Indian National Junior Science Olympiad 2016

Roll Number: | | | | | | | | | | | | |

QUESTION PAPER

INJSO 2016 Date: 30th January 2016
Duration: **3 Hours** Maximum marks: **90**

Please write your roll number on top of this page in the space provided.

- Before starting, please ensure that you have received a copy of this Question paper containing a total of 22 pages (22 sides on 11 sheets including the first 2 cover pages for instructions and values of physical constants).
- In section A, there are 30 multiple choice questions with 4 alternatives, out of which only 1 is correct. You get 1 mark for every correct answer and – 0.25 mark for every wrong answer.
- In Section B there are 12 questions of total 60 marks.
- For Section A, you have to indicate the answers on pages 1 of the Answer sheet by putting a "**×**" in the appropriate box against the relevant question number, like this:

Q. No.	(a)	(b)	(c)	(d)
22	☐	☐	☒	☐

Marking a cross (×) means affirmative response (making your particular choice). **Do not use ticks or any other signs to mark the correct answers.**

- For each of the 12 questions in Section B, a separate page has been provided in the Answer sheet, with the particular question number indicated in the top left hand corner. Two additional pages for answering those questions have also been appended, in case of necessity.
- Blank spaces have been provided in the Answer sheet, for rough work. **Please write the answers in the answer sheet only.**
- C**alculator and mobile phone is not allowed.**
- The Answer Sheet must be returned to the invigilator. You may take this Question paper with you.

Useful Physical constants

Mass of Earth (M_E) = 6×10^{24} kg

Speed of light (c) = 3×10^{8} m/s

Gravitational Constant (G) = 6.67×10^{-11} $m^3kg^{-1}s^{-2}$

Avogadro's number (N) = 6.0×10^{23} / mol

Gas constant (R) = 8.314 J mol^{-1} K^{-1}

Mechanical equivalent of heat (Conversion factor for calorie) = 4.2 J/cal

Specific heat capacity of water = 1 cal/g°C

Specific latent heat for fusion of ice = 80 cal/g

Specific latent heat for boiling of water = 540 cal/g

1.0 L = 1.0 dm^3

1.0 atm = 101325 Pa

Standard pressure = 1 atm

Standard temperature = 273 K

Volume of 1 mole of an ideal gas at S.T.P. = 22.4 L

Element	Relative Atomic Mass
H	1
C	12
N	14
O	16
Na	23
Al	27
S	32
Cl	35.5
K	39
Ar	40
Fe	56

SECTION A

Questions 1 to 30 are Multiple Choice questions with every correct answer carrying 1 mark and every wrong answer carrying – 0.25 mark.

1. Ingestion, digestion, absorption, assimilation and egestion are the steps in food processing in our body. Majority of absorption takes place in small intestine (villi) and which is transported to different organs through the circulatory system. Starting with villi, which of the following is the correct sequence of organs that the absorbed food passes through?

   a) Liver → Other organs → Heart
   b) Heart→ Liver → Other organs
   c) Heart → Other organs → Liver
   d) Liver→ Heart →Other organs

2. There is a regular bus service between Pune and Mumbai (180 km apart) at every hour from both the cities. First bus leaves (Both Mumbai as well as Pune) at 4 am while the last leaves at 11 pm. These busses run at an average speed of 45 km/hr. Taxies also run on the same route at 60 km/hr with regular interval of 30 min. First taxi leaves (Both Mumbai as well as Pune) at 4 am while the last leaves at 10 pm. Following statements are based upon the number of taxies or buses crossed (not overtaken) only during travelling i.e. excluding instances of arrival and departure. Consider following statements.

   (1) Taxi left at 8 pm crosses 10 taxis.
   (2) Last taxi crosses 5 buses.
   (3) Last bus crosses 4 taxies.

   a) Statements 1 & 2 are only correct.
   b) Statements 2 & 3 are only correct.
   c) Statements 1 & 3 are only correct.
   d) All the statements are correct

3. Arun is electrolyzing a mildly acidic aqueous solution containing a mixture of $CuCl_2$ and $ZnSO_4$ using Pt electrodes. The products obtained at the cathode and anode respectively are

   a) H_2 and Cl_2 b) Cu and Cl_2
   c) Zn and O_2 d) H_2 and O_2

4. Vector $\overrightarrow{C}$ is the resultant of vectors $\vec{A}$ and $\vec{B}$. Select correct statement about their magnitudes.

   a) C may be equal to A b) C > A and C > B
   c) C = A + B d) C cannot be less than the smallest among A and B.

5. A colourless solution of compound 'A' gives white precipitate, 'B', when treated with sodium hydroxide solution. The white precipitate dissolves in excess of sodium hydroxide solution. The clear solution thus obtained when treated with hydrogen sulphide gas gives white precipitate (C) Identify A,B, and C .

a) $MgSO_4$, $Mg(OH)_2$,MgS
b) $Al_2(SO_4)_3$, $Al(OH)_3$, Al_2S_3
c) $ZnSO_4$, $Zn(OH)_2$,ZnS
d) $(NH_4)_2SO_4$, NH_4OH, $(NH_4)_2S$

6. To overcome the problem of water shortage, most urban cities in India promote the concept of 'rainwater harvesting'. Although the harvested water can be used variously, the main purpose of water harvesting is to:
   a) directly collect water for household purposes.
   b) use surface water for irrigation.
   c) recharge ground water.
   d) refill lakes and other water bodies.

7. INSAT series of satellites are launched by India for telecommunication. Such satellites appear stationary at a particular point in the sky when observed from the earth. Consider the following statements:
   I. The path of these satellites is always bending towards the earth
   II. These satellites do not need any fuel for its motion.
   III. These satellites do not experience net force.
   IV. Such satellites have to be positioned vertically above the equator.

a) Only II, III & IV are correct.
b) Only I, II & IV are correct.
c) Only I & III are correct.
d) Only I & II are correct.

8. In case of mammals the volume of air inhaled and exhaled with each breath during normal breathing is called as **tidal volume**. The inhaled air at a time is not completely exhaled because the inlet and outlet for air is the same. The air that remains in the lungs after a forced exhalation is called a **residual volume**. As each inhalation mixes fresh air with oxygen depleted residual air the partial pressure of oxygen (P_{O2}) is different from that of the atmosphere. The following statements were made with reference to the above information.

   A. P_{O2} in alveoli is **higher** than that of the atmosphere.
   B. P_{O2} in alveoli is **lower** than that of the atmosphere.
   C. An animal, e.g. bird, in which there is unidirectional flow of air into lungs (i.e. inhaled and exhaled air did not use the same pipe) the maximum P_{O2} in their lungs will be higher than that of mammals.
   D. An animal, e.g. bird in which there is unidirectional flow of air into lungs (i.e. inhaled and exhaled air did not use the same pipe) the maximum P_{O2} in their lungs will be lower than that of mammals.

