HOMI BHABHA CENTRE FOR SCIENCE EDUCATION

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2021

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 28 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 normalized to that corresponding to 50 questions, using the following formula.

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

- 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 X 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 X in a certain box, blacken out the entire box and put a X 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, please submit this question paper along with the Answer Sheet

Quantitative Reasoning, Scientific Literacy and Technical Comprehension

1. Mandar walks on a straight road from his home to the bus stop and catch the same bus every day. If he walks at an average speed of 2 km/hour, he will miss the bus by 20 minutes. If he walks at an average speed of 2.5 km/hour, he will reach 10 minutes before the scheduled time of the bus. How far is the bus stop from his home?

(A) 3 km (B) 4 km **(C) 5 km** (D) 6 km

2. Zuibeda and Sachin bought a car together for Rs. 3,50,000. Later they sold it for Rs. 2,70,000. At the time of purchase if the ratio of capitals of Zuibeda and Sachin was 2:3. How much money Zuibeda lost?

(A) Rs. 32000 (B) Rs. 48000 (C) Rs. 16000 (D) Rs. 64000

3. A rectangular cuboid has a length, width and height of 10 cm, 8 cm and 3 cm, respectively. It is divided into 25 equal compartments. Each of these 25 compartments is further divided into 20 equal, smaller compartments. What is the volume of each smallest compartment?

(A) 0.48 cm^3 (B) 9.6 cm^3 (C) 12 cm^3 (D) 5.3 cm^3

4. Neeta can climb up the stairs at a rate of 12 steps/minute and without changing her orientation, can get down the same stairs at a rate of 6 steps/minute. If she starts at the bottom of the stairs and after every 6 steps she climbs up, she gets 1 step down. How many steps can she climb up in 5 minutes?

(A) 45 steps **(B) 39 steps** (C) 40 steps (D) 50 steps

5. What should be the next number in the series: 19, 21, 25, 33, 49, 81, …..

(A) 126 **(B) 145** **(**C) 155 (D) 121

6. Today, Sita's age is one-third of Gita's age. After 15 years, Sita's age will be two-third that of Gita's age then. Two years from now, what will be the age of Gita and Sita, respectively?

(A) 17 years and 7 years **(**B) 15 years and 5 years
(C) 24.5 years and 9.5 years (D) 22.5 years and 7.5 years

7. If 'KEEPER' is coded as JFDQDS, then how will 'FAMINE' be coded as?

(A) EBLJMD (B) EBNJKD (C) EBLJMF (D) EBLJKF

8. Rakesh has a 20 acre farm. A water body occupies 18% of his farm. Of the remaining area, 2.5% is occupied by his house. He allocates the remaining area to grow tomatoes, carrots and beetroots in the ratio 2:1:3. He obtains a yield of 15 tonnes of beetroots per acre. What is the approximate total yield of beetroot obtained by Rakesh?

(A) 120 tonnes **(**B) 80 tonnes (C) 136 tonnes (D) 123 tonnes

9. In an examination, there are only three subjects P, Q and R. Each student has to pass in each of the three subject to successfully pass the examination. After the evaluation, 20% students failed in subject P, 22% students failed in subject Q and 16% students failed in subject R. What is the most appropriate range of percentage for the total number of students passing the examination?

(A) 16% to 22% (B) 20% to 78% **(C) 42% to 78%** (D) 22% to 78%

10. A mother said to her daughter, "I was as old as you are today when you were born" If the mother's age is 52 years today, what was her age when the daughter's age was 10 years?

(A) 21 years (B) 26 years **(C) 36 years** (D) 42 years

11. A cricketer scored 103 runs in the 19th inning, which increased her batting average by 3 runs. What was her batting average before her 19th inning?

(A) 52 (B) 49 **(C) 46** (D) 43

12. Assuming 1st March 2020 was a Monday. Then 1st March 2019 and 1st March 2021 were respectively:

(A) Sunday and Tuesday **(B) Saturday and Tuesday**

(C) Sunday and Monday (D) Saturday and Monday

13. A bicycle-rider starts from point A with a constant speed riding on a straight path towards point B. He travels a distance of 50 km and meets with flat-tyre. It takes him 10 minutes to repair and fix the flat tyre. He further rides his bicycle but now with ¾ th of his earlier speed. He reaches 55 minutes late than his expected time of arrival at point B. Had the flat-tyre happened 10 km further on and everything else would be the same, he would have reached 45 minutes late. What was his speed before he met with the flat tyre:

(A) 12 km/hr (B) 16 km/hr **(C) 20 km/hr** (D) 24 km/hr

14. Tamal is standing on a playground 20 meters to the West of Prakash and Jignesh is standing 9 meters to the North of Tamal. Milind is standing 21 meters to the South of Tamal; then in which direction is Milind standing with respect to Prakash and at what distance?

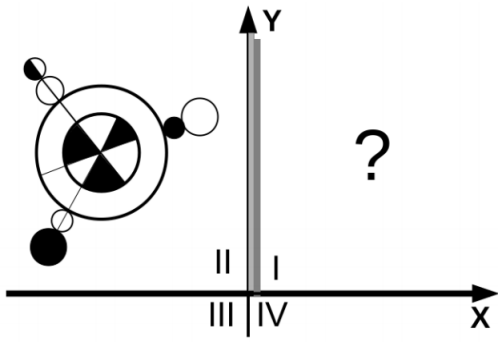
(A) Approximately South-East and at 30 meters

(B) Approximately South-West and at 29 meters

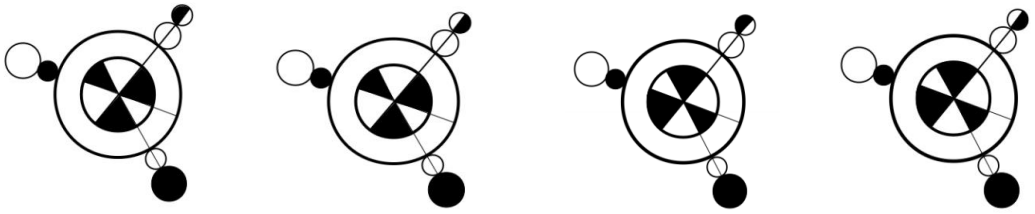
(C) Approximately South-East and at 29 meters

(D) Approximately South-West and at 30 meters

15. A molecule is placed in the IInd quadrant of a X-Y coordinate system as shown in following Figure.



Which of the following options best describes the projection of the molecule on the Ist quadrant (i.e., a mirror image with respect to Y axis)?



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

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

The idea of making merit the basis of appointments grew rapidly in the 19th century. It meant that more and more the selection of people was based on their academic knowledge, which was tested through various kinds of examinations. It came to India in a dramatic way when the Indian Civil Service changed its recruitment model from patronage by the directors of the East India Company to selection through an entrance test.

