

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2018

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 19 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. Pratibha gave one-fourth of her money to Jyoti and Jyoti in turn gave one-third of what she got from Pratibha to Jagruti. If Pratibha now has Rs. 54 with her, how much money did Jagruti get?
(A) Rs. 4 (B) Rs. 4.50 (C) Rs. 6 (D) Rs. 18

2. The number of students in each section of a school is 24. After admitting the new students, three new sections were started. Now the total number of sections is 16 and there are 21 students in each section. The number of new students admitted is
(A) 14 (B) 24 (C) 48 (D) 114

3. The cost price of 12 articles is equal to the selling price of 10 articles. The profit percentage is
(A) 16.67 % (B) 20 % (C) 25 % (D) 33.33 %

4. The salaries of Asmita, Bina and Chetna are in the ratio 2:3:5. If the increments of 15 %, 10 % and 20 % are allowed respectively in their salaries, then what will be new ratio of their salaries?
(A) 3:3:10 (B) 15:10:20 (C) 23:32:54 (D) 23:33:60

5. A man in a train notices that he can count 20 telephone posts in one minute. If the telephone posts are known to be 50 metres apart, then at what speed is the train travelling?
(A) 63 km/hr (B) 60 km/hr (C) 57 km/hr (D) 54 km/hr

6. There are three coins in a box. Two of them are normal coins and the third one has heads on both the sides. If you pick a coin at random and toss it, what is the probability that you get heads?
(A) $\frac{1}{3}$ (B) $\frac{1}{2}$ (C) $\frac{2}{3}$ (D) $\frac{3}{4}$

7. The areas of two circles are 792 meters and 352 meters. Find the ratio between the circumference of the larger and the smaller circles.
(A) $\frac{3}{2}$ (B) $\frac{9}{4}$ (C) $\frac{81}{16}$ (D) Need to know the value of pi to find the ratio.

8. A man travels one-third of the distance from one village to another at 8 km per hour, one-third at 9 km per hour and the rest at 10 km per hour. If he had travelled half of the distance at 8 km per hour and the rest at 10 km per hour then he would have travelled for half a minute more. What is the distance between the two villages?
(A) 12 km (B) 18 km (C) 24 km (D) This cannot happen. Both would take the same time.

9. Last digit of 2^{50} is
(A) 2 (B) 4 (C) 6 (D) 8
10. The perimeter of a rectangular plot is $30\sqrt{3}$ m. If the length of its diagonal is $5\sqrt{6}$ m, what is the area of the rectangle in square meter?
(A) $150\sqrt{6}$ (B) $150\sqrt{3}$ (C) 262.5 (D) 127.5
11. If we consider that a normal human head scalp has 2 hairs/ square mm, the total number of hairs on a human head scalp is approximately of the order of
(A) 10000 (B) 100000 (C) 1000000 (D) 10000000
12. Thirty five percent of students in a class come to school by public transport. Another twenty five percent students use the school bus facility. Forty percent of the remaining students come to school on their bicycles. What percentage of students in this class do not use public transport, the school bus or bicycles to come to school?
(A) 0% (B) 20% (C) 24% (D) 40%
13. The value of $2^9 \times 5^7 =$
(A) 4×10^7 (B) $(2 \times 5)^{16}$ (C) $(2 \times 5)^{63}$ (D) 7^{16}
14. Sara works more hours than her friend Aysha. As a result Sara's monthly income is $\frac{5}{4}$ th of Aysha's income. However, since Sara takes care of her family, her monthly expense is also more and is $\frac{4}{3}$ rd of Aysha's monthly expense. If both are able to save Rs. 12000 per month, what is the monthly income of Sara and Aysha together?
(A) Rs 38000 (B) Rs 48000 (C) Rs 98000 (D) Rs 108000
15. Look carefully for the pattern in the sequence below and then choose which pair of numbers comes next?
30, 27, 1, 25, 22, 1, 20, 17
(A) 14, 1 (B) 15, 1 (C) 1, 14 (D) 1, 15

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

When drawing scientists, U.S. children now depict female scientists more often than ever, according to new Northwestern University research, which analysed five decades of "Draw-A-Scientist" studies conducted since the 1960s. This change suggests that children's stereotypes linking science with men have weakened over time, consistent with more women becoming scientists and children's media depicting more female scientists on television shows, magazines and other media. "Given this change in stereotypes, girls in recent years might now develop interests in science more freely than before," said the study's lead author David Miller. "Prior studies have suggested that these gender-science stereotypes could shape girls' interests in science-related activities and careers."

The study is the first systematic, quantitative review of the "Draw-A-Scientist" literature and combined results from 78 U.S. studies, including more than 20,000 children in kindergarten through 12th grade. In the first landmark study, conducted between 1966 and 1977, less than one percent of nearly 5,000 children drew an image resembling a woman when asked to draw

a scientist. Their artwork almost exclusively depicted men working inside with laboratory equipment, often with lab coats, glasses and facial hair. But in later studies (1985 to 2016), 28 percent of children drew a female scientist, on average. In addition, both girls and boys drew female scientists more often over time, though girls overall drew female scientists much more often than boys.

“Our results suggest that children’s stereotypes change as women’s and men’s roles change in society,” said the study’s co-author Alice Eagly. “Children still draw more male than female scientists in recent studies, but that is expected because women remain a minority in several science fields.” The researchers also studied how children form stereotypes about scientists across child development. The results suggested that children did not associate science with men in early grade school. Around age 5, they drew roughly equal percentages of male and female scientists. During elementary and middle school, the tendency to draw male scientists increased strongly with age. Older children were also more likely to draw scientists with lab coats and glasses, suggesting that children learn other stereotypes as they mature.