E. Birds will have **less** breathing problems at higher altitude than mammals.
F. Birds will have **more** breathing problems at higher altitude than mammals.

Which one is the most correct combination of the above statements?

a) A, C, E
b) B, C, E
c) A, D, F
d) B, C, F

9. Imagine a conductor in a cylindrical shape of radius *R*. Two thin circular discs of radius *R* made up of non-conducting material, carrying charge + *Q* and – *Q* respectively, are attached to the two ends of this cylinder. Consider following statements.

I. Free or conduction electrons in the conducting cylinder will drift towards +*Q*.
II. A constant current will be set up through cylinder.
III. Constant current will flow for very short duration of time.

a) Only I is true.
b) Only II is true.
c) Only III is true.
d) Only I and III are true.

10. Focal length of a concave mirror is *f*. In terms of *f*, the separation between an object and its doubly magnified real image by this mirror is –

a) 9*f*/2
b) 5*f*/2
c) 4*f*
d) 3*f*/2

11. Following is a hypothetical example. In the forests of a mainland, jungle fowls showed variation in the color of their feathers. Fowls with brown feathers were better camouflaged from their predators than those with bright red feathers. Thus in the mainland more number of brown-feathered fowls were observed as compared to the bright red ones. A person transported a few red-feathered fowls to a nearby island that did not have any jungle fowls. Also, there were no predators for the jungle fowl. After several years the island had more red-feathered fowls than brown-feathered fowl. The observed variation in the frequency of red and brown feathered in island as compared to the mainland is due to:

a) Adaptation
b) Natural selection
c) Genetic Drift
d) Competition

12. The composition (v/v) of air is found to be 78% nitrogen, 21% oxygen, and 1% argon. The density of air at STP is

a) 2.24 mg/cm^3
b) 0.65 mg/ cm^3
c) 0.39 mg/ cm^3
d) 1.3 mg/ cm^3

13. Suhita took out 100cm^3 of X molar aqueous solution of hydrogen peroxide from the refrigerator. On warming to 19.5°C, she observed 3dm^3 of oxygen gas was produced (at 1 atm pressure). Assuming complete decomposition of hydrogen peroxide, the value of X is approximately

a) 1.25 b) 2.5
c) 0.8 d) 0.5

14. Weights of a metal ball recorded in air, in water and in a liquid are 56 N, 49 N and 42 N respectively. Specific gravity (or relative density) of the solid and that of the liquid is respectively –

a) 8 & 6 b) 8 & 2
c) 8 & 1.4 d) 7 & 0.6

15. Which are the entities that are oxidized and reduced respectively in the following reaction?

$2\ Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 + O_2$

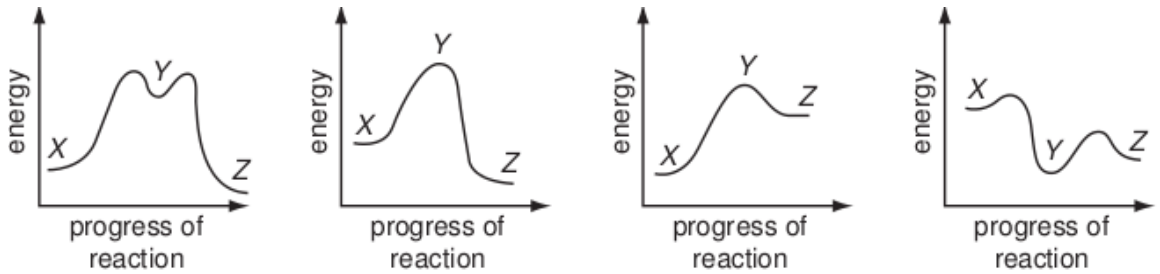
a) Pb and O b) N and O
c) Pb and N d) O and N

16. In the conversion of compound X into compound Z, it was found that the reaction proceeded by way of Y, which could be isolated. The following steps were involved.

X⟶Y; endothermic process
Y⟶Z; exothermic process

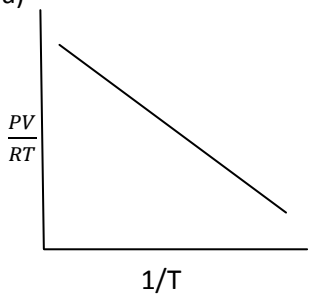
Which is the reaction profile of this conversion from X to Z?

a) b) c) d)

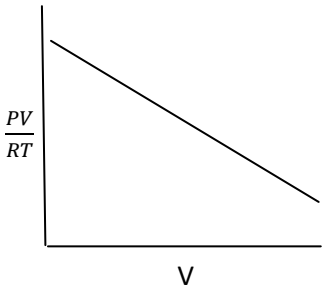


17. For one mole of an ideal gas, which of the following graphical representations holds true

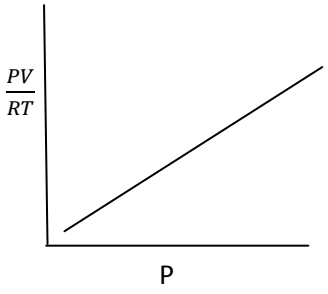
a)



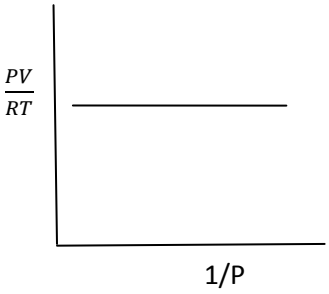
b)



c)



d)



18. Two plane mirrors are kept with their reflecting surfaces inclined at 100°. A mosquito flying in between the combination of these mirror finds multiple images of itself. At a particular moment the mosquito is very close to one of the mirrors. How many images will be formed and how many images can the mosquito see?

a) 2, 1
b) 3, 1
c) 4, 2
d) 3, 2

19. On thermal decomposition, which of the following substances will give oxygen gas.

I. NH_4NO_3 II. NH_4ClO_3 III. $(NH_4)_2Cr_2O_7$ IV. $(NH_4)_2SO_4$

a) I and II
b) II and III
c) III and IV
d) I and IV

20. A star is seen rising from Kolkata (23.5° N, 92° E) at 7:00 pm IST, at about what time IST will it be seen to rise from Mumbai (19° N,72° E)?

a) 7:00 pm
b) 7:20 pm
c) 7:40 pm
d) 8:20 pm

21. Anand wanted to prepare a salt solution of pH 1.0. For that he used solutions of a strong monovalent base and acid. He tried different combinations to obtain the required solution. Can you help him to decide which one is the most correct combination of statements given below?