Meritocracy, as this came to be known, rested upon certain ideas. The first was that achievement and ability should be the basis of choosing people for high posts. The elite should not become so because of whom they were related to, but because of their own hard work and perspicacity. This was a much better way of setting up a group of high officials than by selecting them primarily on the basis of their loyalty. It also made available a much larger pool of talent than from just those who happened to be born to privilege. This was connected to a second idea, individualism, which viewed individuals as masters of their own will and with the capacity to overcome social pressures. Individualism as a social principle for building organisations meant that the social origins of individuals were not to be looked into; their personal attributes and merit were only what mattered. A third idea was about what features constituted merit. When a person's qualities were to be examined, what exactly did one look for? The growing power of universities and university educated people led this to increasingly mean that academic or university knowledge was the sign of ability. This had the advantage of being spelt out clearly and there being the availability of established methods of testing it. The way knowledge was interpreted in academic institutions became the hallmark of merit. So, expertise in school knowledge, and particularly the way examinations were able to identify valued traits, began to define merit.

The overall effect of meritocratic ideas and practices was indeed a liberating one for those times. It helped overcome the shackles of hereditary privilege and gave expression to the ideals of equality and freedom. We were not tied to our history, but as individuals we could be whatever we wanted to be. Such ideas were the basis of principles of democracy, liberalism and, in a way, socialism as well. They were connected to the growth of the nation state, whose citizens were all considered equal. The setting up of a meritocracy provided a process for implementing that equality and for selecting from amongst the citizenry.

The difficulties in this early modern vision of meritocracy are now well known. The notion that merit is created by individual effort and hence is an individual attribute is only partially true. Indeed, hard work and motivation do matter. But so do family environment, caste, economic resources, living in a place where good quality schools are available, and so on. It is no longer possible for the teacher to justify students' differences in performance by their individual talents.

The teacher and the institution must now take responsibility for all the students and not just the older elites.

Excerpts from: Madan, A. (2017). Modernity and meritocracy searching for a fourth way. *Economic Political Weekly L11*(47), 16-20.
http://publications.azimpremjifoundation.org/381/1/Modernity%20and%20Meritocracy.pdf

16. Prior to the 19th century, people were more likely to get a job if they:

(i) had connections with powerful people

(ii) performed well in entrance tests

(iii) were loyal to higher officials

(iv) had good academic knowledge

(v) had hereditary privileges

(A) Statements (ii), (iii) and (iv) **(B) Statements (i), (iii) and (v)**

(C) Statements (ii) and (iv) (D) Statements (i), (iii) and (iv)

17. On which of the following did the preliminary ideas of meritocracy NOT rest?

(A) The candidate's individualism.

(B) Social environment of the candidate.

(C) Acumen and achievements of the candidate.

(D) Ability of the candidate.

18. According to the passage, which of the following statements is false?

(A) Meritocracy helped an employer to choose from a much larger pool of talent than before.

(B) Meritocracy is an impartial way to choose people.

(C) Academic or university knowledge became the endorsement of having merit.

(D) The elite lost their primary advantage with the onset of meritocracy.

19. Which of the following most closely aligns with the author's point of view?

(A) Acknowledges that meritocracy brought in elements of equality, albeit partially.

(B) Strongly against meritocracy due to its unjust nature.

(C) Critiques meritocracy unconditionally.

(D) Strongly stands for meritocracy as it gives importance to equality and academic knowledge.

20. Meritocracy values:

(A) Education, perseverance and acumen.

(B) Academic knowledge, economic background and abilities.

(C) Hereditary privilege, individualism and university degrees.

(D) Hard work, achievements and loyalty.

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

Arguing that 'the kinds of issues that arise in public debate rarely involve scientific questions alone,' Trefil (2008b) seek transformative changes in general education and proposes radical curricula for non-science majors (expounded on in Trefil 2008a). For example, he questions the typical "eight hours of science" requirement, saying that it tends to focus on content in a couple of scientific disciplines to the exclusion of others (instead he calls for teaching broadly applicable, basic principles that underlie today's complex, interdisciplinary problems). He dismisses the notion that students must "do" science, e.g., in lab sections, to be able to appreciate it (reasoning that one need not learn to play a musical instrument nor paint a picture to appreciate a concert or fine art). And he scoffs at teaching the "scientific method" (maintaining that it is but a part of the scientific process and that teaching it will not benefit the future lives of non-majors).

To enter the debate on a science-related issue and reach an informed decision requires the ability to judge the expertise and credibility of the scientists involved (Norris 1995, Trefil 2008, Zimmerman et al 2001). This aspect of scientific literacy has not been given due attention in this author's opinion. It is rarely taught to science majors, let alone non-majors. Zimmerman et al (2001) found that when asked to assess the credibility of science news briefs in the popular press, university students "generally failed" to seek expertise-related information. Trefil (2008a) rightly contends that non-experts are typically ill-equipped to evaluate the evidence associated with a particular claim and must instead make a judgment call; at such times, scientific credibility of the experts should be evaluated. How might one teach this? Norris (1995) recommends devising a scientific credibility exercise that focuses on a "real-world problem" currently impacting students' lives. He believes that students should be taught to maintain a healthy dose of skepticism regarding scientific claims and given practice applying criteria to judge the credibility of the expert(s) - e.g., scientific consensus on the issue, the researcher's reputation in the scientific community, and the publication in which the findings appeared. Readers might include additional criteria; I would add identifying funding sources and whether the reported findings are associated with a political agenda or involve a conflict of interest on the part of the researcher(s).

Excerpts from: Anelli, C. (2011). Scientific literacy: What is it, are we teaching it, and does it matter? *American Entomologist*, 57(4), 235-244.

21. In the extract, you see words "scientific method", "generally failed", "real-world problem". Why are these words within quotation marks?

(A) To highlight the significance of these words

(B) To indicate that the author cannot find words to replace these with

(C) To show that these words are scientific

(D) To represent that this is as stated by original speaker or author

22. Two postdoctoral researchers were looking into the medical susceptibility to a virus among certain ethnicities and the outreach available to them.

What kind of problem are these researchers studying?

