

Joint Graduate Entrance Exam in Biology and Interdisciplinary Life Sciences

Section A: General

1. Which sense has the best frequency resolution?
  - a. Sight
  - b. Smell
  - c. Hearing
  - d. Touch
  
2. The sun produces energy through which of the following processes?
  - a. Nuclear fission
  - b. Nuclear fusion
  - c. Photoelectric effect
  - d. None of the above
  
3. The sum of all numbers from 1 to 1,000,000 is
  - a. 500,000,000,000
  - b. 500,000,000,500
  - c. 500,000,500,000
  - d. 500,500,000,000
  
4. Four friends (A, B, C and D) are sitting on a wall. Seen from the front, A is sitting next to B, while C is sitting somewhere to the left D. How many possible seating arrangements are consistent with this information?
  - a. 2
  - b. 4
  - c. 6
  - d. 8
  
5. While giving a lecture on a mike, you hear a screeching feedback sound. How should you fix this while still staying audible?
  - a. Decrease the speaker volume and move the mike closer to your mouth.
  - b. Increase the speaker volume and move the mike closer to your mouth.
  - c. Decrease the speaker volume and move the mike further from your mouth.
  - d. Increase the speaker volume and move the mike further from your mouth.
  
6. A *Drosophila* fruitfly female weighs about 2 milligrams. The blood volume for this fly is approximately:
  - a. one millilitre
  - b. one microlitre
  - c. one nanolitre
  - d. one picolitre

7. A sphere of one metre diameter is placed in cylinder of one metre diameter and one metre height. Water poured to fill the residual volume. This volume will fill

- a. A sphere of fifty centimetre diameter
- b. Two sphere of fifty centimetre diameter
- c. Four spheres of fifty centimetre diameter
- d. Two spheres of one metre diameter

8. If I am dropped somewhere remote on earth without a watch or compass, which of the following can I not determine from local visual observations?

- a. Latitude
- b. Longitude
- c. North
- d. Local time

9. Each pixel in a liquid crystal display (LCD) colour television is composed of 3 sub-pixels that are designed to transmit blue, green and red colour because:

- a. White light is made of three primary colours, blue, green and red
- b. Liquid crystals can only filter these primary colours
- c. The human retina contains only three types of colour-sensitive cells
- d. These colours are the most pleasing to the human eye

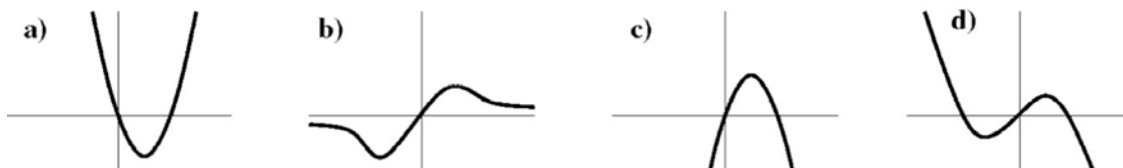
10. At time  $t = 0$ , a set of three points A, B and C forms an equilateral triangle of side 6 cm. If two of the sides of the triangle are decreasing in length at the rate of 0.1 cm/sec and the third side is increasing at the rate of 0.1 cm/sec, how long will it take for the system to just cease to form a triangle?

- a. 5 seconds
- b. 10 seconds
- c. 20 seconds
- d. 30 seconds

11. A hemisphere and a cone have the same base and volume. Which has the greater surface area?

- a. The sphere
- b. The cone
- c. Both have equal surface areas
- d. It cannot be determined from the given information

12. The function  $Y = X * (1 - X)$  is best represented by:



13.  $(80 \times 0.40)^3 (40 \times 1.6)^2 / (128)^4 = (2)^x$ . What is the value of  $x$ ?

- a. -1
- b. -2
- c. 2
- d. 5

14. The heights of adult males follows a Gaussian (normal) distribution. Given three males at random, what is the chance that all of them are shorter than one standard deviation below the mean?

- a.  $1/216$
- b.  $1/27$
- c. 0
- d.  $2/3$

15. 50 fish in a small lake were captured, marked with special tags, and released back into the lake. The next day, 40 fish were captured and 10 of these were found to have tags. The fish are smart, and once captured are less likely to be captured a second time. Which of the following statements best reflects your state of knowledge about the number of fish in the lake?

- a. There are at least 50, but probably less than 200
- b. There are at least 80, but probably less than 200
- c. There are at least 50, and probably more than 200
- d. There are at least 80, and probably more than 200

### Section B: Physics

1. A metal block is suspended in an empty tank from a scale indicating a weight of  $W$ . The tank is then filled with water until the block is covered. If the density of the metal is three times the density of water, what apparent weight of the block does the scale now read?