I. 100ml of (M/10) acid and 100ml of (M/10) alkali.
II. 55ml of (M/10) acid and 45ml of (M/10) alkali.
III. 10ml of (M/10) acid and 90ml of (M/10) alkali.
IV. 75ml of (M/5) acid and 25ml of (M/5) alkali

a) I and III
b) II and IV
c) Only II
d) Only IV

22. The "chief cells" of stomach secrete hydrochloric acid. Consider a hypothetical situation in which the "chief cells" are destroyed resulting in complete inhibition of acid secretion in stomach. In comparison to a normal person, which one of the following is most likely to happen in the stomach during the above condition?

a) Digestion of proteins will increase
b) Digestion of fats will start
c) Digestion of carbohydrates will continue
d) Digestion of fat will decrease

23. Female fruit flies with normal wings were mated with males having vestigial wings. All progeny had normal wings. Based on this observation the following conclusion(s) were proposed:

I. Vestigial wing is a recessive character as compared to normal wing.
II. Alleles for normal and vestigial wings segregate from each other.
III. While flies with normal wings are heterozygous for the alleles controlling the character, flies with vestigial wings are homozygous.

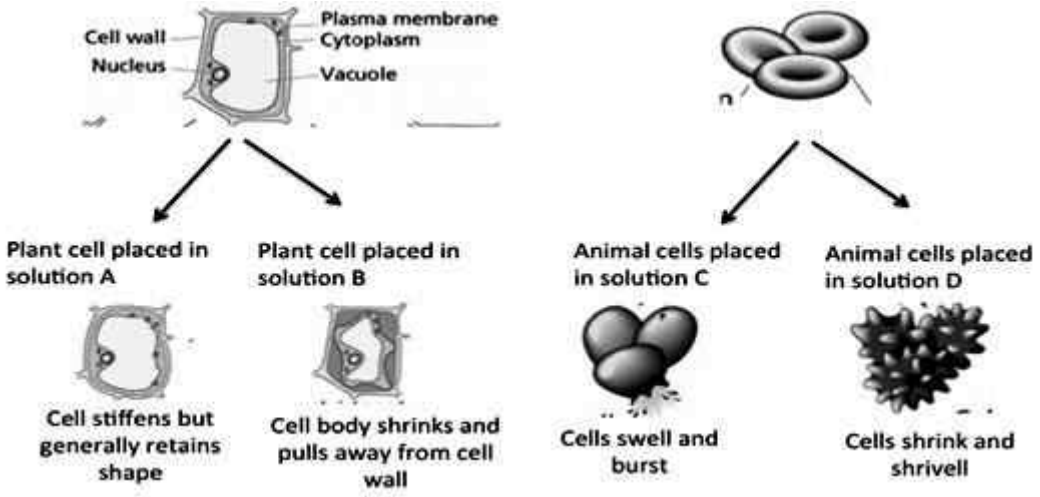
Which of the above statement(s) is/are correct from the above observations?

a) Only I
b) Only III
c) I and II both
d) II and III both

24. A piece of ice, with a stone (denser than water) embedded inside, is kept in a vessel containing water. Size and mass of the stone is such that the stone – ice combination is floating on water. When the ice melts, what will happen to the level of water in the beaker?

a) Water level will rise.
b) Water level will fall.
c) Water level will remain unchanged.
d) Final level of water will depend upon actual density of the stone.

25. In an experiment, plant and animal cells were placed in different solutions (A, B, C and D) as shown below. The outcome of placing them in these solutions is also indicated in the figure.



Identify the nature of the solutions A, B, C and D.

a) A and C are hypotonic, B and D are hypertonic
b) A and C are hypertonic, B and D are hypotonic
c) A and D are hypotonic, B and C are hypertonic
d) A and D are hypertonic, B and C are hypotonic

26. Miska combined one litre oxygen gas and one litre hydrogen gas by applying an electric spark in a vessel at STP. She observed that water is formed. Find the weight of water and the weight of unreacted component respectively.

a) 0.4017 g and 0.7143 g
b) 0.8036 g and 1.4286 g
c) 0.4017 g and 1.4286 g
d) 0.8036 g and 0.7143 g

27. Seema was observing cross section of an unknown plant material which as per her observation was a 'Submerged Hydrophyte'. Which of the following features must have been observed by her to reach this conclusion?

I. Water storage tissues
II. Large air spaces
III. Absence of vascular tissues
IV. Salt glands
V. Sunken stomata
VI. Thick cuticle

a) I, IV and V
b) III and V
c) II and III
d) only V

28. The ABO blood group in humans was first identified by Karl Landsteiner. The four blood groups were identified based on whether blood corpuscles (RBCs) clump (agglutinate) or do not clump in the presence of serum of another individual. Blood groups are defined based on the molecules (antigens) present on RBCs, i.e. A blood group has A antigen, B blood group has B antigen, AB blood group has both A and B antigen, while O blood group have neither A or B antigen. The serum contains antibodies. However, a normal person will not have antibodies for the antigen present on his own RBC. Agglutination occurs during transfusion if serum contains the antibody against the antigen present on the RBC. In the experiment by Landsteiner (Landst.), he mixed the blood corpuscles from five of his colleagues and himself with serum collected from them as shown in the table below. A '+' sign indicated agglutination and '-'indicates lack of agglutination.

Serum	Blood corpuscles of					
	Dr. St.	**Dr. Plecn.**	**Dr. Strul.**	**Dr. Erdh.**	**Zar.**	**Landst.**
Dr. St.	–	+	+	+	+	–
Dr. Plecn.	–	–	+	+	–	–
Dr. Strul.	–	+	–	–	+	–
Dr. Erdh.	–	+	–	–	+	–
Zar.	–	–	+	+	–	–
Landst.	–	+	+	+	+	–

Deduce the blood group of Landsteiner (Landst.).

a) A b) B

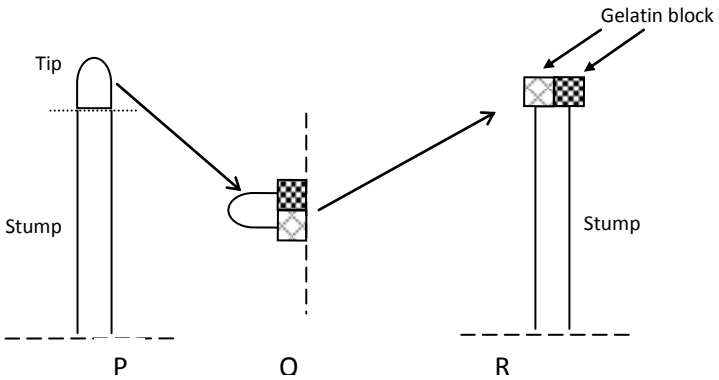
c) O d) AB

29. Evaporation of (sweat) water is an essential mechanism in human beings for maintaining normal body temperature. For human beings, heat of vaporization of water at a body temperature of 37°C is nearly 2.3×10^6 J/kg and specific heat capacity is 3500 $J/kg^{-1}K^{-1}$. On consuming a certain prescribed diet, the body temperature of an athlete of mass 82 kg is expected to increase by 2°C. In order to prevent this, he drinks N bottles of mineral water (250 ml water in each) at 37°C. Assume that the entire amount of this water is given out as sweat, which vaporizes. N is nearly –