(A) social and scientific

(B) scientific

(C) social

(D) cognitive science

23. What is clearly not expounded in this extract?

(A) Policy to change science education

(B) Problems faced by students in checking veracity of scientific claims

(C) What should be taught to enable checking ability of the scientist making claims

(D) Checking funding resource as one of the ways to judge a scientific paper

24. Which of the following statements is true with respect to the extract?

(A) Students must study science compulsorily for fixed number of hours in school

(B) Students must learn how to discern scientific truths from baseless claims

(C) Science and arts are two disparate bodies of knowledge

(D) Science teaching should focus on problems based on canonical knowledge

25. Which of the following are suggestions/ideas by the author?

(i) Issues in public debate rarely involve scientific issues alone

(ii) Scientific literacy is taught neither to science majors not to non-majors

(iii) One must check if the study findings are motivated by a political agenda

(iv) Students must be taught to receive claims with a healthy dose of skepticism

(A) Statements (i) and (ii)

(B) Statements (ii) and (iii)

(C) Statements (iii) and (iv)

(D) Statements (i) and (iv)

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

Green space has been shown to boost learning, improve recovery from hospital operations and lower the risk of mental disorders. Now the power of plants has been linked to levels of violence and self-harm in prisons. Researchers mapped the percentage of green space – trees, lawns and shrubbery – within prisons in England and Wales and compared it with incidents of self-harm, prisoner assaults on staff and violence between prisoners. Taking into account the age of prisons, their security level, population density, and whether they accommodated men, women or young offenders, the researchers from the University of Birmingham and Utrecht University found prisons with a higher presence of green space had lower levels of self-harm, and lower levels of assaults on staff and between prisoners. The number of prisoners in England and Wales put on suicide or self-harm watch has risen by nearly 60% to 27,389 in a decade, with further rises during the coronavirus crisis. There were more than 61,000 incidents of self-harm in English and Welsh prisons in the year to September 2019 alongside 33,000 incidents of violence between prisoners, and more than 10,000 assaults on staff.

The study, published in the *Annals of the American Association of Geographers*, suggests a modest 10% increase in green space inside a prison could reduce prisoner-on-prisoner assaults by 6.6%, with self-harm falling by 3.5% and assaults on staff by 3.2%. "*Our evidence shows clear and demonstrable benefits from the presence of green space for prisoners in all categories of prison*," said the lead researcher, Prof Dominique Moran of the University of Birmingham. "*It's clear that inclusion of green space should be a key design element for new prisons, and existing prisons should convert existing outdoor areas to provide more green space wherever possible*." The research has been shared with the Ministry of Justice, which is presiding over a crisis of rising levels of violence and disorder inside prisons after years of funding cuts. The benefits of green space in urban settings have been widely demonstrated by three decades of scientific studies, alongside evidence of the specific benefits of trees and other green space around hospitals and schools. Another study by Moran in one British prison found that outdoor green space and photographic images of the natural environment that took up a whole wall led prisoners to report restorative feelings of calm and the ability to reflect. Previous research has revealed the benefits of gardening and vegetable-growing projects in prisons but some of those benefits are likely to only be experienced by participants who prosper because of teamwork or physical exertion.

Adapted from: Barkham, P. (2021). The Guardian. (Title withheld)

26. What does the passage suggest?

(A) There is an inverse relationship between presence of green spaces and levels of violence in prisons.

(B) Presence of green spaces and levels of violence in prisons are directly proportional to each other.

(C) Presence of plants is not related to the levels of violence in prisons.

(D) Self harm and the coronavirus are inversely related.

27. What were the 'variables' that were considered in this study?

(i) Gender of the prisoners

(ii) Extent of security in the prison

(iii) Health issues of the prisoners

(iv) Density of prisoners

(v) Cleanliness of the prisons

(vi) Age of the prisoners

(A) (i), (ii), and (vi) **(B) (i), (ii), (iv) and (vi)**

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

28. Based on the information given, what may have been the approximate number of people at risk of self-harm or suicide in England and Welsh prisons about 10 years back?

(A) Around 16400 **(B) Around 17100**

(C) Around 61000 (D) Around 10900

29. The passage does not specifically refer to research done on:

(A) Effect of green spaces on prisoners

(B) Effect of nature-themed photographs on prisoners

(C) Effect of gardening amongst prisoners

(D) Effect of exercising amongst prisoners

30. What is the central focus of this article?

(A) How proximity with nature affects human emotions/actions

(B) How greenery can be the solution to all problems

(C) How prisons can be a site for research

(D) How the coronavirus has affected prisons

Social Sciences, Cognitive Sciences and Education

31. After a review of research, it was found that the results were not representative of real-world situations, then this study lacks which of the validities?

(A) Face validity **(B) Ecological validity**

(C) Content validity (D) Construct validity

32. In the context of education and development, “brain drain” refers to:

(A) a child feeling very tired and exhausted after studying for a long time.

(B) highly educated people migrating to a more developed country.

(C) anxiety and stress faced by children during competitive examinations.

(D) young graduates joining a job instead of pursuing higher studies.

33. Here are some examples of research:

(i) Studying the effect of a drug X on the Indian population

(ii) Studying the difficulties students face while doing geometry

(iii) Analysing the nature of citizen protests over the last 50 years

(iv) Theorizing the evolutionary patterns of human beings using fossils

(v) Understanding health policies in the context of politics

Which of the above are examples of social science research?

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

(B) (iii) and (v)

(C) (ii), (iii) and (v)

(D) All except (i)

34. In the context of feminist studies, what does the metaphor "Leaky pipeline" refer to?

(A) It describes how women travel great distances to get water for their families.

(B) It describes that the number of women in science, mathematics, engineering, and technology decreases at higher classes, degrees, and positions.

(C) It describes the differences in educational backgrounds of women coming from the same family across multiple generations.

(D) It refers to poor or inadequate washroom/toilet facilities in schools that prevent women from pursuing their studies.

35. From the options given below, choose which combination of people/artifacts in a school may intentionally or unintentionally pass on prejudices related to social and economic background:

(i) teachers

(ii) diagrams in a textbook

(iii) words used in the textbook

(iv) policies set by the school administration

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

(B) None of these

(C) All of these — (i), (ii), (iii), and (iv)

(D) Only (i) and (iv)

36. Emile Durkheim feared the loss of collective consciousness to modernity. Which of the following is **NOT related** to this relationship between collective consciousness and modernity?

(A) With modern growth, population will grow, and people will grow apart.

(B) Modernity will make the society more complex.

(C) One needs to explore the intractable subjectivity of consciousness in order to be conscious.

(D) Collective consciousness is based on mechanical solidarity arising out of simple kinship ties.

37. A person desperately wanting to lose weight, finds it difficult to resist the temptation of snacking on foods. This difficulty in losing weight is probably due to:

(A) delayed reinforcement

(B) immediate reinforcement

(C) negative reinforcement

(D) positive reinforcement

38. A researcher wants to investigate whether learning via novel pedagogical techniques leads to changes in students' beliefs about physics. The researcher should:

(A) compare the final exam grades/marks between the treatment and control classrooms.

(B) survey the students in both treatment and control classes on their beliefs about physics at the end of the semester and compare the difference.

(C) survey the students in treatment class on their beliefs about physics at the start and the end of the semester to analyze the change in beliefs.

