist and scientific adventurer, Feb. 21, 2019

26. Which of the following is NOT a correct sequence in the life cycle of a butterfly?
- (A) Eggs → cocoon → caterpillar → new butterfly.
 - (B) Eggs → caterpillar → cocoon → new butterfly.
 - (C) Caterpillar → cocoon → butterfly → eggs.
 - (D) Butterfly → eggs → caterpillar → cocoon → new butterfly.
27. The 2nd paragraph says "Merian is arguably one of the first true field ecologist". The author uses that word "arguably" because
- (A) Merian was just an artist.
 - (B) Merian overlooked behaviour and interactions of living things while painting.
 - (C) Merian did not follow the established norms of naturalism.
 - (D) Merian would collect and raise caterpillars only as subjects of her paintings.
28. According to the passage, why did Merian face problems in collecting and painting insects?
- (i) Merian and her daughter were two unaccompanied women
 - (ii) Dutch planters found Merian's mission suspicious
 - (iii) Dutch planters believed that collecting insects from forests was a worthless task
- (A) (i) only.
 - (B) (i) and (ii).
 - (C) (i) and (iii).

(D) (iii) only.

29. Which statement from the passage reminds us of the “unmitigated horrors of 1600s colonialism”?
- (A) Africans and Amerindian women were enslaved.
 - (B) Amerindian women knew the use of certain seeds for abortion.
 - (C) African slaves and Amerindian women were forced to learn medicinal and culinary uses of plants.
 - (D) African slaves and Amerindian women were unreliable.
30. According to the passage, which of the following beliefs would have been held by Guilding?
- (A) African slaves and Amerindians deserved to be enslaved.
 - (B) Merian’s work was known to all boy entomologists.
 - (C) Artists cannot be naturalists.
 - (D) Males were better entomologists than females.

Social Sciences, Cognitive Sciences and Education

31. Saida reads a problem from the Physics textbook. She restates the problem in her own words so that her friends are able to understand it better. What is this skill called?
- (A) Analysis (B) Knowledge (C) Synthesis (D) Comprehension
32. The zone of proximal development points to that level of knowledge or skills that an individual cannot acquire on her own and needs help with. There are many ways in which a classroom may reflect the awareness of the right application of this knowledge. Which of the following is an instantiation of this awareness in a classroom?
- (A) In a class, a teacher assigns work and provides step-by-step instructions to move forward.
 - (B) In a class, a teacher moves around while students are working.
 - (C) In a class, a teacher sits down to correct papers after assigning some work to students.
 - (D) In a class, a teacher assigns work, moves around to see who needs help and provides accordingly.
33. According to Chomsky, languages have a universal basis in that humans have an innate ability to process language. Which of these has no relation to Chomsky’s postulate?
- (A) Learning a second language.
 - (B) Infants learning a language.
 - (C) Processing complex linguistic features in a language.
 - (D) Computer programming languages.
34. Keya watches a wasp drag a paralysed grasshopper down a hole in the ground. When asked what she was doing, Keya replies: “I’m watching that wasp store paralysed grasshoppers

in her nest to feed her offspring.” Which of the following is the best description of Keya’s reply?

- (A) Keya is making no assumptions.
- (B) Keya is stating a conclusion entirely drawn from her observation.
- (C) Keya is stating a conclusion only partly derived from her observation.
- (D) Keya has stated an hypothesis.

35. Look at the picture below, and then the statements. Which of the following is not an inference?



- (A) A bird has been walking on the snow.
- (B) There are some marks on a white background.
- (C) These are sketches of barren trees.
- (D) These are footprints of an insect on the snow.

36. A teacher asks her students some questions on a topic on the first day of the class. This will help her plan for future directions during the course. This test is not for grading but gives a fair idea to the teacher about students’ preconceptions. What is this form of assessment called?