Adapted from: Anyaso, H. H. (2018). Retrieved from Northwestern University News <https://news.northwestern.edu/stories/2018/march/draw-a-scientist/>

16. Which of the following statements most appropriately summarizes the above passage?
- (A) Since the 1960s, more US children link science with men.
 - (B) Since the 1960s, more US children link science with women.
 - (C) Since the 1960s, US children link science with men more than women.
 - (D) Since the 1960s, US children link science with women more than men.
17. The “Draw-A-Scientist” literature indicates which of the following? (i) Initially, less than 1% students out of nearly 5,000 drew a female scientist. (ii) In the later studies, 1400 out of nearly 5000 of the students drew a female scientist. (iii) Over time, both girls and boys drew female scientists more often.
- (A) (i) and (ii)
 - (B) (i), (ii) and (iii)
 - (C) (i) and (iii)
 - (D) (iii) only.
18. In the sentence “The researchers also studied how children form stereotypes about scientists...”, the word ‘stereotypes’ can be best replaced by
- (A) assumptions.
 - (B) unconventional ideas.
 - (C) typologies.
 - (D) mockeries.
19. Which of the following does the passage clearly **not** say?
- (A) Boys drew a female scientist less often than girls.
 - (B) Women’s and men’s roles in society affects children’s idea of a scientist.
 - (C) Children often associate lab-coats and glasses with scientists.
 - (D) Girls drew more female than male scientists.
20. According to the passage, which of the following associations is observed?
- (A) Early grade school → Association of science with men
 - (B) Age 5 → Higher tendency to draw a male scientist than a female scientist
 - (C) Middle school → Lesser tendency to draw a female scientist than a male scientist
 - (D) Older students → Students drew equal percentage of male and female scientists

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

Researchers at Stanford’s Graduate School of Education have spent more than a year evaluating how well students across the country can evaluate online sources of information. Middle school, high school and college students in 12 states were asked to evaluate the information presented in tweets, comments and articles. More than 7,800 student responses were collected. In exercise after exercise, the researchers were “shocked” by how many students failed to effectively evaluate the credibility of information presented to them. The students displayed a “stunning and dismaying consistency” in their responses, the researchers wrote, getting duped again and again. They weren’t looking for high-level analysis of data but just a “reasonable bar” of, for instance, telling fake accounts from real ones, activist groups from neutral sources and advertisements from articles.

More than 80 percent of middle schoolers believed that ‘sponsored content’ was a real news story. A professional appearance and polished “About” section could easily persuade students that a site was neutral and authoritative, and young people tended to credulously accept information as presented even without supporting evidence or citations. Most middle school students could not tell native advertisements from articles. Many high school students couldn’t tell a real and fake news source apart on Facebook. Most high school students accepted photographs as presented, without verifying them. Moreover, most Stanford students couldn’t identify the difference between a mainstream and a fringe source.

The project began before the recent uproar over the prevalence of fake news online. But its relevance is immediately clear. The solution, the authors write, is to teach students - or, really, all Internet users - to read like fact checkers. That means not just reading “vertically,” on a single page or source, but looking for other sources - as well as not taking “About” pages as evidence of neutrality, and not assuming Google ranks results by reliability.

“The kinds of duties that used to be the responsibility of editors, of librarians now fall on the shoulders of anyone who uses a screen to become informed about the world,” the lead author says. “And so the response is not to take away these rights from ordinary citizens but to teach them how to thoughtfully engage in information seeking and evaluating in a cacophonous democracy.”

Adapted from: Domonoske, C. (2016). Students have ‘dismaying’ inability to tell fake news from real, study finds. Retrieved from [https://www.npr.org/sections/thetwo-way/2016/11/23/503129818/study-finds-students-have-dismaying-inability-to-tell-fake-news-from-real?](https://www.npr.org/sections/thetwo-way/2016/11/23/503129818/study-finds-students-have-dismaying-inability-to-tell-fake-news-from-real)

21. Approximately, how many middle schoolers believed that ‘sponsored content’ was a real news story?
(A) 6250 students (B) 2100 students (C) 1560 students (D) Can’t say
22. Which of the following describes most closely the word “cacophonous”, as used in the passage above?
(A) Screechy (B) Tuneless (C) Discordant (D) Thunderous
23. Which of the following is **not** suggested by the authors in the above passage?
(A) Look for multiple sources.
(B) Only read the ‘About’ section of the website.
(C) Verify the sources of information.
(D) Seek supporting evidences.
24. Which of the following is most likely to be information from a mainstream source?

- (A) An article on “In-vitro fertilizations” by owner of a fertility clinic.
- (B) An article on “In-vitro fertilizations” by a practicing gynaecologist, in a peer reviewed journal.
- (C) An article on “In-vitro fertilizations” by a pharmaceutical company which deals with IVF.
- (D) All of the above.

25. The author hopes that internet users be:

- (A) Vertical readers
- (B) Lateral readers
- (C) Both A and B
- (D) Neither A nor B

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

Microscopes allow scientists to look at structures that cannot be seen with the naked eye - but for micromolecular structures, light beams cannot be used because of their long wavelengths. Instead, beams of electrons may be used with a technique known as transmission electron microscopy (TEM). Scientists can also employ a method known as x-ray crystallography in which x-rays are scattered as they pass through samples, creating patterns that can be analyzed to reveal the structure of molecules. X-ray crystallography can only be applied for biomolecules forming ordered structures, which many fail to do. On the other hand, TEM involves the use of vacuum which leads to drying out and collapsing of the biological samples. These problems were solved by Jacques Dubochet, Joachim Frank and Richard Henderson, a trio of scientists who shared the Nobel prize for chemistry in 2017. They were recognized for their work on development of a technique known as “Cryo-Electron Microscopy” that has allowed scientists to study biomolecules in their native form at a much higher resolution.