- a.  $\frac{1}{2} W$
- b.  $\frac{2}{3} W$
- c.  $W$
- d.  $\frac{3}{2} W$

2. Pigeons don't get electrocuted even when they sit on high-voltage wires all the time, because:

- a. Their feet have a large dielectric constant, which electrically insulates them
- b. Their feet have a very low dielectric constant
- c. The air around them electrically insulates them
- d. The electric potential difference across their bodies, due to the wires, is negligible

3. If a bulb is marked 100 W, 250 V, then

- a. It always produces 100 W of light
- b. It always draws 0.4 A current
- c. Its resistance is  $625 \Omega$
- d. All of the above are correct

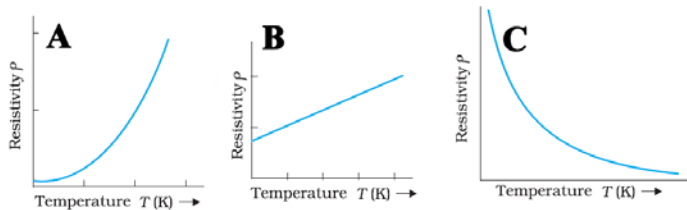
4. A brass vessel feels much colder to touch than a wooden vessel on a chilly day. Which of the following might explain this observation?

- a. Brass has a higher thermal conductivity than wood
- b. Brass has a higher specific heat capacity than wood
- c. The thermal conductivity of our hand depends on the material we touch
- d. Brass is heavier than wood

5. I pour water from a height of 1 m onto the floor, and wait till it has come to rest as a puddle. Where does most of the initial potential energy go?

- a. As sound
- b. As heat
- c. It is transferred to the earth's motion
- d. Into surface tension

6. The temperature variation of resistivity of three materials A, B and C are shown below. Which of the statements that follow are true?



- a. A and B are metals and C is a semiconductor
- b. A is a semiconductor, B is a metal and C is an insulator
- c. A and B are semiconductors and C is a metal
- d. A, B and C all are metals

7. A tank is filled with a liquid to a height of 20 cm. The depth of a needle lying at the bottom of the tank appears to be 10 cm when looking vertically downwards. What is the refractive index of the liquid?

- a.  $\sqrt{2}$
- b.  $1/\sqrt{2}$
- c.  $\sqrt{2}+1$
- d. 2

8. Suppose I do 500 J of work on a 10 kg box in pushing it horizontally along the floor. 375 J of heat is lost to the floor due to the friction between the box and the floor. What is the velocity of the box after the work has been done on it?

- a. 125 m/s
- b. 10 m/s
- c. 5 m/s
- d. 0 m/s

9. The resistance of a wire is  $R$  ohms. If the wire is stretched to double its length, its resistance will become

- a.  $2R$
- b.  $R/2$
- c.  $R/4$
- d.  $4R$

10. Huge blocks of ice were floating on a lake. Upon the ice melting the water level went up. This could be because

- a. The lake heated up
- b. The lake was saline
- c. The ice block was saline
- d. The lake cooled down

11. A copper wire carries a constant current along a wall from left to right, while there is an external, uniform magnetic field going into the wall. Where is the magnitude of the magnetic field minimum?

- a. Right side of the wall
- b. Left side of the wall
- c. Just above the wire
- d. Just below the wire

12. Cubical metal tanks X and Y have the same volumes and share a common wall. 1 gram of He is placed in tank X, 2 grams of  $H_2$  in tank Y, and the system is allowed to reach equilibrium. At the end of this process, which of the following is the same for both tanks?

- a. The average number of collisions per second on the common wall
- b. The average speed of the molecules
- c. The pressure
- d. None of the above

13. 100 amperes pass through a copper bar of  $5 \times 5$  mm cross-section. The resistivity of copper is  $1.7 \times 10^{-8}$  ohm-metres. Its volumetric heat capacity is 3.45 joules per kelvin per cc. Ignoring heat loss, what is the rate of increase of temperature of the copper in degrees C per second?

- a. 0.248 degrees/sec
- b.  $1.97 \times 10^{-6}$  degrees/sec
- c. 0.079 degrees/sec
- d. The answer depends on the length of the bar

14. The dimensional representation of Planck's constant is same as that of:

- a. Angular momentum
- b. Momentum
- c. Torque
- d. Energy

15. For a rigid body, how many independent numbers must be determined so that you can subsequently calculate its moment of inertia about any axis of rotation?

