

## JGEEBILS GS2017

### Section A: General

1. In 1828, Wohler synthesized urea in the laboratory. This was significant because it demonstrated that:

- a. biomolecules are carbon compounds
- b. urea would be an ideal fertilizer
- c. organic compounds can be synthesized without living organisms
- d. life cannot generate spontaneously from non-living matter

2. The use of DNA evidence to find crime suspects is not perfectly conclusive because of

- a. degradation of the sample
- b. contamination by other individuals' DNA
- c. insufficient data to match one individual uniquely
- d. all of the above

3. I hold a bottle vertically, looking down at its cap. To open the bottle I rotate the cap clockwise. This means the thread of the screw on which the cap moves is:

- a. right-handed
- b. left-handed
- c. symmetric
- d. this can't be determined from the given information

4. The relative percentage of oxygen in the air remains constant at 21%, from sea level to the peak of Mt. Everest. Why then do humans suffer from altitude sickness?

- a. Due to the ozone layer.
- b. Due to the increased percentage of nitrogen in the air.
- c. Due to the reduced air pressure at higher altitudes.
- d. Due to the increased exposure to ultra-violet light.

5. In radiocarbon dating, scientists base their estimates of the age of a sample on the measured counts per minute per gram of carbon (cpm/g-C). The half-life of carbon-14 is 5700 years. A relic is found to give an activity of 12 cpm/g-C. If living trees give a count of 16 cpm/g-C, the approximate age of the relic is:

- a. 2300 years
- b. 5300 years
- c. 6300 years
- d. It depends on the total amount of carbon in the relic

6. Which of the following is not a necessary feature of a reflex action

- a. It is mediated by the nervous system
- b. It is involuntary
- c. It serves a protective function
- d. It is a rapid response to a stimulus

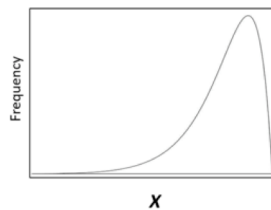
7. Which of the following viruses has been linked to microcephaly?

- a. Yellow fever
- b. Zika
- c. Dengue
- d. Japanese encephalitis

8. A bag contains 8 square and 3 spherical objects, and two objects are drawn one after another. If the first drawn object is put back in the bag before the second object is drawn, the probability that both are of the same shape is  $x$ . If the first drawn object is not put back in the bag, then the probability that both are of the same shape is

- a. smaller than  $x$
- b. equal to  $x$
- c. greater than  $x$
- d. greater than or smaller than  $x$ , depending on which shape is drawn first

9. The figure below shows a frequency histogram for the variable  $X$ . Which of these statements is correct for this histogram?



- a.  $\text{mean} < \text{median} < \text{mode}$
- b.  $\text{mode} > \text{mean} > \text{median}$
- c.  $\text{mode} > \text{mean} > \text{median}$
- d.  $\text{mean} = \text{mode}$ ,  $\text{mode} > \text{median}$

10. The sum of the infinite series  $1 + 1/2 + 1/3 + 1/4 + 1/5 + \dots$  is

- a.  $\log 2$
- b.  $e$
- c.  $\pi$
- d. Cannot be determined because the series diverges

11. It takes 10 seconds to send or read an SMS text message. An earthquake hits me. I want to warn my friend who is located 60 km due west of me. The earthquake epicentre was 25 km due south of me. How many seconds does my friend have to get out of the building after reading my SMS? Assume SMS transmission time is instantaneous. Assume earthquake waves go at 1 km/s.

- a. 45
- b. 40
- c. 30
- d. 20

12. Solar eclipses do not occur every month. This is because:

- a. The Earth is significantly larger than the moon
- b. the moon orbits the earth in the opposite sense as the Earth orbits the sun
- c. the moon's orbit is tilted relative to the Earth's orbit around the sun
- d. the moon presents one face to the Earth at all times

13. A bus is carrying 23 passengers. The average weight of these passengers is  $64 \pm 10$  kilograms (mean  $\pm$  standard deviation). 5 passengers get down at a bus stop. No new passengers board the bus at this stop. Which of the following statements is true about the standard deviation of weights in the bus after it has left from this stop?

- a. It will decrease
- b. It will not change
- c. It will increase
- d. The answer cannot be determined from the given information

14. Suppose paper currency comes in denominations of Ones, Twos, Fives, Tens, Twenties, and Fifties. What is the smallest number of notes I must carry, to exactly generate any amount from Rs. 1 to Rs. 99?