- (A) Formative (B) Diagnostic (C) Criterion-referenced (D) Summative

37. An instructor noticed that many of the students in her class who belonged to a particular tribal community answered the same questions wrong on a standardised assessment. This observation is a typical example of:

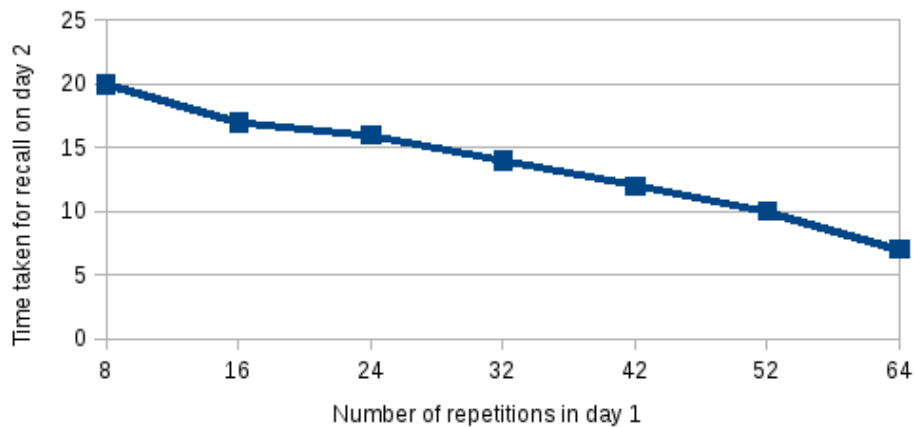
- (A) Stereotyping (B) Racial profiling (C) Item Bias (D) Sample error

38. In an experimental study by Needham and Baillargeon (1993), 4.5 month old infants saw a hand deposit a box fully on a platform. Next, they saw a hand deposit a box beyond the platform, leaving the box suspended mid-air with no apparent support. They stared longer in the second instance. Which of the following is a possible conclusion here?

- (A) Infants were surprised by the length of the arm.
- (B) Infants expected the box to fall and were surprised when it did not.
- (C) Infants knew this experiment is a trick.
- (D) Infants expected another hand to appear and put a box on the platform.

39. A study was developed to determine the relation between time devoted for learning on

day 1 and time of recall on day 2. Observe the graph below, and suggest which of the statements is the best conclusion from the study.

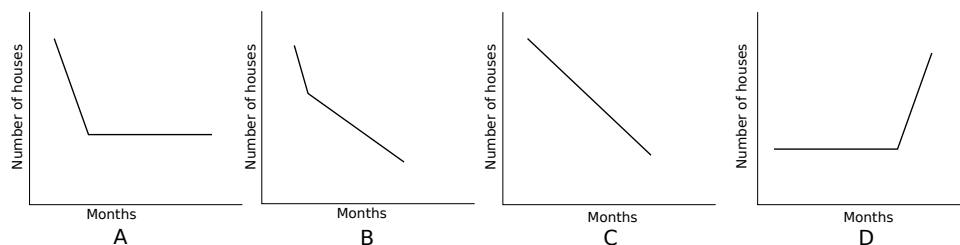


- (A) The greater the number of repetitions initially, the lesser the time that recall takes.
- (B) The lesser the number of repetitions initially, the lesser is the time that recall takes.
- (C) Recall decreases with time.
- (D) Repetitions increase with time.

40. Teachers were interested to know whether there is a difference in learning among two groups of undergraduate students where one group was facilitated with peer instruction and the other was taught using regular instructional methods. What kind of research design should the teachers apply?

- (A) Experimental
- (B) Survey
- (C) Ethnography
- (D) Clinical interview

41. In Mumbai city, due to the steep prices in property, the number of new houses that were bought each month during the first half year decreased at a constant rate. During the second half of the year, the number of new houses bought each month remained the same. Which graph best illustrates the number of new houses bought each month in the city?