Henderson and his team used a glucose solution to prevent molecules from drying out and used a weak beam microscopy technique for imaging. The images were taken from many angles and mathematical approaches were used to build up a 3D image of a protein neatly organised within a biological membrane. Meanwhile, Frank developed an ingenious image processing technique to process TEM data and build up images of biological molecules as they are in solution, where they are oriented in different directions. Henderson’s technique did not work for water-soluble biological molecules. The freezing of samples resulted in the formation of ice crystals which caused damage to the molecular structure and made the resulting images challenging to interpret. Dubochet came up with a sophisticated approach to prevent this problem in aqueous solutions. Dubochet’s solution was to rapidly cool samples at such speed that the water molecules did not have time to adopt a regular structure. Rather, they were left pointing every which way, resulting in a glass within which biomolecules were frozen in time - in their natural shape. The technique of cryo-TEM has really opened up the molecular world of the cell to direct observation.

Adapted from: Davis, N. (2017, October). What is cryo-electron microscopy, the Nobel prize-winning technique? The Guardian. Retrieved from <https://www.theguardian.com/science/2017/oct/04/what-is-cryo-electron-microscopy-the-chemistry-nobel-prize-winning-technique>

26. Electron beams may be used to visualise micro molecular structures but not light beams because

- (A) the wavelengths of electron beams are shorter than that of light beams.
- (B) the wavelengths of light beams are shorter than that of electron beams.
- (C) the wavelengths of electron beams are longer than that of light beams.
- (D) the wavelengths of light beams vary and hence cannot be used.

- 27.** Which of the following statements is true?
- (A) All biomolecules form disordered structures and hence cannot be studied by X-ray crystallography.
 - (B) Most biomolecules form an ordered structure and can be studied by X-ray crystallography.
 - (C) Biomolecules rarely form ordered structures and hence cannot be studied by X-ray crystallography.
 - (D) X-Ray crystallography may be used for some biomolecules which form an ordered structure.
- 28.** The problem of drying of the biological sample was solved by
- (A) using glucose solution only.
 - (B) using glucose solution and a weak beam electron microscopy.
 - (C) using glucose solution combined with a weak electron beam and mathematical approaches for 3D image generation.
 - (D) using weak beam electron microscopy only.
- 29.** The 3D structure of the biomolecules was visualised by:
- (i) using mathematical approaches to build a 3D image. (ii) using a powerful camera to capture 3D image of the biomolecule as viewed under the electron microscope. (iii) taking various images from different angles.
- (A) i and ii (B) i and iii (C) ii and iii (D) ii only
- 30.** The cooling of the aqueous solutions rapidly to low temperature aided in
- (A) preserving the natural shape of the biomolecule by freezing without the formation of ice crystals.
 - (B) freezing of the samples at a fast rate leading to a regular structure of the solvent.
 - (C) formation of a regular structure of the solvent and freezing the biomolecule in the native state.
 - (D) freezing to form a glass like structure.

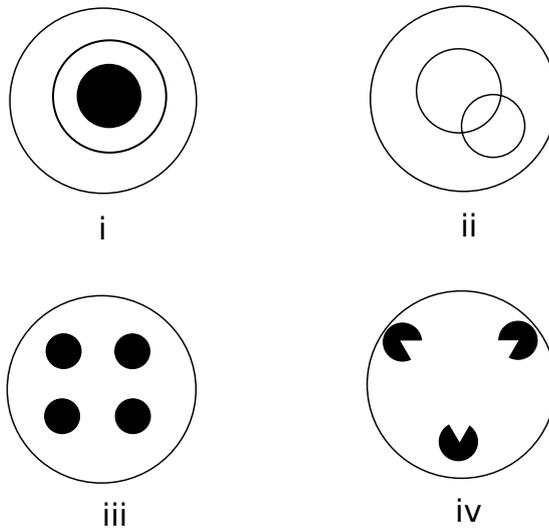
Social and Cognitive sciences and Education

- 31.** In a community of fishermen, every fisherman knows that excessive fishing would eventually lead to depletion of fish stocks. If all the fishermen could agree to fish at sustainable levels then the fish stocks could last forever. However, if one fisherman starts overfishing, then eventually the fish stocks would run out. When this happens, the others might as well overfish to get as much as possible before the stocks run out. This behaviour may be best described as:
- (A) A Prisoner's Dilemma (B) Dominant Behaviour (C) Tragedy of Commons (D) Both A and C
- 32.** A researcher in a public university develops a drug against multidrug resistant tuberculosis. The researcher collaborates with a pharmaceutical company, which pays a huge sum to the researcher for it. According to Merton, this act is a breach of which value in science?
- (A) Universalism (B) Disinterestedness (C) Organized Scepticism (D) Communalism

- 33.** Consumption of coffee has been linked to fat burn in humans. However, reports suggest that the fat burning effect of coffee may not work for all individuals in a population. There is increasing scientific evidence for both sides of the argument. A journalist, who has a personal liking for coffee and believes in the fat burning attributes of the drink, publishes a story supporting the claim by referring to only those scientific studies which favour the claim. This is an example of:
- (A) Confirmation Bias (B) Favouritism (C) Anchoring Effect (D) Ambiguity Effect
- 34.** A research scholar plans to probe the effect of epistemological beliefs on the teaching style of college teachers in Mumbai. The researcher submits a proposal with a statement: ‘Teachers teach the way they were taught’. This could be a:
- (A) Research question (B) Theory (C) Hypothesis (D) Law
- 35.** Imagine that you are participating in a debate on, “Attendance should be mandatory in higher education.” Assuming that you are against the motion, which of the following will not support your argument?
- (A) The quality of teaching should be the motivation to attend the class rather than the rules.
 (B) The students pay fees, so a record of the attendance should be kept.
 (C) Physical presence in the class does not guarantee mental attendance.
 (D) Students are adults and should have the freedom to learn in the way that suits them best.
- 36.** Pick the odd-one-out in the context of educational research methodology.
- (A) Reliability (B) Validity (C) Relativity (D) Generalizability
- 37.** Learning in operant conditioning is considered to be the acquisition of new behaviors based on their associations with consequences. Schedules of reinforcement are therefore an important component of the learning process and in the real-world behaviors are generally not reinforced each and every time they occur. Gambling and lottery games are good examples of which of the following schedules of reinforcement?
- (A) Fixed interval (B) Fixed ratio (C) Variable interval (D) Variable ratio
- 38.** In India, the Charity model, Bio-Centric Model, Functional Model and Human Rights Model depict the shifting historical progression of models in the context of:
- (A) Gender and Education (B) Disability and Education (C) Minority Groups and Education
 (D) Linguistic Groups and Education
- 39.** Consider this example: A child is learning to walk. First, a parent holds the child up. Her feet barely touch the floor as she mimics walking. Slowly, the child is allowed to support more and more of her own weight. Next, she might support herself by holding on to an object like a coffee table while her parents watch. Finally, the child is ready to take steps, though her parent’s hand might still be just inches away. Soon enough, the child is walking - and running - on her own. This example can be considered an analogy to:
- (A) Constructivism (B) Cooperative Learning (C) Instructional Scaffolding (D) Inquiry-Guided Learning
- 40.** Generally, the effectiveness of cooperative learning is attributed to