- a. 8
- b. 16
- c. 32
- d. 64

15. The function  $x + \sin(x)$  is best described as

- a. non-decreasing
- b. non-increasing
- c. decreasing
- d. increasing

## Section B: Physics

1. A beam of light from a laser pointer passes through air and then enters a glass block of refractive index 1.33. The wavelength of this laser beam in air is 490 nm. What is the wavelength in the glass block?
  - a. greater than 490 nm
  - b. smaller than 490 nm
  - c. equal to 490 nm
  - d. answer cannot be determined from given information
  
2. Why is it easier to throw a Frisbee only with one hand, rather than with both?
  - a. Throwing with both hands accelerates the Frisbee, making it unstable.
  - b. Momentum conservation is violated when you throw with both hands.
  - c. Throwing with one hand imparts angular momentum to the Frisbee.
  - d. All of the above.
  
3. Two children hold opposite ends of a rope and excite a sinusoidal travelling wave in the vertical plane. A bystander notices that the time it takes for the rope to go from its maximum height to its minimum height at any point along the rope is 0.5 s, and that the distance between two peaks at any instant is 1.5 m. What is the speed of the wave?
  - a. 1.5 m/s
  - b. 3 m/s
  - c.  $\sqrt{1.5}$  m/s
  - d.  $\sqrt{3}$  m/s
  
4. Unpolarized light is passed through a polarizing sheet. Which of the following statements describes the output beam?
  - a. It is polarized and its intensity is reduced.
  - b. It is unpolarized and its intensity is reduced.
  - c. It is polarized but its intensity is unchanged.
  - d. It is unpolarized and its intensity is unchanged.
  
5. I measure time using a pendulum. I find that a pendulum swinging from a fixed support oscillates with a different period than one whose support is accelerated horizontally with respect to the laboratory frame. This is mainly because of:
  - a. The effect of Earth's rotation
  - b. Lorentz contraction
  - c. Doppler effect
  - d. None of the above

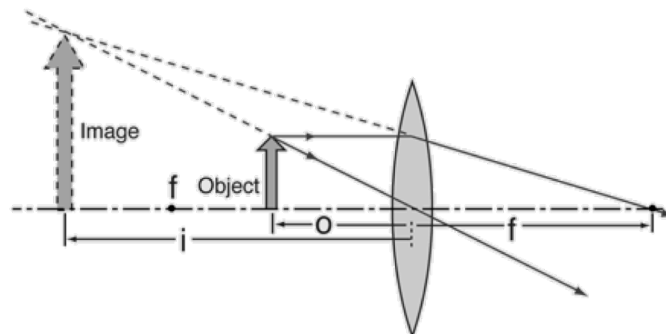
6. I force  $200 \text{ cm}^3$  of water through a slanted pipe whose cross-sectional area is constant at  $10 \text{ cm}^2$ . The pressure at the pipe inlet is  $150 \text{ N/cm}^2$  higher than at its outlet. How much work have I done on the system?

- a. 150 J
- b. 300 J
- c. 3000 J
- d. It depends on the height difference at the ends of the pipe

7. I measure the strength of a signal from a radio tower to be  $20 \text{ uW/m}^2$  at a distance of 2 km from the tower. What is the total power radiated by the tower, assuming it is transmitting uniformly in all directions?

- a. 1 mW
- b. 1 W
- c. 1 kW
- d. 1 MW

8. I use a lens to form a virtual image of an object, as shown below. What must be done to record this virtual image onto camera film?

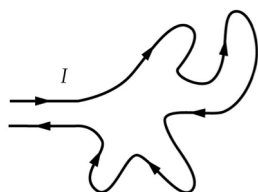


- a. It's not possible: virtual images are only apparent sources of light.
- b. Focus the camera on the virtual image, creating a real image on film.
- c. Use a pinhole to capture only the light passing through the lens centre.
- d. Place the film at the location of the virtual image.

9. A car of mass 1500 kg is mounted on four suspension springs, one for each wheel. When empty, the car oscillates vertically at a frequency of 3 Hz. When the car has four passengers each of mass 75 kg, it will oscillate at approximately:

- a. 0.75 Hz
- b. 1.75 Hz
- c. 2.75 Hz
- d. 3.75 Hz

10. Current is passed through this flexible loop of wire, which is placed on a frictionless insulating table. What will be the resulting effect on the shape of the wire?