- a. 1
- b. 3
- c. 6
- d. 9

## Section C: Chemistry

- You are given 10 ml of a 1 M salt solution and asked to make 10 ml of a  $1 \times 10^{-3}$  M salt solution. The best way to do this is:
  - Do three serial dilutions of 1 ml solution in 9 ml water, starting with the 1 M solution
  - Take 1 ml of the 1M solution and add to 999 ml of water
  - Take 10  $\mu$ l of the 1M solution and add to 9990  $\mu$ l of water
  - Take 0.1 ml of a 1M solution and add to 9.9ml of water
- How do polar covalent bonds differ from non-polar covalent bonds?
  - In a polar covalent bond the electrons are shared equally between the atoms
  - In a non-polar covalent bond there is a charge attraction between the atomic nuclei
  - There is a large difference in electro negativity of the atoms in a non-polar bond
  - There is a large difference in electro negativity of the atoms in a polar bond
- The final stage of conversion of vegetable matter into coal is called
  - Anthracite
  - Bituminous
  - Lignite
  - None of above
- The unit of the rate constant of a second-order process is:
  - $\text{mol L}^{-1} \text{s}^{-1}$
  - $\text{s}^{-1}$
  - $\text{L mol}^{-1} \text{s}^{-1}$
  - $\text{mol L}^{-1}$
- Indicate the correct statement
  - $\text{Na}^+$  is smaller than Na atom
  - $\text{Na}^+$  is larger than Na atom
  - $\text{Cl}^-$  (ion) is smaller than Cl atom
  - $\text{Cl}^-$  (ion) and Cl atom are equal in size
- Under similar conditions oxygen and nitrogen are taken in the same mass. The ratio of their volumes will be
  - 7:8
  - 5:6
  - 6:5
  - 8:7
- The general formula of a single-ring cyclo alkane is
  - $\text{C}_n\text{H}_{2n+2}$
  - $\text{C}_n\text{H}_{2n-2}$
  - $\text{C}_n\text{H}_{2n}$
  - $\text{C}_n\text{H}_n$

8. The maximum number of hydrogen bonds that can be formed by a water molecule is

- a. 2
- b. 3
- c. 4
- d. 6

9. Among the following, the compound that contains ionic, covalent and coordinate linkages is

- a.  $\text{NH}_4\text{Cl}$
- b.  $\text{NaCl}$
- c.  $\text{NH}_3$
- d.  $\text{CaO}$

10. A radioactive atom  ${}^X_Y\text{M}$  emits 2  $\alpha$ -particles and 1  $\beta$ -particle successively. The number of neutrons in the nucleus of the product will be

- a.  $X-Y-6$
- b.  $X-Y-5$
- c.  $X-Y-4$
- d.  $X-Y-3$

11.  $A + B \rightarrow C$  is an irreversible reaction. I mix equal volumes of 2M A with 1M B. I measure the rate of the reaction at the start and when half of B is consumed. What is the ratio of the final rate to the starting rate?

- a. 0
- b. 3:8
- c. 3:4
- d. 1:1

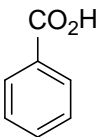
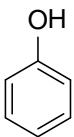
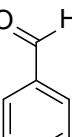
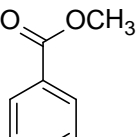
12. The highest magnetic moment is shown by the transition metal ion with the configuration

- a.  $3d^2$
- b.  $3d^5$
- c.  $3d^7$
- d.  $3d^9$

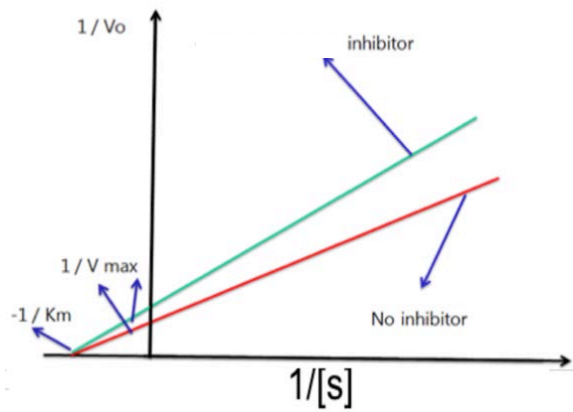
13. I have volume V of gas A and an equal volume V of gas B at room temperature and pressure. I mix, ignite, and find I have a gas (mixture of A and product C) at room pressure, 325 degrees C, and total volume 3V. What was the stoichiometry of the reaction?

- a.  $2A + B \rightarrow C$
- b.  $A + 2B \rightarrow 2C$
- c.  $2A + B \rightarrow 2C$
- d.  $A - 2B \rightarrow C$

14. The compound that liberates  $\text{CO}_2$  on treatment with aqueous sodium bicarbonate solution is:

- a. 
- b. 
- c. 
- d. 