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

42. What type of memory loss is most common during the initial stage of Alzheimer’s disease?

- (A) Short term memory loss
- (B) Semantic memory loss
- (C) Episodic memory loss
- (D) Procedural memory loss

43. A recent study showed that when the visually challenged do algebra, the visual areas of their brain are activated. This indicates that:

- (A) Algebra can be used to activate dormant visual areas of the brain.
- (B) The visually-challenged understand algebra differently from people with regular vision.
- (C) Algebra cannot be done without visual processing.
- (D) The brain can rewire the visual cortex to do non-visual processing.

44. A neural network recently learned all the rules of chess, when provided data on different chess moves. It then improved its chess playing ability by playing against itself. Finally, it decisively beat Stockfish, a chess playing program with grandmaster rating. This whole process (i.e moving from no knowledge of chess to grandmaster-level knowledge) took only four hours. Which of the following is a valid interpretation of this finding?

- (A) Human beings can learn to play chess without learning the rules.
- (B) Complex rules can be learned implicitly.
- (C) Neural networks think like chess players.
- (D) Machines will learn all human rules soon.

45. A website article explains various kinds of skin disorders and how they can be treated. Which of the following affirms that the information provided on the website is reliable?

- (i) The website gets listed in the top five of your search engine.
- (ii) Sources of the data and references are credible.
- (iii) The English used in the website is error-free.
- (iv) The author of that particular article has done substantial work in the area of skin disorders.

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

46. Here is a quote: "I absolutely will not play a part of one who prescribes solutions. I hold that the role of the intellectual today is...not proposing solutions or prophesying, since by doing that one can only contribute to the determinate situations of power that must be criticised." - M. Foucault, quoted in Muller, J. (2000). Reclaiming Knowledge. London: Routledge.

What is the likeliest conclusion that follows from this quote?

- (A) One must weigh socio-political stances and be critical.
- (B) One must weigh the solutions before prophesying in any situation.
- (C) One needs to understand who is in power before proposing solutions.
- (D) One must offer solutions only when one is an intellectual.

47. A study collected test scores of students in a class and the average time they spent playing video games over a month. The following table shows the data:

No	Score (out of 40)	Time spent on playing games (hr)
1	40	0
2	25	15
3	15	30
4	39	2
5	35	4
6	27	15
7	20	18
8	10	23
9	5	40
10	18	35

What is the likeliest description of the relation between test scores and time spent on games as seen in the data?

- (A) No correlation.
 - (B) Chi correlation.
 - (C) Negative correlation.
 - (D) Positive correlation.
48. Polanyi said, “We can know more than we can tell.” In other words, what is expressed in words and language may not represent all that we know. What is NOT an implication of this statement?
- (A) We need not judge a student by what she can formalise.
 - (B) We may need to help students to create analogies and models.
 - (C) We can deduce that the student who talks knows a lot.
 - (D) We need to understand that language may not be enough to express what is known.

Read the paragraph and answer the questions 19 and 20:

Jack Welch explains that candor leads to winning for businesses by adding more ideas to the conversation, speeding up discussion and avoiding meaningless meetings. However, he acknowledges that in any society, people have been schooled to avoid speaking their minds. Nobody likes a person who speaks her/his mind. Kant argued that not speaking one’s mind is about self-interest but one who avoids candor may be lacking foresight. One may prevent alienating others by avoiding the temptation to be candid. In doing so, one may appease people momentarily but eventually destroy trust and contribute to erosion of society.

Adapted from: The Candor Effect In Winning by J. Welch S. Welch, published by HarperCollins (2009).

49. Which of the following does NOT apply to what is being said in the paragraph:
- (A) Being candid can contribute to discussions.

- (B) Not being open might be an outcome of socialisation.
- (C) Being candid may put off people.
- (D) Being candid is good in all situations.

50. Which of the following statements is true about the paragraph:
- (A) Welch is making a case for being open during discussions.
 - (B) Welch is discussing different opinions.
 - (C) Welch shows how to avoid anger and resentment.
 - (D) Welch is suggesting ways to avoid anger during discussions.