- a. The wire will expand to form a circular loop
- b. The wire will bunch up further
- c. The wire will lift off the table
- d. There will be no effect

11. A planet of constant density  $\rho$  and radius  $R$  rotates with period  $T$ . Let  $G$  represent the gravitational constant. What is the shortest possible period of rotation? Hint: think of the forces acting on a point mass at the equator.

- a.  $T = G \frac{4}{3} \pi R^3 \rho$
- b.  $T = G \frac{4}{3} \pi R \rho$
- c.  $T = \sqrt{1/G\rho}$
- d.  $T = \sqrt{3\pi/G\rho}$

12. I place a block in a tub of mercury, and find that  $1/4$  of its volume is submerged. Now I pour just enough water so that the object is fully submerged. At the end of this procedure, approximately how much of the block's volume will remain immersed in mercury? The density of mercury and water are, respectively,  $13.6$  and  $1.0 \text{ g/cm}^3$ .

- a.  $1/2$
- b.  $1/3$
- c.  $1/4$
- d.  $1/5$

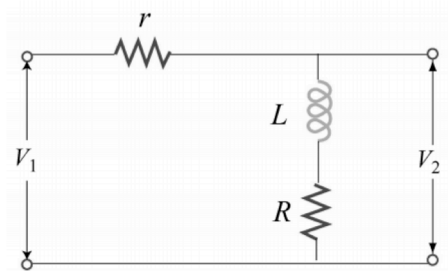
13. A box of volume  $V$  and temperature  $T$  contains a mixture of two ideal gasses A and B, whose molecules have masses  $m_A$  and  $m_B$ , respectively. Suppose there are  $N$  molecules of each type at the beginning of an experiment. Each molecule of A combines with a molecule of B to form a new molecule C of mass  $m_A + m_B$ . The experiment runs until all of A and B are converted to C. What is the ratio of the pressure after the reaction to the pressure before (assuming no change in temperature)?

- a.  $1/2$
- b.  $2$
- c.  $m_A/(m_A + m_B)$
- d.  $m_B/(m_A + m_B)$

14. Consider a Boson that can be in one of two states. How many distinct states can there be for a 3-particle system of such Bosons?

- a. 2
- b. 4
- c. 8
- d. It depends on the spin of the Boson

15. Consider the following circuit, with  $r = 15.0 \Omega$ ,  $R = 10 \Omega$ , and  $L = 250 \text{ mH}$ . What is the frequency  $f$  at which the amplitude of the output voltage is half that of the input voltage? Hint: the impedance of the inductor is  $X_L = \omega L = 2\pi fL$ .



- a. 35 Hz
- b. 11 Hz
- c. 5.5 Hz
- d. 1.1 Hz

## Section C: Chemistry

- The number of electrons in 18 ml of H<sub>2</sub>O is
  - $60.23 \times 10^{23}$
  - $6.023 \times 10^{23}$
  - $3.011 \times 10^{23}$
  - $0.6023 \times 10^{23}$
- 0.22 g of a colourless oxide of nitrogen occupies 112 ml at STP. The compound is:
  - NO
  - N<sub>2</sub>O
  - NO<sub>2</sub>
  - N<sub>2</sub>O<sub>2</sub>
- Which of the following molecules have a sugar moiety as an integral part?
  - Amino acids
  - Nucleic acids
  - Phospholipids
  - All of the above
- The pOH of a solution of NaOH is 11.30. [H<sup>+</sup>] in M of this solution is:
  - $5.0 \times 10^{-12}$
  - $6.2 \times 10^{-8}$
  - $2.0 \times 10^{-3}$
  - $9.0 \times 10^{-3}$
- Reactions with positive free energy change ( $\Delta G_0 > 0$ ) can be made to occur by:
  - coupling them with exergonic reactions via a common intermediate
  - manipulating the concentrations of products and reactants
  - coupling them to hydrolysis of ATP
  - All of the above
- The compound H<sub>2</sub>NC(CN)=C(CN)NH<sub>2</sub> is a tetramer of HCN (hydrocyanic acid). How many geometrical isomers are possible in this compound?
  - 1
  - 2
  - 4
  - 6