(D) survey the students in both treatment and control classes on their beliefs about physics at the start of the semester and compare results

39. Teachers must have high expectations of all students and check for their own treatment of students. Teachers must bear this in mind when dealing with students because -

(i) Teachers' expectations affect student outcomes.

(ii) Teachers' perceptions of students may be inaccurate.

(iii) Teachers' perceptions of students is always right.

(iv) Teachers must not have low expectations of their students.

(A) (i) and (ii) are correct (B) (ii) and (iii) are correct

(C) (iii) and (iv) are correct (D) (iv) and (i) are correct

40. Physically aggressive individuals have a heightened tendency to decide that ambiguous faces are angry. This tendency is thought to contribute to their destructive interpersonal behavior. A common interpretation of this result is that such individuals have a cognitive bias. A recent study showed that such individuals process anger-related information more efficiently. Based on this result, the study authors argued that this efficiency, rather than bias, explains aggressive individuals' classification tendency.

This result suggests that:

(A) Physically aggressive individuals are not responsible for their actions, because their brains are wired for picking up aggression in the environment

(B) Physical aggression cannot be prevented by laws and policing, as some people are wired for aggression

(C) Pacifism is the best response to physical aggression, as pacifist behavior would lower stimuli aggressive people would find provocative

(D) Character traits, such as aggression, could emerge from information processing differences

41. A person is more likely to answer quicker to an easy question than to a hard question. If an experimental study was conducted, the statistical analysis would result as:

(A) Lower response times for difficult questions than for easy questions

(B) Higher response times for difficult questions than for easy questions

(C) Similar response times for difficult and easy questions

(D) none of the above

42. Extreme or Deviant case sampling focus on cases that are special or unusual. This is a type of:

(A) Purposive sampling (B) Random sampling

(C) Probability sampling (D) Cluster sampling

43. From the following statements and conclusion, which of the following is true:

"If today is monday, then I have to visit library"

"Today is monday"

"Therefore, I have to visit library"

(A) affirming the antecedent (B) affirming the consequent

(C) denying the antedent (D) denying the consequent

44. Some researchers are conducting a study on the effect of a novel pedagogy on students' learning. Which of the following would be a violation of research ethics?

(A) The researchers take the permission of only the instructor for administering a survey

(B) The researchers include in their research the conversations they accidentally overhear between friends as they were entering the classroom

(C) The researchers reveal the names of students who did well on a survey to the instructor

(D) All of the above

45. A researcher wants to investigate differences in physics problem-solving strategies used by students in two classes. Which amongst the following will help the researcher answer this question? The researcher should:

(A) develop an interview protocol for understanding students' beliefs about physics problem-solving

(B) collect students' physics final exam marks.

(C) design a few physics questions which can be answered in multiple ways

(D) design a multiple-choice survey assessing students' beliefs about physics

46. Perception divides everyday experience into meaningful events. This process is known as event segmentation. Studies show that cultural background impacts online (real-time) event segmentation, by: 1) emphasizing different aspects of experiences as being important for comprehension, memory, and communication, and (2) by providing different exemplars of how everyday activities are performed, which objects are likely to be used, and how scenes are laid out.

> In a recent study, Indian and US viewers (N = 152) identified events in everyday activities (e.g., making coffee) recorded in Indian and US settings. US viewers segmented the activities into more events than did Indian viewers. Furthermore, event boundaries identified by US viewers were more strongly associated with visual changes, whereas boundaries identified by Indian viewers were more strongly associated with goal changes. There was no evidence that familiarity with an activity impacted segmentation. The study authors argued that culture impacts event perception

by altering the types of information people prioritize when dividing experience into meaningful events.

Based on the above study, which of the following inferences is valid?

(A) Indians and Americans perceive the world differently

(B) Indians make sense of the world differently from Americans

(C) Americans pay less attention to activity goals, compared to Indians

(D) Indians' experiences of the world have less events, compared to Americans' experiences

47. Recent research shows that speakers of most languages find smells difficult to categorise , i.e. abstract and name. A recent study tested whether verbal labels enhance the human capacity to learn smell categories. This was done by studying whether different types of training change learning gains in odor categorization. Participants were provided four intensive days of training to categorize odors, which were co-presented with arbitrary verbal labels, in two modes: consistent labels and inconsistent labels.

People who learned odor categories with odor-label pairs that were more consistent were significantly more accurate than people with the same perceptual experience, but who had odor-label pairs that were less consistent. Both groups' accuracy scores improved, but their pattern of learning differed. The context of consistent linguistic cuing supported an increase in correct responses from the third day of training. However, inconsistent linguistic cuing delayed target odor categorization, until after the fourth day. According to the study authors, these results show that associations formed between odors and novel verbal labels facilitate the formation of odor categories. They also interpreted this as showing a causal link between language and olfactory perceptual processing.

Which of the following statements is implied by the study results?

(A) Learning more languages can improve olfactory capabilities

(B) Labels allow perceptual inputs to be segmented and kept separate

(C) Perfume brand names are based on label-odor associations

(D) Smells activate language areas of the brain

48. A recent longitudinal study investigated the effects of early childhood socioeconomic status on language-related neural activation (resting-state functional connectivity) and reading outcome in adolescence. Seventy-nine children participated in this study. Socioeconomic status was measured using a questionnaire, measuring parental education and family income at 1 month. At age 14, resting-state neural imaging data and reading-related behavioral data of the children were

collected. The neural connectivity patterns related to parental education was found to be positively correlated with neural connectivity related to children's reading skills (word list reading and sentence reading fluency). Which of the following interpretations of this data is valid?

(A) Lack of reading culture in the family can affect children's reading skills

(B) Children who read better are always from educated families

(C) Parents' ability to read are inherited by children

(D) Children's brain development is based on parents' brain development

49. A researcher wants to understand the dynamics of how social status gets formed amongst the students in a school. Which of the following would be the **most suited** for such an investigation?

(A) Survey-based quantitative study of students

(B) Ethnographic study of student-student interactions

(C) Interviewing a few faculty

(D) Interviewing the principal

50. A researcher wants to investigate how students navigate a physics problem when they get stuck. Which of the following is an acceptable strategy for investigating this? The researcher should:

(A) Do a quantitative analysis of students' responses to a multiple-choice survey on problem-solving skills

(B) Compare the average final exam marks between the treatment and control classes.