Biology

51. Hemophilia is a rare hereditary disorder in which blood does not clot due to the lack of sufficient blood clotting proteins. The affected individual suffers from blood loss over a prolonged period as the clotting process fails. X -linked recessive genes are responsible for this condition. Consider a situation where a hemophilia carrier female $X^H X^h$ marries a normal male $X^H Y$. What is the probability that a male child of this couple will have the disease?

- (A) 25 % (B) 50 % (C) 75 % (D) 100 %

52. A few types of behaviors and some examples are tabulated below.

<i>Behavior</i>	<i>Example</i>
1. Altruism	I. Infant cry
2. Imprinting	II. A turtle stops withdrawing its head into its shell after repeatedly being touched on the head
3. Instinct	III. Bonobos aid injured or handicapped bonobos
	IV. Incubator-hatched geese would follow the first suitable moving stimulus they saw

Choose the option that correctly matches the type of behavior (1 - 3) with the correct example (I - IV).

- (A) 1-I; 2-II; 3-IV
- (B) 1-III; 2-IV; 3-II
- (C) 1-III; 2-IV; 3-I
- (D) 1-IV; 2-III; 3-I

53. Differential centrifugation is a process where cell organelles or sub-cellular particles are separated from each other from a mixture with the help of repeated centrifugation at increasing speeds. It works on the basis of different sedimentation rates of these particles under centrifugal force. The cells are initially lysed or ruptured by mechanical or chemical process. The mixture is then subjected to centrifugation from low to high speed at specific

time intervals. The pellet collected each time after centrifugation has different intracellular particles depending on their size and rate of sedimentation.

If any animal tissue is subjected to differential centrifugation, which of the following sequences would correctly describe the separation from low to high speed?

- (A) Fragmented plasma membrane + Endoplasmic reticulum → Mitochondria, lysosomes and peroxisomes → Nuclei → Ribosomes
- (B) Nuclei → Mitochondria, lysosomes and peroxisomes → Fragmented plasma membrane + Endoplasmic reticulum → Ribosomes
- (C) Mitochondria, lysosomes and peroxisomes → Fragmented plasma membrane + Endoplasmic reticulum → Ribosomes → Nuclei
- (D) Fragmented plasma membrane + Endoplasmic reticulum → Ribosomes → Mitochondria, lysosomes and peroxisomes → Nuclei

54. Osmoregulation is an important aspect of excretion in all animals. It is necessary for maintaining optimum osmotic potential of body fluids. All metabolic activities may get affected if this balance is disturbed. In case of fresh water fishes, the surrounding water is more hypotonic than the body fluids. This ultimately affects the water intake and excretion pattern. Thus, fish in freshwater habitats:

- (A) take in large amounts of water and release hypotonic urine in large quantities.
- (B) have a very limited intake of water and excrete small amounts of hypotonic urine.
- (C) take in high amounts of water and excrete very less amount of hypertonic urine.
- (D) have less water but release large amounts of hypertonic urine.

55. The events occurring during photosynthesis in plants are listed (I - V) below. A few potted plants were kept in dark for one day. Which of the following events would NOT occur when the plants were in the dark?

- I. Reduction of carbon dioxide
- II. Releasing of oxygen
- III. Splitting of water molecule
- IV. Conversion of light energy into chemical energy
- V. Formation of carbohydrates