7. Between ethanol, ethylamine and ethanethiol, which is the most nucleophilic:

- a. ethanol
- b. ethylamine
- c. ethanethiol
- d. Both ethylamine and ethanethiol are equally nucleophilic

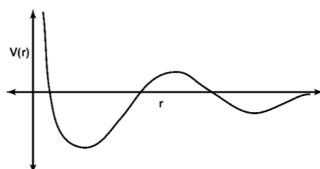
8. The most basic naturally occurring amino acid is:

- a. lysine
- b. arginine
- c. serine
- d. tryptophan

9. The three  $pK$ 's of the amino acid lysine are approximately 2.1, 9.2 and 10.8. Which of the following is true in an electrophoresis experiment:

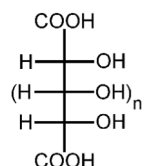
- a. Lysine does not migrate at pH 1.2
- b. Lysine does not migrate at pH 3.1
- c. Lysine does not migrate at pH 9.5
- d. Lysine does not migrate at pH 13.6

10. The graph below gives an interaction potential between two atoms as a function of the distance between them. What sort of bonds do you expect the two atoms to have?



- a. Only a single kind of strong long bond.
- b. Only a single kind of weak long bond.
- c. A weak long bond and a strong short bond
- d. A strong long bond and a weak short bond

11. How many chiral carbons does the following structure have when  $n$  is even?

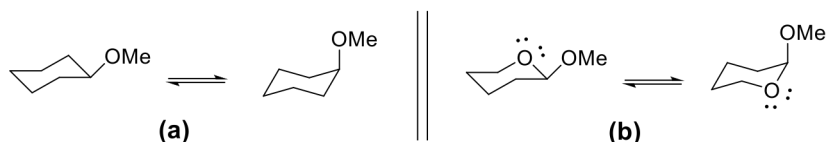


- a. all its carbons are chiral
- b.  $n$
- c.  $n+1$
- d.  $n+2$

12. Element X crystallizes into an FCC lattice with cell edge of 200 pm. The density of the element is 5 g/cm<sup>3</sup>. 200 g of this element contain how many atoms?

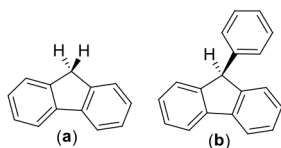
- a.  $2.0 \times 10^{23}$
- b.  $2.0 \times 10^{25}$
- c.  $6.02 \times 10^{23}$
- d.  $6.02 \times 10^{25}$

13. Two equilibria are shown below: The following is true for these equilibria:



- a. Both (a) and (b) have equal populations of the isomers
- b. Both (a) and (b) have much greater amounts of the isomer on the left.
- c. Equilibrium (a) lies to right more than equilibrium (b)
- d. Equilibrium (b) lies to right more than equilibrium (a)

14. What is the correct order of acidity for these compounds?



- a. (a) < (b)
- b. (a) = (b)
- c. (a) > (b)
- d. It depends on the pH

15. A molecular cage allows the nitrogen of ammonia to become sp<sup>2</sup> hybridized (instead of the usual sp<sup>3</sup> hybridization). What do you expect the structure of this ammonia molecule to be, and how many orbitals originating from the 2nd shell do you expect it to have?

- a. Flat and 4
- b. Flat and 2
- c. Pyramidal and 3
- d. Pyramidal and 2

## Section D: Biology

1. When antibiotic-sensitive bacteria are spread on a plate containing antibiotic, colonies of resistant bacteria grow. The best explanation for this is:
  - a. the antibiotic is mutagenic
  - b. the antibiotic induces resistance through epigenetic effects
  - c. cells only become resistant once they sense the antibiotic
  - d. some cells in the original population were already resistant
  
2. During growth and division of *E. coli*, the daughter strand is recognized due to
  - a. Hemimethylation of newly synthesized DNA
  - b. Nicks in newly synthesized DNA
  - c. double stranded breaks in newly synthesized DNA
  - d. DNA damage in newly synthesized DNA
  
3. Which of the following molecules is useful in protein phosphorylation studies?
  - a.  $\alpha$ - $^{32}\text{P}$  ATP
  - b.  $\beta$ - $^{32}\text{P}$  ATP
  - c.  $\gamma$ - $^{32}\text{P}$  ATP
  - d. ATP- $\gamma$ -S
  