15. The effect of an enzyme inhibitor is shown in the following graph. Which type of inhibitor is it?



- a. Competitive
- b. Non-competitive
- c. Uncompetitive
- d. None of the above

#### Section D: Biology

1. During photosynthesis the source of oxygen is:

- a. Water
- b.  $\text{CO}_2$
- c. Glucose
- d. Chlorophyll

2. How many molecules of dsDNA does a Drosophila cell nucleus contain?

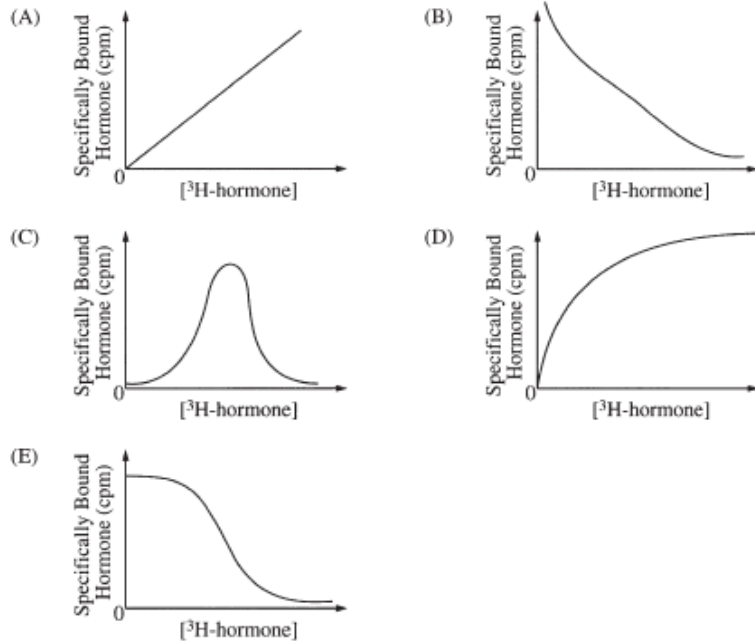
- a.  $2 \times 10^9$
- b. 46
- c. 8
- d. 0

3. An allele has different effects depending on whether it was inherited from the father or mother. This is most likely due to

- a. Sex-linkage
- b. Imprinting
- c. Penetrance
- d. Epistasis



4. A cell membrane isolated from a eukaryote was analysed for specific binding of hormone receptor by incubating a constant amount of membrane with the varying concentrations of  $^3\text{H}$  radiolabelled hormone. Which of the following graphs best depicts the expected results?



5. Which of the fo

- a. H
- b. C
- c. Electrostatic interactions
- d. Van der Waals forces.

plexes?

6. Polyomavirus (a DNA virus) causes tumors in "nude mice" (nude mice do not have a thymus, because of a genetic defect) but not in normal mice. The best interpretation is that

- a. Macrophages are required to reject polyomavirus-induced tumors.
- b. Natural Killer cells can reject polyomavirus-induced tumors without help from T lymphocytes
- c. T lymphocytes play an important role in the rejection of polyomavirus-induced tumours.
- d. B lymphocytes play no role in rejection of polyomavirus-induced tumors.

7. Which of the following sequence correctly describes the cell cycle?

- a. G1 phase: G2 phase: Mitosis: Cytokinesis
- b. Mitosis: G1 phase: G2 phase: Cytokinesis
- c. Cytokinesis: Mitosis: G1 phase: G2 phase
- d. S phase: G2 phase: Mitosis: Cytokinesis: G1 phase

8. The genome of a virus has a composition of 25% G, 25% C, 30% A and 20%U. The genome is a

- a. ssDNA
- b. dsDNA
- c. ssRNA
- d. dsRNA

9. In the Meselson-Stahl DNA replication experiment, what percent of the DNA was composed of one light strand and one heavy strand after one generation of growth in  $^{14}\text{N}$  containing growth media?

- a. 25
- b. 50
- c. 75
- d. 100

10. If offspring of heterozygous parents ( $Aa$  at a single locus) are 25 percent  $AA$ , 50 percent  $Aa$ , and 25 percent  $aa$ , then all of the following are true except:

- a. The parents are diploid organisms.
- b. The  $a$  allele is recessive lethal.
- c. The alleles assort independently.
- d. The gametes combine at random.