- (A) I, II and III (B) I, II and IV (C) II, III and IV (D) III, IV and V

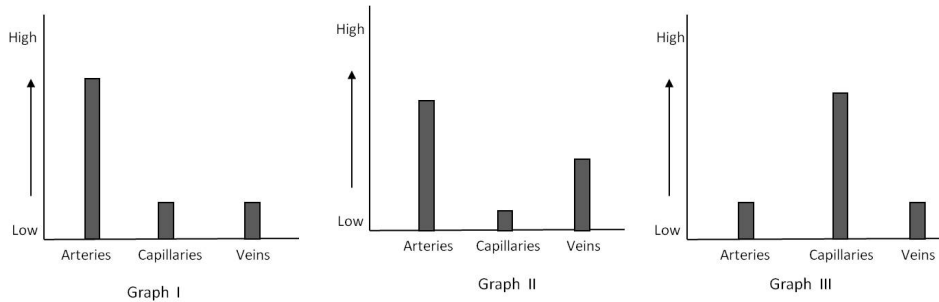
56. Earthworms tend to escape when introduced into NaCl solution. In an experimental study, the time of escape was recorded. Distilled water was used as a control for this experiment. Assign the independent variable (IV) and dependent variable (DV) in the experimental design.

- (A) Concentration of NaCl solution (IV) and Time (DV)
- (B) Time (IV) and Concentration of NaCl solution (DV)
- (C) Distilled water (IV) and Concentration of NaCl solution (DV)
- (D) Time (IV) and Distilled water (DV)

57. A selectively permeable sac containing starch solution was placed in a beaker of iodine solution. After some time, the bag was removed and it was observed that the starch inside had turned blue due to the presence of iodine solution. Which of the following processes was responsible for the iodine entering the sac?

- (A) Active transport (B) Endocytosis (C) Pinocytosis (D) Diffusion

58. Bar graphs for three parameters in various components of the human circulatory system are shown.



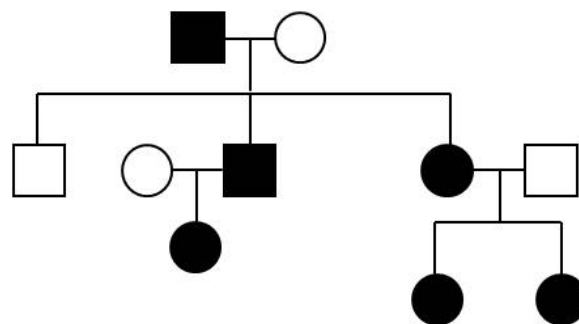
I, II and III respectively represent:

- (A) Total area, velocity and blood pressure
 (B) Blood pressure, velocity and total area
 (C) Velocity, blood pressure and total area
 (D) Blood pressure, total area and velocity

59. In a controlled experiment in a coastal ecosystem, a research group removed sea stars from the water body. Over time it was observed that an indigenous species experienced crowding due to an increase in a particular type of bivalve mollusc. The type of interaction between the *sea star-mollusc* and *mollusc-indigenous species* respectively are:

- (A) Parasitism and mutualism
 (B) Mutualism and parasitism
 (C) Commensalism and predation
 (D) Predation and competition

60. A pedigree depicting the transmission of hereditary juvenile glaucoma is shown below.

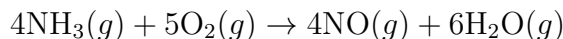


The transmission is:

- (A) X-linked recessive
- (B) X-linked dominant
- (C) Autosomal dominant
- (D) Y-linked

Chemistry

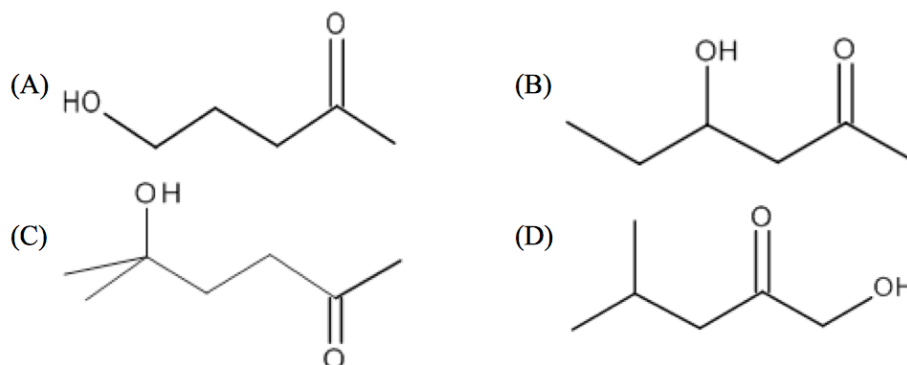
61. In the Ostwald process for nitric acid production, NH_3 is first converted to NO as per the reaction