(C) Interview students as they solve a few hard physics problems

(D) Do a quantitative analysis of students' responses to a multiple-choice survey assessing physics conceptual knowledge

Biology

51. Which of the following is/are responses of mammals to a decrease in the external environmental temperature?

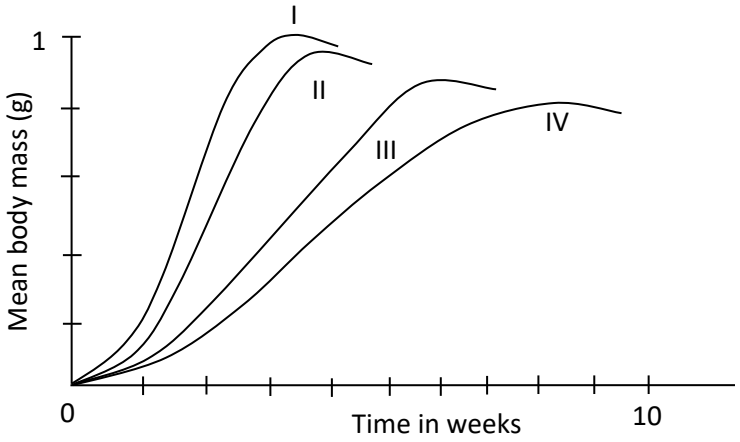
(i) Rhythmic involuntary muscle contraction

(ii) Relaxation of hair erector muscles

(iii) Vasoconstriction to reduce blood flow between core and skin

(A) (i) only (B) (i) and (ii) (C) (ii) and (iii) **(D) (i) and (iii)**

52. In an experiment, tadpoles were grown in groups of (I) 5, (II) 40, (III) 60 and (IV) 160 in four identical confined areas. When the growth of the tadpoles was measured, the following graph was obtained.



What is the correct interpretation?

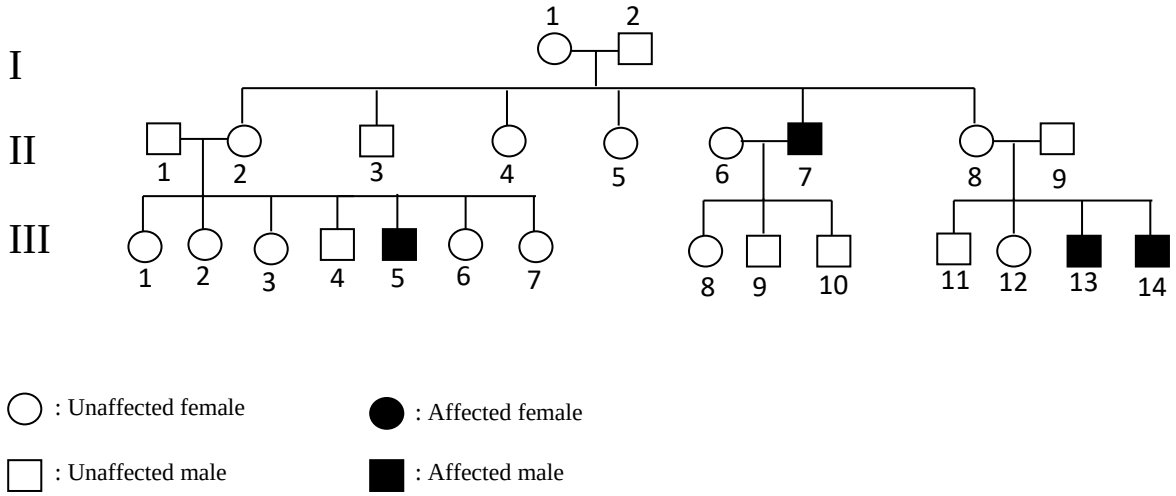
(A) Competition for resources is highest in group I.

(B) Population density and rate of body growth are directly proportional.

(C) The results indicate that the resources are limited.

(D) Irrespective of the group, the amount of resources available to any tadpole is the same.

53. A pedigree depicting the inheritance of hemophilia, an X-linked recessive disorder is shown below.



Which of the following statements is true?

(A) Individual III – 11 should be affected.

(B) II – 2 is heterozygous for the trait.

(C) I – 1 and II – 8 are the only carriers in the family.

(D) II – 9 should be a carrier to have affected male progeny.

54. The *pregnancy detection kit* works on the antigen-antibody reaction principle. The ideal way of using this kit is by retaining urine overnight so that the level of hormone in the urine rises. The next morning, a few drops of urine are added on the strip from the kit. The antibodies embedded on the strip react with the specific hormone (antigen) present in the urine. This reaction leads to coloured band formation indicating positive result. A particular hormone produced by the body only after conception helps in confirming pregnancy. Descriptions of four hormones that play an important role in gestation are listed below.

Choose the one that is ideal to be used for confirming pregnancy by the kit method.

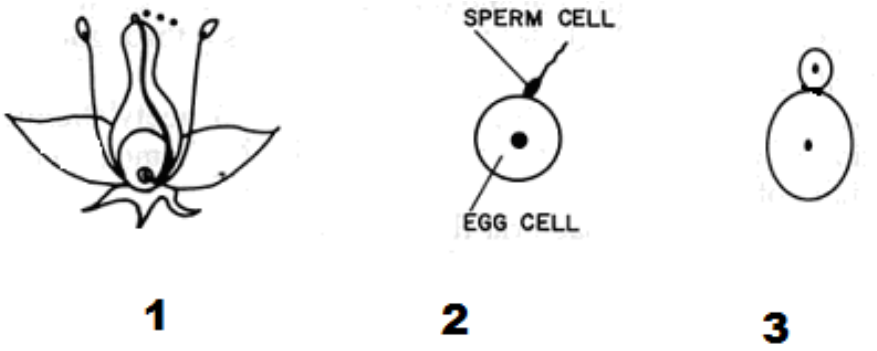
(A) Hormone which controls the selection of follicle that will ovulate.

(B) Hormone secreted by cells surrounding the blastocyst once it is implanted in the uterus wall.

(C) When the egg is not fertilised, the level of this hormone drops leading to menstruation.

(D) A higher concentration of this hormone results in the enlargement of mammary glands.

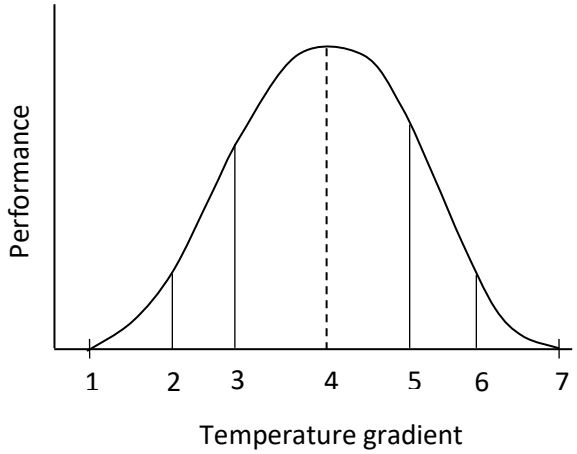
55. Which of the following mode/s of reproduction (1 – 3) would result in offspring that is genetically identical to the parent?