11. In the resting state of a neuron, the axonal membrane is

- a. Comparatively more permeable to  $\text{K}^+$  ions and nearly impermeable to  $\text{Na}^+$  ions
- b. Comparatively more permeable to  $\text{Na}^+$  ions and nearly impermeable to  $\text{K}^+$  ions
- c. Equally permeable to both  $\text{Na}^+$  and  $\text{K}^+$  ions
- d. Impermeable to both  $\text{Na}^+$  and  $\text{K}^+$  ions

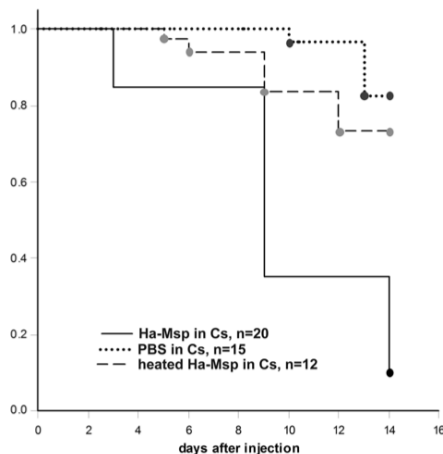
12. Why do glycolipids exist almost exclusively on the exterior side, but not on the cytoplasmic side of the cell membrane?

- a. The inner layer of the membrane is not thick enough to accommodate carbohydrates
- b. Carbohydrates are added only to lipids on the luminal side of the ER and Golgi
- c. Flippases move the glycolipids to the exterior side of the membrane
- d. Carbohydrates are enzymatically removed from the cytoplasmic side of the membrane

13. You discover a single-gene mutation, which causes lack of pain sensations. This turns out to affect a sodium channel and thus block conduction in nerves that convey pain. So you develop a toxin to block the channel in the hope of making it a cure for pain. It doesn't block pain though it binds and blocks the channel just fine even in the live organism. What might be a good reason why it fails to block pain?

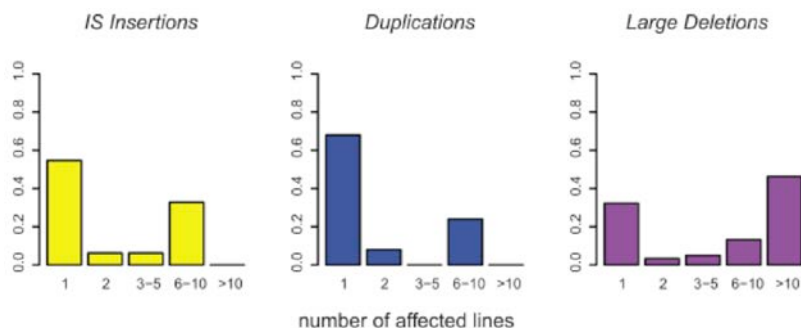
- a. There is a developmental requirement for the channel in wiring up the pain centres, but if it is blocked after adulthood the pain centres are intact and alternative pathways can stimulate them.
- b. There is a rapid adaptation to the toxin block and other channels take over the role of nerve conduction for pain.
- c. Pain is also conveyed through non-neuronal mechanisms such as inflammatory cytokines, so this block is insufficient.
- d. The toxin itself causes pain

14. Some species of plants and animals invade new habitats across continents, and an interesting problem is to know how or why these invaders are successful. One hypothesis is that invaders carry parasites that do not harm them, but that infect native species in the new habitat. Vilcinskas and colleagues (Science, 2013) tested this using an invasive beetle *Harmonia* (Ha) that carries microsporidian parasites (Msp) and invades populations of the native beetle *Coccinella* (Cs). Below, you see a graph from one of their experiments showing the fraction of *Coccinella* beetles surviving as a function of time. Ha-Msp = live microsporidia from *Harmonia* haemolymph; Cs = *Coccinella*; PBS = phosphate buffered saline; n = sample size. What can you infer from these data?



- a. Microsporidia cause substantial mortality in the native *Coccinella*
- b. Microsporidia are susceptible to heat
- c. Microsporidia kill most *Coccinella* within 4 days
- d. Both a and b

15. In a recently published study, Tenailon and colleagues allowed 114 independent replicate populations (“lines”) of *E. coli* to evolve in the laboratory at high temperature (42°C) for 2000 generations, and then sequenced the entire genome of one bacterium from each evolved line. The figure below shows a subset of their data: for each of three types of mutations, the fraction of mutations that were common to 1, 2, 3-5, 6-10 or more than 10 of the independently evolved lines is plotted. Based on the graphs shown, which of the following is NOT true?



- a. Approximately 60% of gene duplications are unique to a single evolved line
- b. Mutations unique to a single evolved line are more likely to be duplications
- c. Most large deletions are shared between many different lines
- d. The probability of observing a shared mutation between 2 to 5 lines is very low