If 3.25 kg of NH_3 (molar mass = 17 g/mol) is mixed with 3.50 kg of O_2 (molar mass = 32 g/mol), the amounts of NO (molar mass = 30 g/mol) formed and of excess reactant that remain if the reaction goes to completion are

- (A) 2.62 kg of NO and 1.76 kg of NH_3
 - (B) 4.10 kg of NO and 0.925 kg of O_2
 - (C) 4.10 kg of NO and 1.76 kg of O_2
 - (D) 4.10 kg of NO and 0.925 kg of NH_3
62. An aqueous sample contains the ions Ag^+ , Ba^{2+} , and Cu^{2+} . Aqueous 0.1 M solutions of NaCl , Na_2S , and Na_2SO_4 are available. If the goal is to precipitate each of the three cations out of the sample separately, the order in which these solutions should be added to the sample is
- (A) Na_2S , Na_2SO_4 , NaCl
 - (B) Na_2S , NaCl , Na_2SO_4
 - (C) Na_2SO_4 , Na_2S , NaCl
 - (D) NaCl , Na_2SO_4 , Na_2S
63. The nitrogen atoms in NH_3 , NH_2^- , and NH_4^+ are all surrounded by eight electrons. The correct arrangement of these three species in terms of decreasing H-N-H bond angle is
- (A) $\text{NH}_3 > \text{NH}_2^- > \text{NH}_4^+$
 - (B) $\text{NH}_4^+ > \text{NH}_2^- > \text{NH}_3$
 - (C) $\text{NH}_3 > \text{NH}_4^+ > \text{NH}_2^-$
 - (D) $\text{NH}_4^+ > \text{NH}_3 > \text{NH}_2^-$
64. When an aqueous solution of Na_2SO_4 with several drops of phenolphthalein added is electrolysed between *Pt* electrodes, the observation will be
- (A) The colorless solution turns pink at the anode but remains colorless at the cathode.
 - (B) The colorless solution turns pink at the cathode but remains colorless at the anode.
 - (C) The pink solution becomes colorless at the anode but remains pink at the cathode.
 - (D) The pink solution becomes colorless at the cathode but remains pink at the anode.

65. Of the following, the compound which can be the primary product of an aldol reaction is



66. A solid mixture **Z** was burned in an oxidizing flame. The ash thus, obtained when added to water made it alkaline. This observation indicates:

- (A) **Z** cannot be containing an acidic compound.
- (B) **Z** must be containing an alkaline compound.
- (C) **Z** must be containing a metal or a metal compound.
- (D) **Z** must be containing a water-soluble amine.

67. A student took 5 mL ethanol (molar mass 46 g/mol, density 0.78 g/mL) in a 250 mL round bottom flask at 25°C. He sealed it with air tight cap and heated the flask to 80°C. At this temperature, he could observe only 2 mL ethanol in the flask. If all the gases in flask behave as ideal gases, the pressure inside the flask now is

- (A) 7.08 atm (B) 5.90 atm (C) 1.076 atm (D) 1.059 atm

68. A chemist dipped Cu and Zn rods in a beaker containing 2M H₂SO₄. She tried to measure voltage across the rods. The correct observations would be:

- (A) this is a non-equilibrium system, hence voltage reading would be zero.
- (B) the voltage reading would be non-zero if the electrodes are not touching each other at any point.
- (C) the voltage reading would be zero irrespective of electrodes touching each other or not.
- (D) the voltage reading would be zero initially but would become non-zero after a few minutes of dipping.