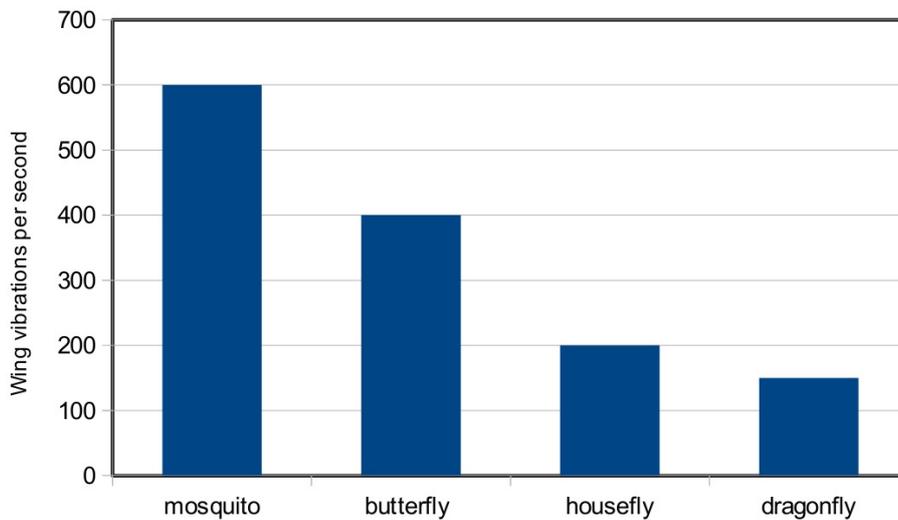
- (A) homogeneous grouping. (B) heterogeneous grouping. (C) non-random grouping.
 (D) self-selected grouping.

41. Which of the following images depicts the Gestalt principle of closure?



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

42. Based on the following graph which of the given options is correct?



- (A) The number of wing vibrations of insects can be compared based on the graph.
 (B) The number of wing vibrations of insects depends on the size of the insect.
 (C) Both A and B
 (D) Neither A nor B

43. A recent report made a conclusive statement: “Most Indian 14-18-year-olds in rural areas are reading at class two level”. Such a statement can be made after a study using which kind of research methodology ?

(A) Survey (B) Phenomenography (C) Ethnography (D) Case Study

44. A hospital wanted to test the effect of a certain antibiotic on 10 patients with fever. Five of them were administered the antibiotic and the other five were given a placebo. The body temperatures were considered to be a measure of finding the effectiveness of the treatment. Determine the independent and dependent measures from the following sequence:

	Independent Measures	Dependent Measures
i	Antibiotic and Placebo	Body temperature
ii	Body temperature	Antibiotic and Placebo
iii	Antibiotic	Placebo
iv	Antibiotic	Body temperature

(A) i (B) ii (C) iii (D) iv

45. Annual Status of Education Report (ASER) evaluates which of the following elements of education?

(A) Children's learning outcomes (B) Children's enrolment and basic learning (C) Children's scientific and mathematical literacy (D) Children's creativity

46. The term "sociological imagination" was coined by the American sociologist C. Wright Mills in 1959 to describe the type of insight offered by the discipline of sociology. The term is used in introductory textbooks of sociology to explain the nature of sociology and its relevance in daily life. Which of the following notions would be useful to explain the term?

- (A) Sociologists make the familiar strange.
(B) Sociologists connect personal troubles to public issues.
(C) Sociologists have multiple points of view.
(D) All of the above.

47. Many people think that sociology presents information that is obvious or commonsensical. Sociology differs from common sense in that

- (A) it focuses on the researchers' own experiences.
(B) it makes little distinction between the way the world is and the way it ought to be.
(C) it is statistical.
(D) its knowledge is accumulated from many different research contexts.

48. Amina's favourable attitude towards death penalty began to change when she was asked to offer arguments opposing it in a public speaking class. Her attitude adjustment is best explained by which theory?

(A) Cognitive Dissonance (B) Schachter's Two Factor Theory (C) Opponent Process Theory (D) Social Exchange Theory

49. When 12-year-old Devansh saw an old woman lying on the sidewalk in discomfort, he prepared himself to offer help. However, when he noticed several adults walking past the woman, he

concluded that the woman did not need any help. His reaction most clearly illustrates which social psychology term?

- (A) Fundamental Attribution Error (B) Door-in-the Face Phenomenon (C) Exposure Effect
(D) Bystander Effect

50. The term “banking model” was first used by Paulo Freire in his highly influential book *Pedagogy of the Oppressed*. The term refers to

- (A) teaching as transmission. (B) economics education. (C) problem-based learning.
(D) constructivism.