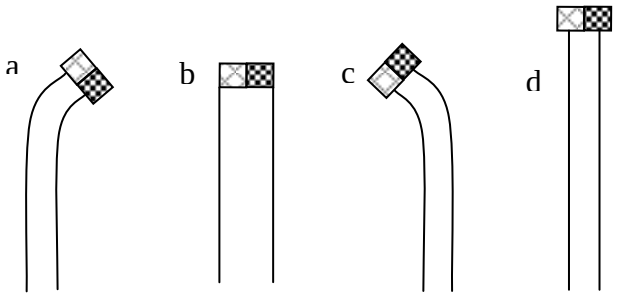
a) 4 b) 3

c) 2 d) 1

30. Plants show phototropism, wherein shoots respond by bending towards light. The plant hormone auxin is responsible for this phototropic effect. An experiment was carried out where the tip of growing seedling was cut and placed horizontally with its cut end in equal contact with two gelatin blocks as shown in the figure (P) below. Auxin diffuses into the gelatin blocks. After some time the gelatin blocks were placed on seedling stump as shown in the figure (R). The complete experiment was carried out in dark condition.



Which one of the following represents the correct result after a few days?



SECTION B

Questions 31 to 42 are long questions. Marks are indicated in the brackets. Answer the questions only in the answer sheet provided.

QUESTION 31

31.A. Zinc and iron are two metals which have many uses and they are part of the process of galvanizing. Zinc is 24th most abundant element in earth's crust. It has five stable isotopes. The most common ore of zinc is zinc sulfide. Zinc is extracted from its ores by the process of roasting and calcination. In roasting zinc sulfide ore is converted into zinc oxide when heated in excess of oxygen. Zinc is also extracted from its carbonate ore by the process of calcination where it is heated at very high temperature and converted into zinc oxide. Both reactions are carried out in different reaction vessels. Zinc oxide is heated with carbon to extract the metal.

[2.0]

I) Write balanced chemical equation for the process of roasting.

II) Write the balanced chemical equation for the process of calcination.

III) Write balanced chemical equation when zinc oxide is heated with carbon.

31.B. The iron pillar near Qutub Minar in Delhi was built more than 1600 years ago by metallurgists in India. They had developed the process which prevents iron from rusting. It has been examined by scientists from all over the world. Iron can be extracted from its ore Hematite by **Thermite reaction.**

[2.0]

I. Which of the following statement is correct about Thermite reaction?

i. It is an endothermic reaction between Alumina and iron where iron acts as reducing agent and Alumina acts as oxidizing agent.

ii. It is an exothermic reaction between Alumina and iron where iron acts as oxidizing agent and alumina acts as reducing agent.

iii. It is an exothermic reaction between iron oxide and aluminium where aluminium acts as oxidizing agent and iron acts as reducing agent.

iv. It is an exothermic reaction between iron oxide and aluminium where aluminium acts as reducing agent and iron acts as oxidizing agent.

II. Write balanced equation for Thermite reaction?

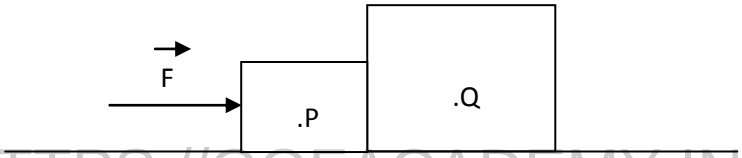
31.C. An iron cylinder contains helium at a pressure of 250 kPa at 300 K. The cylinder can withstand a pressure of 1 x 10^6 Pa. If the room in which the cylinder is placed catches fire, predict whether the cylinder would blow up before it melts (melting point of cylinder is 1800 K). [1.0]

[Total = 5 marks]

QUESTION 32

32.A. Pralay pushes two solid cubical boxes P and Q (that stay in contact) along a rough horizontal table by applying a horizontal force *F* on P. Box P has a mass of 4.0 kg and box Q has a mass of 8.0 kg having same density. Coefficients of kinetic friction between block P and table is 0.4 and that between block Q and table is 0.6.

I) Calculate *F*, if both the boxes are moving with constant speed.
II) Determine magnitude and direction of the resultant reaction force exerted by the table on the block Q.
III) Draw a labeled diagram in right proportion indicating all the forces acting on both the blocks. [3.0]



32.B. A student of mass 75 kg rides a bicycle of mass 25 kg. The student has a habit of standing on the paddle, one leg at a time, so that the force of his weight drives the bicycle. Distance between the top and the bottom positions of the pedal is 20 cm. Ratio of the paddle wheel (bigger) and the gear (on the rear wheel) is 10. Radius of the rear wheel of the cycle is 50 cm. the student takes 6 seconds for one full pedal (both the legs) and spends only that much energy so that the cycle runs continuously with constant velocity.

I) Calculate the average power that the student provides to the cycle.
II) Calculate the kinetic energy of only the cycle during this uniform motion.
III) What fraction of this kinetic energy (of the cycle) is the loss of energy in various dissipation mechanisms during one full pedal?

[3.0]

[Total = 6 marks]

QUESTION 33

Whenever we charge a conductor, its electrical potential goes on increasing (as work is done). At any instant, the charge to potential always bear a constant ratio (q/V = constant). This constant is defined as the capacitance C of the conductor. Capacitor is just a mechanical

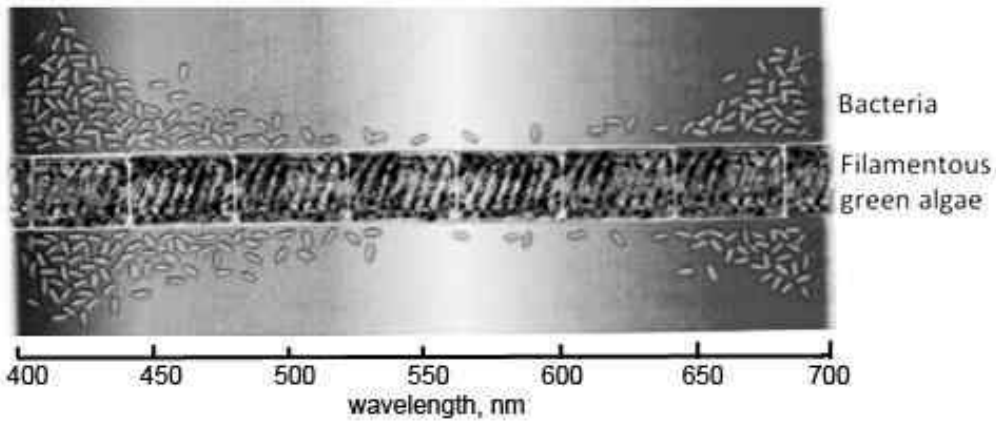
arrangement to increase the capacity of an isolated conductor that makes it possible to store more charge at less potential. Electron volt (1 eV = 1.6 x 10^{-19} J) is a much smaller unit of energy, popularly used for energies of electron.