4. Place these steps in temporal order, first to last. 1. Diffusion of neurotransmitter across the synaptic cleft. 2. Binding of neurotransmitter to its receptor. 3. Influx of calcium into the presynaptic terminal. 4. Release of neurotransmitter. 5. Generation of an action potential at the postsynaptic membrane. 6. Influx of sodium ions.
  - a. 3, 4, 1, 6, 5, 2
  - b. 4, 3, 1, 6, 2, 5
  - c. 1, 2, 3, 4, 5, 6
  - d. 3, 4, 1, 2, 6, 5
  
5. Which of the following statements is NOT a necessary consequence of meiosis?
  - a. Chromosome number remains constant generation after generation.
  - b. Each daughter cell receives the same number and kinds of chromosomes.
  - c. Each generation has a different genetic makeup than the previous one.
  - d. Four daughter cells are produced at the end of the process.

6. Which of the following is NOT used for the generation of transgenic animals?
- Somatic cell nuclear transfer
  - Pronuclear injection
  - Embryonic stem cells
  - Next-generation sequencing
7. What is the correct order of action of these enzymes during DNA replication?
- helicase, primase, polymerase
  - helicase, polymerase, primase
  - primase, helicase, polymerase
  - polymerase, primase, helicase
8. Which of the following point mutations would be most likely to affect protein function?
- TAA to TGA
  - CAA to TAA
  - AGG to AGA
  - CTT to CTC
9. A mutation in an X-chromosome gene “green” results in a green beard. If a green bearded man marries a non-carrier woman,
- all sons will have a green beard
  - half the sons will have a green beard
  - all daughters would be carriers
  - all daughters would be non-carriers
10. Bacteria isolated from hospital surfaces (e.g. furniture or floors) are often very resistant to antibiotics. What features of bacterial biology promote this phenomenon?
- Bacterial cells are very small
  - Bacterial genomes are relatively small
  - Bacteria have very low mutation rates
  - Bacteria can exchange genetic material
11. In resting skeletal muscle, contraction does not occur because
- there is very little ATP in the cytoplasm
  - there is very little myosin in the cell
  - there is very little calcium in the cytoplasm
  - myosin is inactivated

12. In a sucrose density gradient, what is the order of organelle sedimentation from lower to higher concentrations of sucrose?

- a. Golgi, smooth endoplasmic reticulum, rough endoplasmic reticulum
- b. smooth endoplasmic reticulum, Golgi, rough endoplasmic reticulum
- c. rough endoplasmic reticulum, smooth endoplasmic reticulum, Golgi
- d. Golgi, rough endoplasmic reticulum, smooth endoplasmic reticulum

13. We are studying a protein-coding gene in an organism whose genome is not sequenced. The nucleotide sequence of 20 bases at the 5' end of its 900 base exon is known. What is the most efficient way to find the entire coding sequence of the gene?

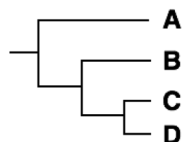
- a. Use NGS to compare the known 20-base sequence to the transcriptome.
- b. PCR amplify from purified genomic DNA using a 5' primer against the known sequence, and a random hexamer primer. Then do Sanger sequencing.
- c. Reverse transcribe, then PCR amplify the resulting DNA using a 5' primer against the known sequence, and oligo-dT primers. Then do Sanger sequencing.
- d. Do in-situ hybridization using a fluorescently labeled RNA probe against the known sequence, and compare with a control RNA against a random sequence.

14. In a purification experiment, a mixture of 3 proteins A, B and C are separated through gel exclusion or cation exchange chromatography. During elution, the buffer used is of pH 7. Which of the following statements is true?

	Molecular weight	Isoelectric point
A	45 kDa	11
B	70 kDa	3
C	115 kDa	9

- a. A elutes last in both the cases
- b. C elutes last in gel exclusion, A elutes last in ion exchange chromatography
- c. A elutes last in gel exclusion, B elutes last in ion exchange chromatography
- d. C elutes last in gel exclusion, B elutes last in ion exchange chromatography

15. Which of the following can be reasonably inferred based on this phylogeny of four species?



- a. The ancestral species at the root of the tree most closely resembles A
- b. Species B arose after species A
- c. A is equally related to both C and D
- d. Since A is an outgroup, it is unrelated to B, C, and D

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**Answer Sheet**

	Section A				Section B				Section C				Section D			
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