Biology

51. A few cellular features of organisms P, Q and R are listed in the table below. Presence of a feature is indicated by ‘1’ while absence is indicated by ‘0’.

Organism	Organism P	Organism Q	Organism R
Cell Wall	1	0	1
Linear DNA	1	1	0
Nucleus	1	1	0
Membrane bound organelles	1	1	0

Organisms P, Q and R respectively represent:

- (A) *E. coli*, fruitfly and onion
(B) Onion, fruitfly and *E. coli*
(C) Fruitfly, onion and *E. coli*
(D) Onion, *E. coli* and fruitfly

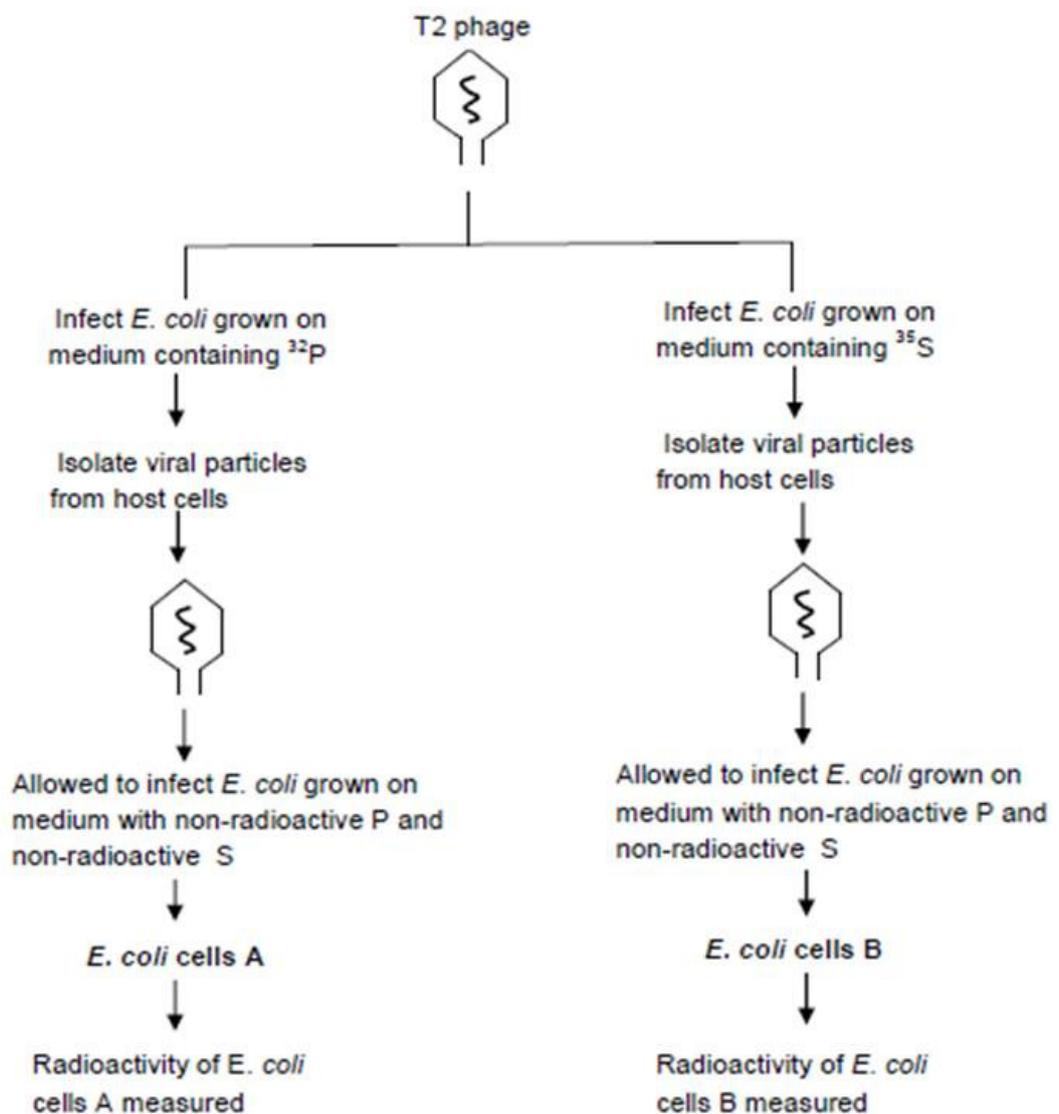
52. In an experiment, 1 mL of catalase solution was added to hydrogen peroxide solution at different pH values while all other conditions were kept constant and the time taken to collect 10mL of oxygen was measured. The results obtained are tabulated below.

pH of solution	Time taken to collect gas (min)
4.0	20.0
5.0	12.5
6.0	10.0
7.0	13.0
8.0	17.4

Which of the following conclusions can be drawn from the experiment?

- (A) The optimum pH for catalase activity is 4.0.
(B) Catalase is only active at pH 6.0.
(C) pH 6.0 is the optimum pH for catalase activity.
(D) Hydrogen peroxide is inactive at pH 4.0 and 8.0.

53. A blood typing experiment was being carried out using the blood of a person with the blood group 'O' Rh positive. Which of the following results could be expected in this situation?
- (A) The blood would show agglutination with anti-A antibodies only.
 - (B) The blood would show agglutination with anti-B antibodies only.
 - (C) The blood would show agglutination with both anti-A and anti-B antibodies.
 - (D) The blood would not show agglutination with either anti-A or anti-B antibodies.
54. In the famous Hershey and Chase experiment, T2-phage particles were allowed to initially infect *E. coli* cells that were grown on medium containing radioactive isotopes of either sulphur (^{35}S) or phosphorus (^{32}P). An outline of the experiment is depicted below.



What would be the expected outcome of this experiment?

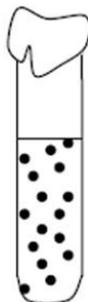
- (A) Cells A would show radioactivity but cells B would not.