In detection of nuclear radiation, scintillation detector is a very useful device which converts high energy radiation into a more readable quantity like voltage. This detector consists of a scintillator which converts high energy radiation into low energy photons. For a material called Anthracene 15 photons are generated per 1000 eV radiation absorbed. These low energy photons are then incident on a photomultiplier which generates electrons with an efficiency of 10% in its initial section. The number of electrons generated is too low to be read by any device. To convert the number of electrons to a measurable signal, later section of photo multiplier multiplies this number of electrons by a multiplication factor `f'. These electrons (basically charges) are then collected in a capacitor to produce a voltage across capacitor V.
Now let 10 keV β particles be incident on such a detector. Assume that all photons produced by the scintillator reach the photomultiplier. If the capacitance of the capacitor is 120 pF, and it produces a voltage of 2 mV, then find out the multiplication factor of photomultiplier.

[Total = 3 marks]

QUESTION 34

In 1883, Theodor W. Engelmann carried out an experiment to determine which wavelengths of light are most effective in driving photosynthesis. He illuminated a filamentous alga with white light that had been passed through a refracting prism, exposing different segments of algae to different wavelengths of light. He used aerobic bacteria that concentrate near an oxygen source indicating different rates of O_2 release. The picture below illustrates the result of the experiment.



I) From the above figure which of the following wavelength(s) (nm) of light drive the highest rate of photosynthesis:

(i) 400 (ii) ~425 (iii) 500 (iv) ~550 (v) 600 (vi) ~680 (vii) 700

II) What colors of the spectrum are absorbed in the wavelengths chosen by you in the above answer?

III) Which pigment in the leaves absorb the colors in the answer to (B) above?

IV) Plant leaves appear green in color because pigments in leaves _____violet-blue and red light and _____ green light. **[Choose between absorb and transmit to fill in the blank. Provide only the correct option in the correct order in your answer sheet.]**

V) Can photosynthesis occur in red light? Yes/No

VI) Why was oxygen sensing bacteria used in this experiment? Answer with the help of a chemical equation representing photosynthesis.

VII) The ability of a pigment to absorb various wavelengths of light can be measured with an instrument called a _____ **[Fill in the blank. Provide only the correct option in your answer sheet].**

[Total = 5 marks]

QUESTION 35

Acid base reactions are extremely common in nature and therefore it is of utmost interest to a chemist. A chemist gets a sample of drain cleaner and wants to find out the exact amount of sodium hydroxide present in it. He uses 23mL of 0.9M Phosphoric acid to completely neutralize the base.

I) Write the balanced chemical equation for the reaction.

II) How many grams of Sodium hydroxide did the chemist find in the sample?

III) A chemist needs to find the molarity of 10% w/w HCl. What is the molarity of the solution if the density of the solution is 1.047 g/cm^3 and molecular weight of HCl is 36.5g/mole

IV) There are many acid base reactions that take place in the body. If the acid content in the stomach is increased, antacids are used to neutralize it. A particular sample of antacid tablet contains sodium bicarbonate. When ingested, it reacts with the gastric juice (hydrochloric acid) in the stomach to give off carbon dioxide gas. When a 1.2 g tablet reacted with 40.00 mL of hydrochloric acid (density: 1.140 g/mL), carbon dioxide gas was evolved and the resulting solution weighed 46.7 g. Calculate the volume of carbon dioxide gas released at STP if its density is 1.98 g/L.

[Total=5 marks]

QUESTION 36

36.A. One of the popular astronomical objects is a black hole, having enormous density and hence enormous gravity.

The gravity inside a boundary around a black hole is so immense that even light cannot escape from within this boundary (that is why these objects are called black hole). This boundary is called the event horizon. The event horizon is spherical. Radius of the event horizon of a black hole is known as Schwarzschild radius.

Schwarzschild radius depends upon mass (m) of the black hole, universal gravitational constant (G) and speed of light (c) in vacuum.

I) Determine x, y & z if the Schwarzschild radius of event horizon is given by $r = 2[G^x\ c^y\ m^z]$.

II) Calculate Schwarzschild radius of the earth (mass of the earth = 6×10^{24} kg) if it gets converted into a black hole. By how much will the gravitational force between the earth and the moon change? [2.0]

36.B. At $t = 0$, Prashant is at $x = 0$ when he sees Milind at $x = 6$ m. Prashant now begins to run towards Milind with 5 m/s, while Milind begins to run ***towards*** Prashant with $a = 2\text{m/s}^2$.

I) When and where will they cross? Also plot their displacement – time plots together**.**

II) Prove that Prashant will cross (meet) Milind twice if Milind accelerates away from Prashant (from his original position, at t = 0) with $a = 2\ \text{m/s}^2$. Also plot their displacement time plots together**.** [4.0]

[Total = 6 marks]

QUESTION 37

Rising CO_2 levels are a cause of concern as it has been linked to many climate changes. A suggested solution is phytosequestration- storing CO_2 in plants *instead* of keeping it in the air.

CO_2 is "fixed" by the plants to produce sugars: in presence of sunlight, CO_2 reacts with water to form sugar ($C_6H_{12}O_6$) with release of O_2.

I) Write the balanced chemical reaction for the above process.

II) The idea behind phytosequestration is to grow enough plants so that the carbondioxide released by fossil fuel combustion is safely sequestered in the plant biomass. What weight of biomass (sugar) is made when the carbon from 1 ton of bituminite coal (70% weight of Carbon) is sequestered?

III) The heat of combustion of coal is 21 MJ/kg. Efficiency of converting heat to electricity of a standard coal fired power plant is 30%. A thermoelectric power plant of capacity 500 MW runs for 8000 hours in a year. How much coal must be burned in a year to run the plant?

IV) The most optimistic estimate of biomass growth rate puts it at 50 tons of biomass per hectare per year. How much land, in hectares, is necessary to sequester the carbon-dioxide emitted by one such 500 MW power plant?

V) At a given place, the average solar insolation is about 800 W/m^2 and there are about 2000 sunny hours in a year. (1 hectare is 10,000 m^2.) Assuming that the heating value of biomass is equivalent to the heating value of the coal in (III) whose carbon it sequestered, what is the efficiency of solar radiation conversion by biomass i.e. what fraction of the solar radiation incident on the fields can be converted to electricity?

[Total = 5 marks]

QUESTION 38

Potassium chlorate ($KClO_3$) decomposes on heating into potassium chloride (KCl) and oxygen (O_2) gas. Potassium bicarbonate ($KHCO_3$) decomposes on heating to give potassium carbonate (K_2CO_3) and releases water vapour and carbon dioxide. Potassium carbonate (K_2CO_3) on further heating decomposes to potassium oxide (K_2O) and carbon dioxide. However, potassium chloride (KCl) does not decompose on further heating.

Dina has a mixture of potassium chlorate, potassium bicarbonate and potassium carbonate. When she heated 1000g of the mixture, she observed that 18g water vapour, 290g carbon dioxide and 40g oxygen gas. Assuming complete decomposition, what is the composition of the initial mixture in weight%?