(A) 1 only (B) 1 and 2

(C) 2 and 3 **(D) 3 only**

56. Response of an animal to an environmental gradient such as temperature is shown.



Mark the correct interpretation.

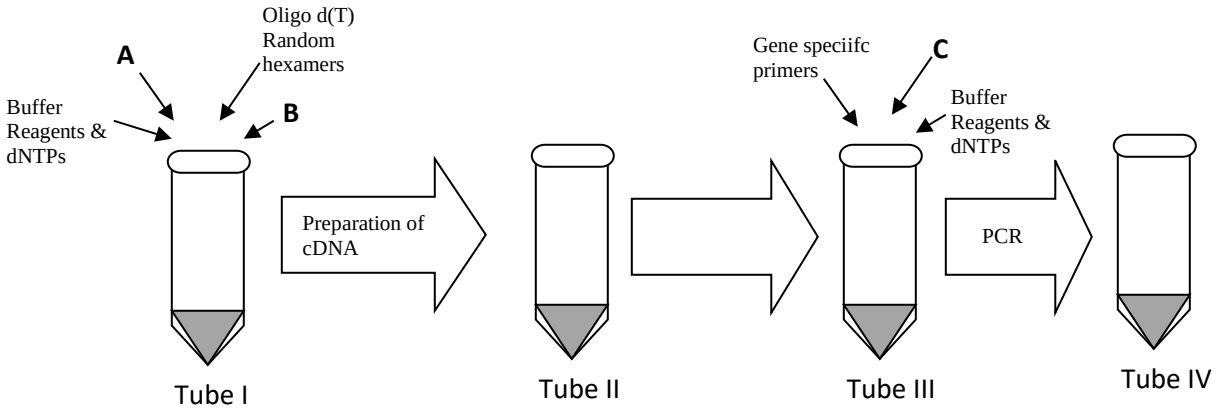
(A) Point 1 and 7 indicate the limit for growth of an animal.

(B) Region 2-3 indicate optimum region for reproduction.

(C) Graph shown for performance against temperature gradient will remain same for all animals.

(D) Region close to 4 will be optimum for growth and reproduction.

57. A reliable method for the detection of the human coronavirus is the RT-qPCR method wherein nasal and throat swabs are tested for the presence of the virus. One of the protocols followed for the RT-qPCR is the two- step method where the first step involves preparation of cDNA followed by the amplification reaction. A diagrammatic representation of this method is given below.



A, B and C to be added to the tubes respectively would be:

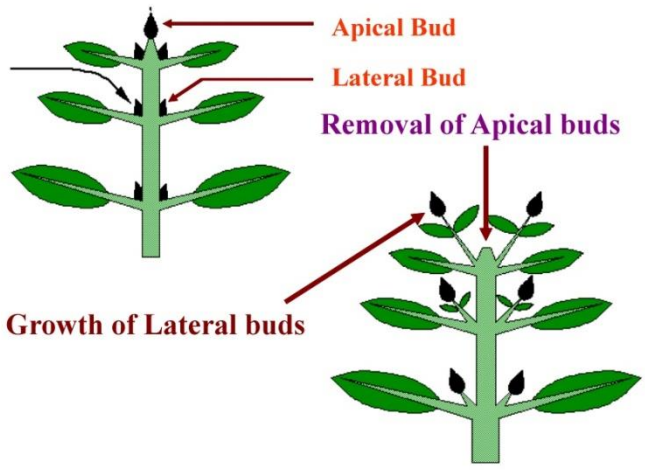
(A) Viral DNA from patient sample; Reverse transcriptase and RNA polymerase

(B) Viral RNA from patient sample; RNA polymerase and DNA polymerase

(C) Viral RNA from patient sample; Reverse transcriptase and DNA polymerase

(D) Whole virus from patient sample; RNA polymerase and Taq polymerase

58. A researcher was studying growth in Coleus plantlets. Plant growth can be distinctly seen by observing its growing terminal shoot end. The lateral buds present near the tip do not grow as prominently as the apical bud. But those present away from the tip portion (towards the base of the plant) grow into small branches.
As part of the experiment, she cut a small portion of shoot apex and observed the change in growth pattern over the next few days. It was observed that the lateral buds close to the tip showed significant increase in growth (as shown in image below).



The most probable reason for this occurrence could be that:

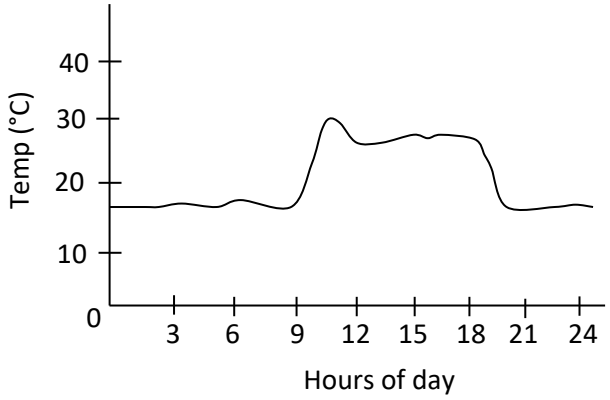
(A) the inhibitory effect on lateral growth imparted by hormone produced in the terminal bud is absent.

(B) the growth hormones from the apical bud translocated to the lateral buds.

(C) the nutrients were redirected to axillary buds as apical meristematic cells were absent.

(D) the wound healing mechanism at the cut tip portion triggers cell division in axillary buds too.

59. When the body temperature of an animal was recorded over 24 hours, the following graph was obtained



Mark the most appropriate interpretation of the graph.

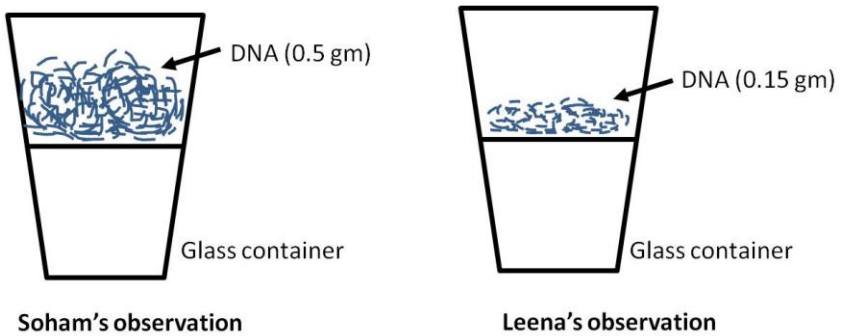
(A) The animal is likely to be a mammal.

(B) The metabolism of the animal will be double if the temperature rises from 20°C to 22°C.

(C) The animal is likely to be a reptile.

(D) The graph represents that the animal is aquatic.