- (B) Cells B would show radioactivity but cells A would not.
- (C) Cells A as well as B both would show radioactivity.
- (D) Both cells A and B would not show radioactivity.

55. The Koala bear is an arboreal herbivorous animal native to Australia. The digestive tract of this animal has a long cecum (almost 2 m) which is a unique feature. In general, cecum is the pouch-like portion present at the end of small intestine and the beginning of large intestine. The function of the elongated cecum in Koala bear most likely is:

- (A) The cecum acts merely as an extra storage space for food in case of the Koala since it requires more time for digestion due to slower metabolic rate as compared to other animals of equivalent size.
- (B) Being voracious eaters, Koalas need a longer digestive tract which provides a higher surface area for the continuous digestion process.
- (C) The cecum works as a fermentation chamber for rough herbaceous diet of Koala.
- (D) The cecum acts as a secretory gland to secrete digestive juices required for digestion of the fibrous leafy food.

56. The distribution of bacteria grown in an undisturbed tube containing culture medium is shown below. The organism most likely would be:

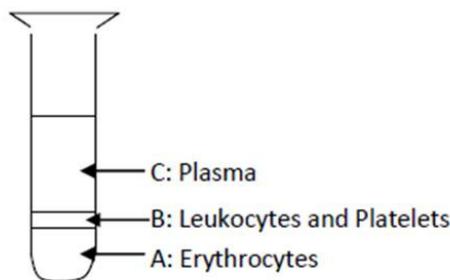


- (A) A facultative aerobe. (B) An obligate aerobe. (C) An obligate anaerobe. (D) Microaerophilic.

57. An ocular micrometer is used for measuring the size of microscopic objects. Seema collected water sample from a lake and observed a small drop using the 10X objective lens. She used an eyepiece with 5X power which was fitted with a micrometer. She found euglena in her water sample with the length measuring 14 divisions of the micrometer. The least count of the micrometer scale was 5 μm . The actual length of the euglena cell must be:

- (A) 0.0014 mm (B) 0.0046 mm (C) 0.07 mm (D) 3.5 mm

58. A student carried out differential centrifugation to separate the constituents of human blood. She obtained the following results. She was interested in extraction of genomic DNA from these separated fractions. Which fraction/s should she use to get optimum results?



- (A) Only fraction A (B) Only fraction B (C) Only fraction C (D) Either fraction B or C

59. Two species of the meadowlark birds namely the eastern meadowlark (*Sturnella magna*) and the western meadowlark (*Sturnella neglecta*) are difficult to distinguish based on their appearance alone. However, the whistle-like call of the eastern meadowlark is easily distinguishable from the flute-like call of the western meadowlark. This difference prevents members of both populations from mating with each other. This is an example of:

- (A) Pre-zygotic isolation (B) Temporal isolation (C) Mechanical isolation (D) Post-zygotic barrier

60. Which of the following statements regarding diffusion is true?

- (A) Steeper the concentration gradient, slower is the rate of diffusion.
 (B) Larger a cell, greater is the surface area in relation to its volume. Hence greater is the rate of diffusion.
 (C) Polar molecules such as some amino acids diffuse easily across cell membranes.
 (D) The rate of diffusion decreases rapidly with distance.

Chemistry

61. In a solution obtained by mixing 150 mL of a 1.50 M *NaCl* solution with 250 mL of a 0.750 M *MgCl₂* solution, the concentration of chloride ions is

- (A) 0.563 M (B) 1.03 M (C) 1.50 M (D) 2.25 M

62. Baking powders generally contain monocalcium phosphate (*CaHPO₄*), which serves as an acid. Aqueous solution of *CaHPO₄* show presence of various ions. In this solution, the conjugate base of the *HPO₄²⁻* ion is

- (A) *Ca²⁺* (B) *OH⁻* (C) *H₂PO₄⁻* (D) *PO₄³⁻*

63. A student determines the acetic acid concentration of a vinegar sample by titrating a known volume of vinegar with standardized sodium hydroxide solution using phenolphthalein as an indicator. Which of the following possible errors in the analysis will give lower concentration of acetic acid than actual concentration in vinegar?

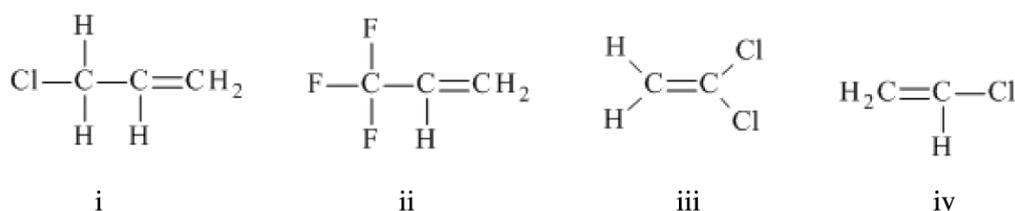
- (A) The *NaOH* solution is kept for a prolonged period after standardization and absorbs carbon dioxide from the air before it is used for titration.

- (B) Some of the vinegar is spilled when being transferred to the titration flask.
 (C) The endpoint is recorded when the solution turns dark pink instead of faint pink.
 (D) The vinegar is diluted with distilled water in the titration flask before the $NaOH$ solution is added.

64. Generally for an ionic compound, the size of the cation is usually smaller than the anion. There are some exceptions usually to every rule. From the following compounds identify the compound where the cation is larger than the anion.