[Total = 5 marks]

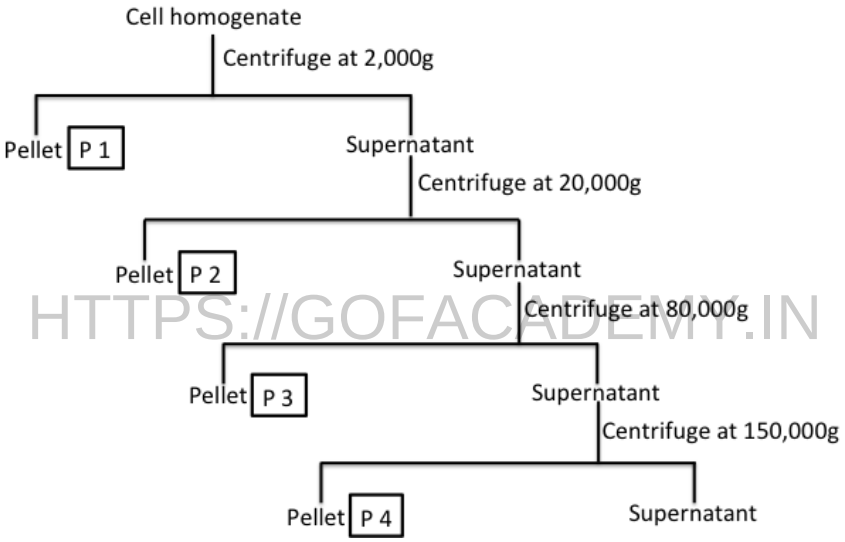
QUESTION 39

Two projectiles are fired simultaneously from ground level with same initial speed (u). Both cover same horizontal distance of 160 m on reaching the ground level. One of them reaches 6 sec. prior to the other. Only gravitational acceleration g = 10 m/s^2 governs the motion of both the projectiles. Calculate (u).

[Total = 5 marks]

QUESTION 40

By the process of mechanical breaking such as homogenization in a blender homogenizer, the membranes of cells can be broken to make a cell homogenate. Sub-cellular organelles such as nucleus, mitochondria, ribosome particles and membrane fractions remain present in the homogenate. The different organelles from the above homogenate can be separated from one other by a process called as cell fractionation. Since, these organelles vary in their size; they can be selectively pelleted (sedimented) by differential centrifugation. Experiments on cell fractionation have established the required relative centrifugal force (RCF) to pellet selectively one organelle while the other organelles remain in the supernatant. In the repeated centrifugation process of organelle isolation, the organelles are separated on the basis of their size, where the larger organelles are pelleted at low RCF (g) and smaller organelles are pelleted at higher RCF (g). Given below is a scheme of such an isolation process.



I) Predict which organelle(s) from the following: nuclei, mitochondria and ribosome, will be present in P1, P2 and P4 pellet fraction. P3 contains the membrane fractions. (Provide the correct answers in your answer script)

P1_____

P2_____

P3 Membrane Fraction

P4_____

II) Different organelles can selectively be stained by taking into consideration their composition and function. Below is a chart of different type of stains used for staining different organelles. Predict which stain can be used for staining the P1, P2 and P3 fractions, independently. **(Choose only the best stain for each from the list below. (Provide the correct answers in your answer sheet.)**

Stain	Specificity
Redox dyes	ATP generation centers
Hematoxylin (basic dye)	DNA and RNA
Acidic stain	Lysosome
Lipophilic stains	Lipid containing organelles

P1 _____
P2 _____
P3 _____

III) Slim tea presently used for shaping body, contains 2,4-Dinitrophenol (DNP) which acts as a proton ionophore, an agent that can shuttle protons (hydrogen cations) across biological membranes. It dissipates the proton gradient across membranes, collapsing the proton motive force that the cell uses to produce most of its ATP (chemical energy). Now in the cell the energy of the proton gradient is lost as heat instead of producing ATP.

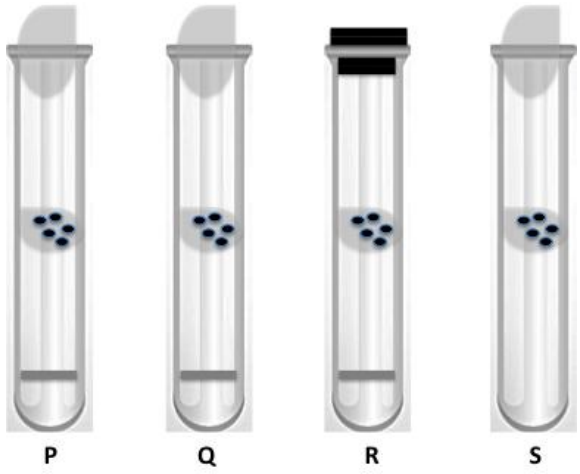
With this information, predict membranes of which sub-cellular organelle(s) of a plant and an animal cell will be mostly affected by consumption of slim tea.

IV) A person unknowingly consumed some poisonous substance. Which sub-cellular organelle of the patient would contain the maximum concentration of the toxin?

[Total = 5 marks]

QUESTION 41

During the study of factors affecting germination, Lata used 4 tubes P, Q, R and S. Seeds of green gram were subjected to different condition as described below



P- Seeds soaked in water were kept on moist cotton wool and placed in a tube with water. The tube was closed with loose cotton wool and kept at 25°C

Q- Same arrangement as above (P) but tube stored at 4°C

R- Seeds soaked in water was kept on moist cotton wool and placed in a tube with Pyrogallol instead of water. Pryogallol removes oxygen. The tube was closed tightly with a wooden block and kept at 25°C

S- Dry seeds kept on dry cotton wool, kept at 25°C without adding water.

Every experiment should have controls. A control can be positive or negative. Negative control is a condition where the phenomenon (germination of seeds in this example) is not expected to happen while in positive control the phenomenon is expected to happen with respect to the parameter being tested.

(For questions I-V, provide only the correct option number in your answer sheet.)