69. A student extracted benzaldehyde from bitter almonds, checked for its purity and stored it in a stock bottle (half filled) in January. Three months later she took 2g of benzaldehyde from the stock bottle and checked for its purity through thin layer chromatography (TLC). She observed two spots in TLC. The two spots must be of:

- (A) benzaldehyde and benzoic acid
- (B) benzyl alcohol and benzoic acid
- (C) benzaldehyde and benzyl alcohol
- (D) benzene and benzoic acid

70. The boiling points of CH_3COCH_3 and $\text{CH}_3\text{COC}_2\text{H}_5$ are 56°C and 80.1°C , respectively. The higher boiling point of ethyl methyl ketone can be attributed to:
- I. dipole-dipole interactions.
 - II. van der Waals Forces.
 - III. hydrogen bonding.
- (A) I and II (B) I only (C) II only (D) I, II and III

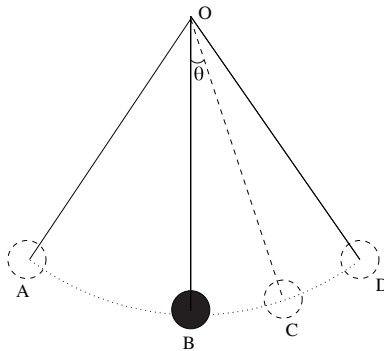
Mathematics

71. In how many different ways can a committee of at least 2 people be formed from a given set of 10 people?
- (A) ${}^{10}C_2$ (B) ${}^{10}C_2 \times 2^8$ (C) ${}^{10}C_2 - 1$ (D) $2^{10} - 11$
72. Let X be the set of all numbers from 1 to 100. Let
- $A = \{n \in X, n \text{ is divisible by } 2\}$
 - $B = \{n \in X, n \text{ is divisible by } 3\}$
 - $C = \{n \in X, n \text{ is divisible by } 4\}$
- Then the number of members in $A \cup B \cup C$ is
- (A) 55 (B) 64 (C) 67 (D) 80
73. The domain of definition of the real-valued function $\sqrt{\cos(x) - 1}$ is
- (A) \emptyset (B) $\{2n\pi, n \in I\}$ (C) \mathbb{R} (D) None of the above
74. If p and q are positive real numbers such that $p^2 + q^2 = 1$, then the maximum value of $p + q$ is
- (A) 2 (B) $\frac{1}{2}$ (C) $\sqrt{2}$ (D) $\frac{1}{\sqrt{2}}$
75. What is the slope of a line perpendicular to the line joining (1, 1) and (2, 2)?
- (A) -1 (B) 0 (C) 1 (D) Not enough information
76. Consider a triangle with sides of length 5, 5 and 8. What is the sine of the smallest angle of the triangle?
- (A) $\frac{5}{8}$ (B) $\frac{8}{5}$ (C) $\frac{4}{5}$ (D) $\frac{3}{5}$
77. Let S be a disc of radius r ($r > 0$) in the complex plane. Which of the following must be true?
- (A) For any point z in S , $|z| \leq r$
 - (B) There will be a point $z = x + iy$ in S such that x and y are both rational numbers
 - (C) There will be a point $z = x + iy$ in S such that x and y are both integers
 - (D) If a point $z = x + iy$ belongs to S , then its complex conjugate will also belong to S

78. Consider the sequence $\{s_n\}$ of irrational numbers defined as follows: $s_0 = \pi$, s_1 is the mid point of π and 4, and for any $i > 1$, s_i is the midpoint s_{i-1} and 4. Then which of the following is true for $\{s_n\}$?
- (A) $\lim_{n \rightarrow \infty} s_n = \alpha$ for some irrational number α less than 4.
 (B) $\lim_{n \rightarrow \infty} s_n = 4$
 (C) $\lim_{n \rightarrow \infty} s_n = \infty$
 (D) $\lim_{n \rightarrow \infty} s_n$ does not exist
79. Let A be a fixed point on a circle ω . Let P and Q be arbitrary points on ω . The locus of the centroids of all triangles PAQ as P and Q vary on ω such that $\angle PAQ = 90^\circ$ is a
- (A) point (B) straight line (C) circle (D) hyperbola
80. Suppose XY is a given line segment in the plane and T is a scalene triangle. The number of points Z in the plane such that the triangle with vertices X, Y, Z (in some order) is similar to triangle T is
- (A) 4 (B) 6 (C) 12 (D) 24