60. Leena and Soham were doing a project to compare DNA extraction efficiency from buccal cells using simple reagents. Both of them used identical protocols to obtain sufficient buccal cells as starting material. However, Soham used detergent for cell lysis, while Leena used SDS-free shampoo for the same purpose. Both used the same filtration / centrifugation and precipitation techniques to obtain DNA. Results are shown in the diagrams below.



When 0.05 gm of DNA from both the containers was dissolved in 1 ml water and DPA (specific test for DNA) test was performed, both samples gave similar absorbance readings.

What can be deduced from these findings?

i. More concentrated DNA was extracted using shampoo compared to the DNA obtained using detergent.
ii. Larger quantity of DNA was extracted using detergent compared to the DNA obtained using shampoo.
iii. Leena's buccal cells had less DNA compared to Soham's buccal cells.
iv. Detergent was more efficient than shampoo for extracting DNA.

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

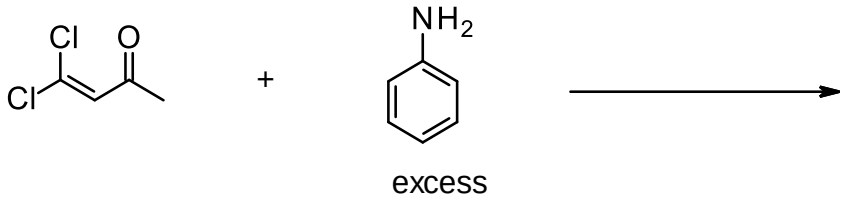
(C) (ii) and (iv) only (D) (iii) and (iv) only

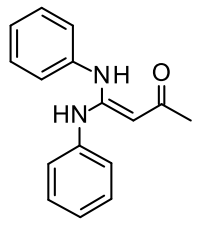
Chemistry

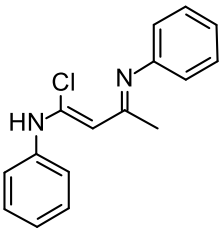
61. A system can achieve thermodynamic equilibrium only if it is

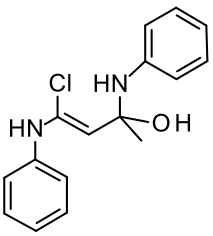
(A) open (B) closed **(C) isolated** (D) adiabatic

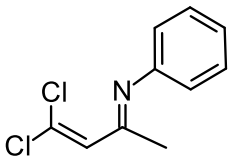
62. Amines can react as nucleophiles with ketones leading to a diversity of products depending on the molecular structure of the reactants and reaction conditions. Identify the major product of the following reaction.



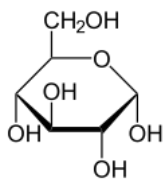
(**A**) 

(B) 

(C) 

(D) 

63. The following equation indicates the net transformation taking place in photosynthesis:

$$6CO_2 + 6H_2O \rightarrow 6O_2 +$$ 

In this transformation,

(A) some of the C atoms undergo oxidation.

(B) some of the H atoms undergo oxidation.

(C) some of the O atoms undergo reduction.

(D) all C atoms undergo reduction.

64. An iron wire if held in yellow zone of a candle flame for some time, starts showing a reddish glow. This observation shows that the temperature of such yellow zone of a candle flame should be in the range:

(A) 70 - 90 °C

(B) 90 -110 °C

(C) 100 - 200 °C

(D) above 600 °C

65. A student mixed 10 mL of a NaOH (aq) solution with 10 mL of a solution of HCl (aq) in a petri dish and left this mixture open on a bench. The student wanted to obtain NaCl crystals by this method. After several days, a solid started appearing in the container. However, even after several days, the solid did not completely dry up. This could be because

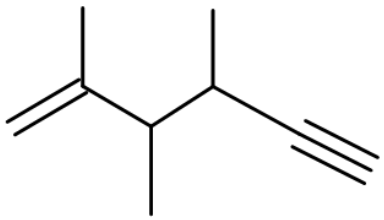
(A) moles of base were more than moles of acid in the 10 mL portions mixed initially.

(B) the HCl (aq) had higher molarity than NaOH (aq).

(C) NaCl is a hygroscopic salt.

(D) the final mixture was losing HCl on evaporation.

66. The correct IUPAC name for the following compound is:



(A) 2,3,4-trimethylhex-5-yne-1-ene

(B) 2,3,4-trimethylhex-1-ene-5-yne

(C) 3,4,5-trimethylhex-5-ene-1-yne

(D) 3,4,5-trimethylhex-1-yne-5-ene

67. For a triprotic acid H_3A (like phosphoric acid), $K_{a1} = 1 \times 10^{-2}$, $K_{a2} = 1\times 10^{-6}$, and $K_{a3} = 1\times 10^{-10}$. The pH range where $[H_2A^-]$ will be maximum is between

(A) 1 – 3 **(B) 3 – 5** (C) 5 – 7 (D) 7 – 9

68. The correct statement for the two ions, $[ClF_4]^-$ and $[ClF_2]^-$ as per VSEPR theory is

(A) The three lone pairs on $[ClF_4]^-$ occupy the equatorial positions giving trigonal bypyramidal shape whereas the two lone pairs in $[ClF_2]^-$ lead to linear shape.
(B) The three lone pairs on $[ClF_4]^-$ occupy the equatorial positions giving trigonal bypyramidal shape whereas the two lone pairs and the fluorine atoms in $[ClF_2]^-$ occupy the four positions of a distorted tetrahedron.
(C) The two lone pairs and the four fluorine atoms in $[ClF_4]^-$ occupy the six octahedral position whereas the three lone pairs in $[ClF_2]^-$ lead to linear shape.
(D) The two lone pairs and the four fluorine atoms in $[ClF_4]^-$ occupy the axial and four equatorial positions respectively and give a square planar shape whereas the three lone pairs in $[ClF_2]^-$ lead to linear shape.

69. The melting point of ice is 273 K at 1 atm whereas that of CCl_4 is 250 K. The statement that **cannot** be correctly inferred from the above information is

(A) Both chlorine in CCl_4 and oxygen in ice have lone pair of electrons and thus, can interact with other molecules through these lone pairs in the respective solid states.
(B) The intermolecular forces of attraction in ice is greater than that in CCl_4, which lead to higher energy requirement during melting
(C) Based on the intermolecular interactions, the boiling point of water should be higher than that of CCl_4.
(D) ΔH(fusion) of ice should be higher than that of solid CCl_4.