I) Which tube will have the highest frequency of germination
(i) P (ii) Q (iii) R (iv) S

II) Which tube serves as a positive control?
(i) P (ii) Q (iii) R (iv) S

III) Which tube works as negative control for oxygen?
(i) P (ii) Q (iii) R (iv) S

IV) In the above experiment the influence of which of the following factor(s) on germination is/are being tested?
(i) O_2 and H_2O only
(ii) CO_2 and Pyrogallol only
(iii) O_2 , H_2O and temperature
(iv) Only H_2O

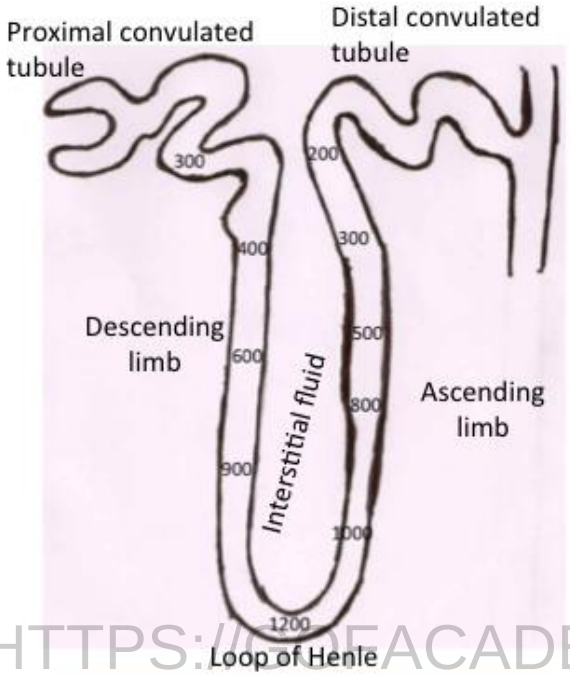
V) What is most likely to happen to the frequency of germination in tube R if the wooden block is replaced with loose cotton wool?
(i) No change in germination frequency
(ii) Increase in germination frequency
(iii) Decrease in germination frequency

[Total = 5 marks]

QUESTION 42

The nephron is a basic unit of kidney which is made of Bowman's capsule, proximal convoluted tubule, loop of Henle and distal convoluted tubule. The proximal convoluted tubule absorbs major amount of water, glucose, other essential elements from the filtrate but still around 180 liters of filtrate passes through loop of Henle daily, out of which only 1 – 2 liters is thrown out of body in the form of concentrated urine. Hence Loop of Henle plays a

crucial role in reabsorption of water and salts. The Loop of Henle is located in medulla part of kidney and consists of descending and ascending limb. The ascending one has thicker walls which are non permeable to water. It is important factor for creating concentration gradient throughout the loop's length. The filtrate entering the loop has 300 units concentration and it keeps on changing as shown in the figure due to reabsorption process. Study the diagram and answer the following questions.



(For questions I-V, provide only the correct option number in your answer sheet.)

I) The concentration of filtrate increases as it passes down the descending tubule due to reabsorption of _____ in the interstitial fluid:

(i) NaCl
(ii) Water
(iii) Amino acids
(iv) Glucose

II) In ascending tubule the filtrate shows decrease in concentration as it reaches distal convoluted tubule. This is because of:

(i) active transport of water from interstitial fluid to ascending tubule.
(ii) active transport of salts from ascending tubule to interstitial fluid.
(iii) passive transport of salts from interstitial fluid to ascending tubule.
(iv) passive transport of water from interstitial fluid to ascending tubule.

III) In an animal 'X', Loop of Henle is shorter than normal length. The result would be:

(i) It will excrete lesser amount of concentrated urine.
(ii) It will excrete same amount of urine without any difference.
(iii) It will excrete large amount of dilute urine.
(iv) It will excrete lesser amount of dilute urine.

IV) What is the likely habitat of such animal 'X'?

(i) Aquatic
(ii) Hot, Arid desert
(iii) Polar
(iv) Grasslands

V) An artificial kidney is a device to remove nitrogenous waste products from the blood during dialysis. The device contains tubes that are suspended in a tank filled with dialyzing fluid. The patient's blood is passed through these tubes. During this passage, waste products from the blood pass into the dialyzing fluid.
Pick the correct options given below to fill the blanks in the following statement:

"The tubes of the artificial kidney are _____, while the dialyzing fluid is _____to the blood. The waste products from the blood pass into the dialyzing fluid by _____transport."

(i) semipermeable, isotonic, passive
(ii) permeable, hypotonic, active
(iii) permeable, isotonic, passive
(iv) semipermeable, hypotonic, active

[Total = 5 marks]

SECTION A

Q. No.	(a)	(b)	(c)	(d)	Q. No.	(a)	(b)	(c)	(d)
1	☐	☐	☐	☒	16	☒	☐	☐	☐
2	☐	☐	☐	☒	17	☐	☐	☐	☒
3	☐	☒	☐	☐	18	☐	☒	☐	☐
4	☒	☐	☐	☐	19	☒	☐	☐	☐
5	☐	☐	☒	☐	20	☐	☐	☐	☒
6	☐	☐	☒	☐	21	☐	☐	☐	☒
7	☐	☒	☐	☐	22	☐	☐	☒	☐
8	☐	☒	☐	☐	23	☒	☐	☐	☐
9	☒	☐	☐	☐	24	☐	☒	☐	☐
10	☐	☐	☐	☒	25	☒	☐	☐	☐
11	☐	☐	☒	☐	26	☐	☐	☐	☒
12	☐	☐	☐	☒	27	☐	☐	☒	☐
13	☐	☒	☐	☐	28	☐	☐	☒	☐
14	☐	☒	☐	☐	29	☐	☐	☐	☒
15	☐	☐	☐	☒	30	☒	☐	☐	☐

(For questions 31-42 all valid alternative solutions have been considered)

31. A.

I) $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$

II) $ZnCO3 \longrightarrow ZnO + CO_2$

III) **$ZnO + C \longrightarrow Zn + CO$**

$ZnO + CO \longrightarrow Zn + CO_2$

OR

$2ZnO + C \longrightarrow 2Zn + CO_2$

31. B.

I. iv. It is a reaction between iron oxide and aluminium where aluminium acts as reducing agent and iron acts as oxidizing agent and reaction is exothermic.

II. $Fe_2O_{3(s)} + 2Al_{(s)} \longrightarrow Al_2O_{3(s)} + 2Fe_{(l)}$

31. C.

P1 / T1 = P2 / T2 at constant volume

P2 = $(250 \times 10^3 \times 1800)/ 300 = 1.5 \times 10^6$ Pa

Hence the cylinder will blow up.

32. A.

I) Consider P + Q as a system. As the speed is constant, applied force must be equal and opposite of total frictional force (or balances total frictional force).

$$\therefore F = (\mu_P m_P + \mu_Q m_Q)g = 64 \text{ N}$$

II) Block Q experiences two forces from the table

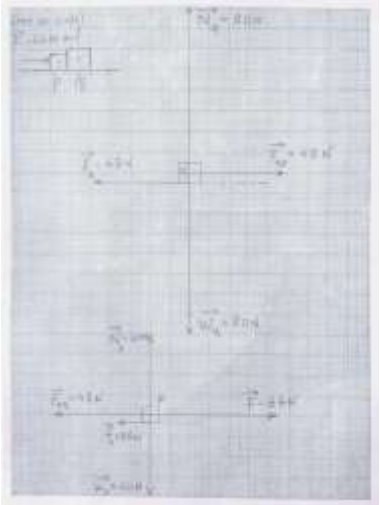
A) Horizontal frictional force $\mu_Q . m_Q . g = 48$ N

B) Vertical (normal) reaction force (numerically) equal to weight $W_Q = 80$ N

This gives magnitude of the reaction force as $R = \sqrt{48^2 + 80^2} = 16\sqrt{34} = 93.29$ N

Direction of $\vec{R}$ makes angle of $tan^{-1}(5/3)$ with the horizontal, inclined towards P.