Physics

81. Consider a simple pendulum oscillating around the mean position. Let m be the mass of the pendulum bob and θ is the angle of the string from the mean position at any instant (g is the acceleration due to gravity). Through out the motion of the pendulum, the tension on the string is



- (A) a non-zero constant, T .
 (B) zero.
 (C) non-zero and varies.
 (D) equal to $mg \cos(\theta)$ at every instant.
82. Consider a Carnot engine of efficiency 60%. If the low temperature reservoir of the engine is at 300 K, the high temperature reservoir is at
- (A) 600 K (B) 650 K (C) 700 K (D) 750 K
83. A ball is thrown vertically upward. At the point of its maximum height which of the following is zero?

- (A) Velocity of ball only.
- (B) Acceleration of the ball only.
- (C) Both velocity and acceleration of the ball.
- (D) Net force on the ball.

84. Consider a square of side a . Initially there lies positive charges of magnitude q fixed at 2 adjacent vertices of the square. Let the resulting electric field due to these 2 charges at centre of the square (the point where diagonals meet) be E . Now 2 more charges of the same magnitude q are fixed at the remaining 2 vertices. The net electric field at the centre due all the four charges is

- (A) 0 (B) $2E$ (C) $4E$ (D) $16E$

85. Dimensional formula of Planck's constant h is

- (A) ML^2T^{-3}
- (B) ML^2T^{-1}
- (C) MLT^{-1}
- (D) none of the above. It is a constant and therefore dimensionless.

86. The escape speed at the surface of Jupiter is approximately:

[Mass of Jupiter = 1.9×10^{27} kg; Mass of Earth = 5.98×10^{24} kg; Radius of Jupiter = 7.15×10^7 m; Radius of Earth = 6.37×10^6 m.]

- (A) equal to that of Earth.
- (B) twice that of Earth.
- (C) five times than that of Earth.
- (D) ten times that of Earth.

87. Which of the following statements is **NOT** true?

- (A) One of the reasons why Tides occur is because the Earth is **not** a point object.
- (B) We see only one side of Moon because its orbital period around Earth and the rotation period of Earth is same.
- (C) Tidal force is the cause for a natural satellite to break at a particular distance from its parent body.
- (D) High tide occurs simultaneously on diametrically opposite sides of the Earth.

88. A 6W, 12V bulb consumes 6W when connected across a 12V supply. What is the resistance of the filament of the bulb?

Next, two bulbs of the same specification as above are connected in parallel across the 12V supply. How much power is consumed in this case?

- (A) $24\Omega, 12W$ (B) $24\Omega, 6W$ (C) $6\Omega, 12W$ (D) $0.5\Omega, 6W$

89. The rate of flow of liquid through a tube depends on the pressure difference between the ends of the tube (ΔP), the dimensions of the tube (radius R and length L) and the coefficient of viscosity (η) of the fluid. The rate of flow in this case is given as

$$\text{Rate of flow} = \frac{\Delta P(\pi R^4)}{8L\eta}$$

According to this law, the most effective way to increase the rate of flow of transfusing fluid into a patient is to

- (A) increase the pressure at the level of the arm by raising the height of the bag.
- (B) dissolve the fluid in less viscous material.
- (C) increase the radius of the needle.
- (D) decrease the length of the tubing from the bag to the needle.

90. A digital voltmeter measures

- (A) peak value.
- (B) peak-to-peak value.
- (C) average value.
- (D) rms value.

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2019

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.

Roll Number:

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(Do not write any thing below this line)

91	92	93	Total
15	15	20	50