70. In the reaction;

$2HCO_3^-$ (aq) $\rightleftharpoons$ H_2CO_3 (aq) + CO_3^{2-} (aq)

the hydrogen carbonate ion, HCO_3^- is functioning as

(A) a Bronsted-Lowry acid only

(B) both a Lewis base and a Lewis acid

(C) both a Bronsted-Lowry acid and a Bronsted-Lowry base

(D) a Lewis acid

Mathematics

[Notations used: Z: set of all integers; N: set of all natural numbers; $n!$: $1 \times 2 \times \cdots \times n$;

gcd: Greatest Common Divisor]

71. Let $f : N \to N$ be defined by $f(n) = n! + 2$. Then the number of perfect squares in the infinite sequence $\{f(n)\}_{n\geq 1}$ is

(A) Infinite **(B) Same as the number of perfect cubes in $\{f(n)\}_{n\geq 1}$**

(C) 2 (D) Finite, but cannot be determined from the given information

72. Consider a square $ABCD$ of side 8 and let E, F be the midpoints of AB, CD respectively. Now, take a point P on EF such that $AP = r$, and $PC = s$.

Then, the area of the triangle whose sides are r, s, 8 is

(A) 32 **(B) 16** (C) $\frac{rs}{2}$ (D) $\frac{rs}{4}$

73. 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

74. Three non-collinear points A, B and C are such that $AB = 3$, $BC = 4$ and $CA = 5$. A fourth point D is chosen in the plane determined by A, B, and C in such a way that these four points become the vertices of a parallelogram Π.

The greatest possible value of the length of a diagonal of Π is

(A) 5 (B) $2\sqrt{13}$ **(C) $\sqrt{73}$** (D) 10

75. Which of the following is an equivalence relation on the set of all functions from $Z \to Z$

(A) $\{(f,g) \mid f(x) - g(x)$ is equal to 1, for all $x \in Z\}$

(B) $\{(f,g) \mid f(x) - g(x)$ is an integer, for all $x \in Z\}$

(C) $\{(f,g) \mid f(0) = g(0)$ or $f(1) = g(1)\}$

(D) $\{(f,g) \mid f(0) = g(1)$ and $f(1) = g(0)\}$

76. How many 6 digit numbers greater than 600000 can be made by rearranging the digits 1, 2, 2, 3, 4, 6?

(A) 30 **(B) 60** (C) 20 (D) 720

77. For three positive numbers n, m and k, the *gcd* of $(4^n - 1)$ and $(4^m - 1)$ is k. Which of the following cannot be the value of k?

(A) 15 **(B) 65** (C) 255 (D) 1023

78. Which of the following numbers is not a factor of 25**!**?

(A) 26 (B) 46 (C) 52 **(D) 58**

79. Shabnam has n candies such that $50 < n < 100$. If she divides these n candies between 4 children equally, then 3 candies remain. If she divides these n candies between 5 children equally, then 2 candies remain. If she divides these n candies between 6 children equally, then 1 candy remains. How many candies will remain if she divides these candies equally among 7 children?

(A) 0 (B) 2 **(C) 4** (D) 6

80. In the xy-plane, line l is such that it does not pass through the origin. Which of the following statements are necessary to conclude that the slope of line l is positive?

I: For every point on l, the x-coordinate is less than the y-coordinate of that point.

II: If l passes through two points (p, q) and (r, s), then $(p - r)(q - s) > 0$.

(A) Neither I, nor II (B) Only I **(C) Only II** (D) Both I and II

Physics

81. Consider a fundamental particle with a very small, but non-zero mass. Which of the following is **not** correct?

(A) It is affected by gravity, but the effect would be tiny.

(B) Its speed in vacuum must be less than the speed of light in vacuum.

(C) Its speed in a material medium must be less than the speed of light in that medium.

(D) It is not necessary for such a particle to have a charge.

82. Which of the following represents the dimension of latent heat?

(A) $L^2 T^{-2}$ (B) $M^1 L^2 T^{-2} K^{-1}$ (C) $M^1 L^2 T^{-2}$ (D) $L^2 T^{-2} K^{-1}$

83. A sitar player is playing a sitar whose strings are fixed at both ends and has length of 1.0 metre. As she plays, standing waves are generated. Five stable antinodes can be seen on a particular string. If the wave velocity in the string is 100 m/s, what is the frequency?

(A) 500 Hz **(B) 250 Hz** (C) 125 Hz (D) 400 Hz

84. A driver of a stationary car sees another car at a far-off distance u in his rear-view mirror. The actual velocity of the other car is $u'$and focal length of the mirror is f. Which of the following expressions correctly represents the speed of the image seen in the mirror?

(A) $-\left(\frac{f}{u-f}\right)^2 u'$ (B) $-\left(\frac{f}{u-f}\right) u'$ (C) $-\left(\frac{u-f}{f}\right) u'$ (D) $-\left(\frac{u-f}{f}\right)^2 u'$

85. Pieces of three different materials - metal, acrylic glass, and wood - of equal mass and equal temperature are removed from a hot oven and dropped into a vat of crushed ice. Which will melt more ice before cooling to the ice temperature?

(A) Metal (B) Glass

(C) Wood (D) All three will melt equal amount of ice.

86. Consider two sinusoidal waves $x(t) = sin(2\pi t - \phi_1)$ and $y(t) = sin(2\pi t - \phi_2)$ forming Lissajous figures, in the following cases; (i) $\phi_1 - \phi_2 = 0^o$ (ii) $\phi_1 - \phi_2 = -225^o$

What will be shape of these figures?

(A) (i) circle & (ii) line (B) (i) line & (ii) circle

(C) (i) line & (ii) ellipse (D) (i) circle & (ii) ellipse

87. A conical pendulum (which traces a cone while oscillating), has length *l*, height *h*, angle of cone α and radius of the base of cone *r.* Which of the following is the correct expression for its period *P*?

(A) $P = 2\pi\sqrt{\frac{lcos\alpha}{g}}$ (B) $P = 2\pi\sqrt{\frac{lsin\alpha}{g}}$

(C) $P = 2\pi\sqrt{\frac{htan\alpha}{g}}$ (D) $P = 2\pi\sqrt{\frac{rtan\alpha}{g}}$

88. In an experiment on diffraction due to single slit, the wavelength of laser used is given as

$$\lambda = \frac{d}{n} sin\theta$$

In this experiment, the grating element used had 12700 lines/inch and the separation between the screen and slit was 30.0 cm. If the separation between the two first order maximas is 20.0 cm, calculate the wavelength of the laser.

(A) 250 nm (B) 263 nm **(C) 632 nm** (D) 667 nm

89. The orbital period of a solar system object at a mean distance from the Sun is 10 au (where 1 au is defined as the average distance between Sun and Earth) is,

(A) 100 yr **(B) 32 yr** (C) 10 yr (D) 4.5 yr

90. Light rays travelling in air are incident on a glass surface at some angle. The reflected component of this light gets completely plain polarised. If the refractive index of this particular glass with respect to the air is 1.52, what is the angle of reflection of the polarised light?

(A) 4^o (B) 33.34^o (C) 35.79^o **(D) 56.66^o**