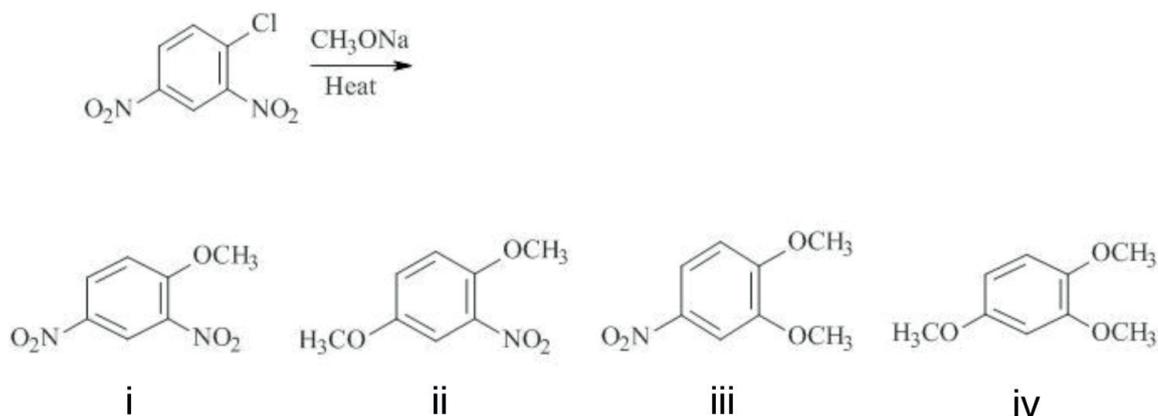
- (A) Magnesium Iodide (B) Lithium Chloride (C) Calcium Bromide (D) Cesium Fluoride

65. Among the following, the compound that is **most** reactive towards electrophilic addition reactions is:



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

66. The major product of the following reaction is:



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

67. The combination that on dissolving in water cannot give a buffer solution is:

- (A) HNO_2 and $NaNO_2$ (B) HCN and $NaCN$ (C) NH_3 and $(NH_4)_2SO_4$ (D) $HClO_4$ and $NaClO_4$

68. If 1 g of hydrogen gas and 1 g of oxygen gas are mixed together in a closed container and ignited, then (atomic masses: $H = 1 \text{ g/mol}$, and $O = 16 \text{ g/mol}$)

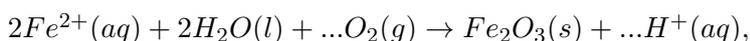
- (A) 2 g of water will be produced.

- (B) no water will be produced because H_2 and O_2 are not in correct mass ratio.
 (C) 1.125 g of water will be produced.
 (D) 1.50 g of water will be produced because always half moles of O_2 react with one mole of H_2 to yield water.

69. When lime juice is added to wood ash, brisk effervescence is observed. Such effervescence could indicate presence of which of the following in ash?

- (A) K_2CO_3 (B) KCl (C) Na_2SO_4 (D) $NaNO_3$

70. For the chemical reaction representing oxidation of Fe^{2+} in an aqueous solution when exposed to air:



the correct statement is:

- (A) The reaction will be faster in presence of acids.
 (B) The pH of the Fe^{2+} solution in contact with air will decrease over time.
 (C) The stoichiometric coefficients of O_2 and H^+ in the equation will be 1 and 2 respectively.
 (D) The stoichiometric coefficients of O_2 and H^+ in the equation will be 1 and 4 respectively.

Mathematics

71. If α and β are roots of the quadratic polynomial, $x^2 + 5x - 3$, then the value of $\alpha^3 + \beta^3$ is

- (A) 170 (B) 65 (C) -65 (D) -170

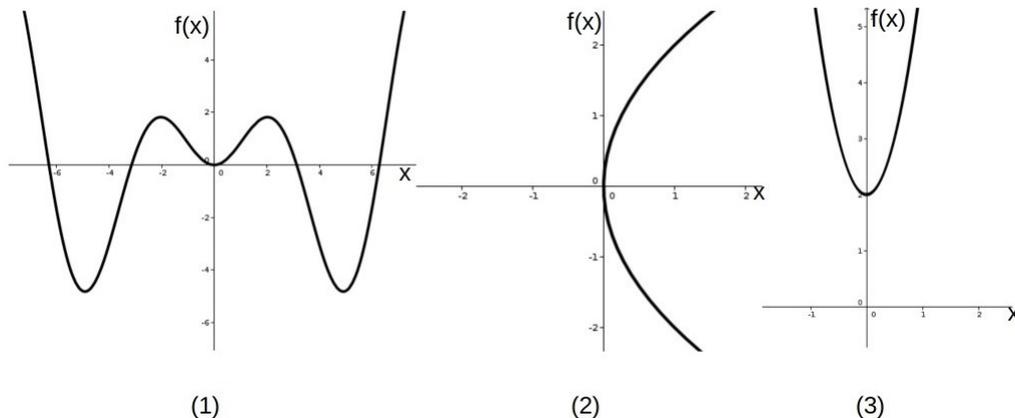
72. The value of $e^{i\pi}$ is

- (A) 1 (B) 0 (C) -1 (D) not defined.

73. The number of common solutions of the two equations: $\frac{x^2}{2} + \frac{y^2}{3} = 5$ and $y = 5x$ are

- (A) 0 (B) 1 (C) 2 (D) 3

74. Observe the three graphs below.



Which of the following statements is true?

- (A) Graphs (1) and (3) are even functions
- (B) Only Graph (3) is an even function.
- (C) Graph (2) is an odd function.
- (D) Graph (1) is neither an even function nor an odd function.

75. The derivative (with respect to variable z) of the complex function $f(z) = 3z^2 + 4iz$ at $z = 2 + 2i$ is

- (A) $6 + 16i$ (B) $12 + 8i$ (C) $12 + 16i$ (D) $6 + 8i$

76. Which of the following statements is true?

- (A) There exists at least one Pythagorean triplet with all odd integers.
- (B) Every odd integer greater than 1 is part of at least one Pythagorean triplet.
- (C) Every Pythagorean triplet has at least one odd integer.
- (D) Any given positive integer can be part of at most one Pythagorean triplet.

77. A function $f(x)$ is continuous in $[a, b]$ and $f(a)f(b) < 0$. Which of the following statements will always be true?

- (A) There exists c such that $c \in (a, b)$ and $f(c) = 0$
- (B) There exists c such that $c \in (a, b)$ and $f'(c) = 0$
- (C) There exists c such that $c \in (a, b)$ and $f''(c) = 0$
- (D) $f(x)$ is differentiable in (a, b) .

78. In a card game with 52 playing cards, two cards were drawn by a player at random. Which of the following events will have the minimum probability?

- (A) Both cards having same number or picture (i.e. a pair).
- (B) Both cards belonging to the same suit.
- (C) Both cards having consecutive numbers or pictures (i.e they are in sequence), but not necessarily from the same suit.
- (D) Both cards are picture cards.

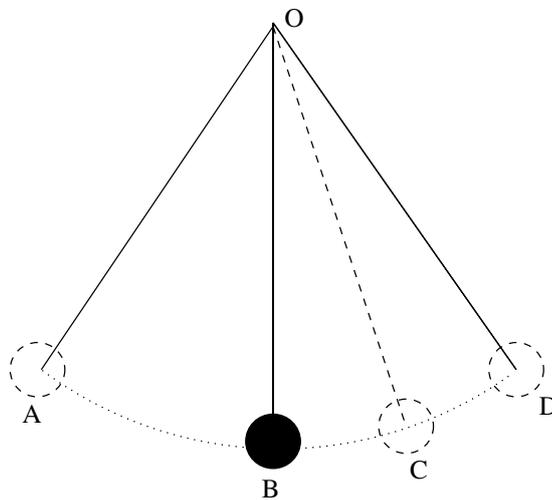
79. Let R be the set of points inside a rectangle of side a and b ($a, b > 1$) with two sides lying on the positive side of x -axis and y -axis. Then

- (A) $R = \{(x, y) : 0 \leq x \leq a, 0 \leq y \leq b\}$
- (B) $R = \{(x, y) : 0 \leq x < a, 0 \leq y < b\}$
- (C) $R = \{(x, y) : 0 < x \leq a, 0 < y \leq b\}$
- (D) $R = \{(x, y) : 0 < x < a, 0 < y < b\}$

80. Let $A_n = \{a_n\}$ be an arithmetic progression with 100 elements, $a_1 = 5$, $a_2 = 8$ and so on. $B_n = \{b_n\}$ is another arithmetic progression also having 100 elements, but $b_1 = 3$, $b_2 = 7$ and so on. How many common elements are there in A_n and B_n ?
- (A) More than 20 but less than 30 (B) More than 10 but less than 20 (C) More than 1 but less than 10 (D) Exactly 1 common element

Physics

81. A fan is switched off in a room at the end of office hours. The angular speed of the fan reduces to half its initial value after completing 24 rotations. If we assume uniform angular deceleration, how many more rotations will be made by the fan before it comes to rest?
- (A) 8 (B) 12 (C) 24 (D) 48
82. Consider a spring of length L and spring constant k . The spring is then cut into two pieces such that the length of one piece is $2/3$ of the other. The spring constant of the shorter piece is
- (A) k (B) $k/3$ (C) $2k/3$ (D) $5k/2$
83. In a Young's double slit experiment, two interfering waves of wavelength λ have a phase difference of $2\pi/3$. The path difference between them is
- (A) $\lambda/4$ (B) $\lambda/2$ (C) $\lambda/3$ (D) $2\lambda/3$
84. Figure shows a simple pendulum oscillating about the point O. The extreme positions to the left and right are A and D respectively. The mean position is denoted by B and C is the midpoint between B and D. If T is the time period of the pendulum, the time taken for the bob to reach C from D is



- (A) $T/3$ (B) $T/6$ (C) $T/8$ (D) $T/12$
85. A block on an infinite horizontal frictionless plane is given an initial push/force of magnitude 1 N. As per Newton's first law the block will continue in motion on the frictionless plane indefinitely. The work done by the initial push/force on the block
- (A) is infinite. (B) is zero. (C) is non-zero and finite. (D) cannot be calculated since mass of the block is not given.

86. Consider two spherical balls A and B of same radius but made of copper and iron respectively. It may be noted that the density of copper is higher than that of iron. If both spheres are completely immersed in water,
- (A) the buoyant force on A is greater than the buoyant force on B.
 - (B) the buoyant force on B is greater than the buoyant force on A.
 - (C) the buoyant force on A is equal to the buoyant force on B.
 - (D) buoyant forces do not act on A and B since they have density higher than that of water.
87. Speed (v) of an electromagnetic wave is given by the expression $v = \nu\lambda$, where ν is the frequency and λ is the wavelength. When the wave travels from one medium to another (of a different refractive index), which of the following remain(s) unchanged?
- (A) Wavelength only
 - (B) Both speed and frequency
 - (C) Speed only
 - (D) Frequency only
88. Water of mass m initially at temperature $\theta^{\circ}\text{C}$ is frozen into ice at 0°C . The specific heat capacity of water is c and specific latent heat of fusion of ice is l . It may be noted that m , c and l are all in SI units. The amount of heat released in the process (in SI unit) is
- (A) $mc\theta + ml$
 - (B) $mc\theta$
 - (C) ml
 - (D) $mc\theta - ml$
89. Consider a container of water with a cube of ice floating in it. What will happen to the level of water in the container, when the ice cube melts completely?
- (A) The level of water will increase.
 - (B) The level of water will remain same.
 - (C) The level of water will decrease.
 - (D) The level of water may increase or decrease depending on the size of the ice cube.
90. A stone at rest is dropped from the top of a tall building. The ratio of the distance fallen in first 8 seconds to the distance fallen in first 4 seconds
- (A) is equal to 2.
 - (B) is equal to 4.
 - (C) is equal to 8.
 - (D) is equal to 16.

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2018

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 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