III)



32. B.

I) P = 300J/6 = 50 W

II) K = ½ mv^2 = ½ x 25 x $(31/6)^2$ = 334 J

III) The student provides 300J of energy to the cycle in one full pedal. However the kinetic energy of the cycle remains constant as it moves with uniform velocity. So 300 J of energy is lost in dissipation in one full pedal.

Fraction = 300/334 = 0.9 or 90%

33.

1000 eV β particle will give 15 low energy photons.

So 10 keV i.e. 10,000 eV β particle will give 150 photons.

At 10% efficiency photomultiplier will generate 15 electrons.

Now these 15 into m i.e. 15m electrons will generate a charge of 15fq.

C=120 pF and voltage is 2 mV so Q on capacitor is CV = 120 x 10^{-12} x 2 x 10^{-3} = 240x10^{-15} Q

Which is same as f x 15 x 1.6 x 10^{-19}Q ➔ f=$10^{5.}$

34.

I. (ii) ~425

II. Violet-blue, violet or blue.

III. Chlorophyll

IV. Plant leaves appear green in color because pigments in leaves **absorb** violet-blue and red light and **transmit** green light.

V. Yes

VI. $6CO_2 + 12\ H_2O$ + Light energy ------> $C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$
OR , $6CO_2 + 6H_2O$ + Light energy ------> $C_6H_{12}O_6 + 6O_2$. Release of oxygen is a measure of rate of photosynthesis in this experiment. Thus oxygen sensing bacteria was used in this experiment.

VII. Spectrophotometer / colorimeter

35.

I) $3NaOH + H_3PO_4 \longrightarrow Na_3PO_4 + 3H_2O$

II) 23mL of 0.9M of H_3PO_4 gives 0.0207 moles. Which implies 0.0621 moles of NaOH is consumed. 1 mole of NaOH is 40 grams and therefore 0.0621 moles of NaOH gives 2.48 grams.

III) 10% solution ⇒ 10 g of HCl are found in 100 g of the solution

The mass 100 g is converted to volume of the solution using the density: $\rho = m/V \rightarrow V = m/\rho$

(V = 100/1.047 = 95,5 mL) ⇒ 10 g of HCl are found in 95.5 mL of the solution. Therefore 104.7 g of HCl are found in 1000 mL of the solution.

1 mol = 36.5 g
x mol = 104.7 g
Therefore x = 2.87 and hence it is a 2.87 M solution

IV) Mass of HCl is 40X1.140 = 45.60 grams
Therefore mass of reactants = 1.2 + 45.60 = 46.80 g
But mass of reactants = mass of products
46.80g = mass of solution + mass of CO_2
46.80g = 46.7g + mass of CO_2
Therefore mass of CO_2 = 0.1g
Volume of CO_2 is 0.1/1.98 = 0.051 L

36. A.

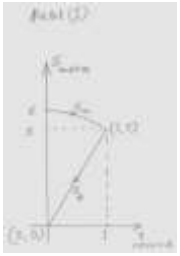
I) from dimensional analysis, x = 1, y = - 2 & z = 1, $r_s = 2Gm/c^2$

II) r_e = 0.9 cm.

Gravitational force between earth and the moon is unaffected.

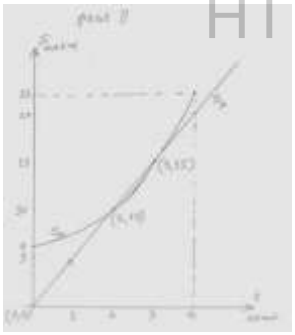
36. B.

I) At the instant they cross, $s_m = 6 - s_p$ ∴ t^2=6-5t ∴t=1



II) In this case, $s_p = s_m + 6$ ∴ $5t = t^2 + 6$

$\therefore t = 2\ s\ (Prashant\ overtakes)\ and\ 3\ s\ (Milind\ overtakes)$



37.

I) $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

II) 70% of 1 ton is 700 kg of Carbon.
Mol. Wt of sugar is 180 gm/mol of which 72 gm/mol is Carbon.
Hence carbon is 72/180*100 = 40% of sugar.
Hence 700 kg carbon corresponds to 700/0.4 = 1750.0 kg of sugar/biomass.

III) $500MW$ over 8000 hrs is $500 \times 8000 \times 3600MJ$ of electricity.

At 30% power plant efficiency, this needs: $500 \times 8000 \times \frac{3600}{0.3} MJ$ of heat. i.e. $500 \times 8000 \times \frac{3600}{0.3} \times \frac{1}{21}$ kg of coal i.e. 2.3 MT (mega tons) of coal.

IV) We need to sequester 2.3 MT of coal. 1 ton of coal needs 1.75 tons of biomass to sequester. Hence we need to grow 1.75×2.3MT= 4 MT of biomass of biomass.
Since 1 hectare produces 50 tons of biomass per year, 4 megatons of biomass will need 4/50=0.08 million hectares of land i.e. 80,000 hectares of land.

V) 80,000 hectares of land will receive $80000 \times 10000 \times 800 = 640 \times 10^9$ watts of solar radiation i.e. in a year, $640 \times 10^9 \times 2000 \times 3600 = 4.6 \times 10^{18} J$ of solar energy.
This is turned into $500 \times 10^6 \times 8000 \times 3600 = 1.44 \times 10^{16} J$ of electricity.

Solar to electric conversion efficiency is therefore: $\frac{1.44 \times 10^{16}}{4.6 \times 10^{18}} \times 100 = 0.3$

38. $2KClO_3 \rightarrow 2KCl + 3O_2$

$$2 \times 122.5 = 2 \times 74.5 + 96$$

$$i.e. 1\ gm\ KClO_3 = \frac{96}{2 \times 122.5} = 0.39\ gm\ O_2$$

$$2KHCO_3 \rightarrow K_2CO_3 + H_2O + CO_2$$

$$2 \times 100 = 138 + 18 + 44$$

$$i.e. 1\ gm\ KHCO_3 = \frac{18}{2 \times 100} = 0.09\ gm\ H_2O, \frac{44}{2 \times 100} = 0.22 gm\ CO_2$$

$$K_2CO_3 \rightarrow K_2O + CO_2$$

$$138 = 94 + 44$$

$$i.e. 1\ gm\ K_2CO_3 = \frac{44}{138} = 0.32\ gm\ CO_2$$

Let w, c, o be the weight of water, carbondioxide and oxygen evolved.

Since all oxygen comes from chlorate, hence the weight of $KClO_3$ in the sample is $\frac{o}{0.39} = \frac{40}{0.39} = 102\ gm.$

Since all water comes from bicarbonate, hence the weight of $KHCO_3$ in the sample is $\frac{w}{0.09} = \frac{18}{0.09} = 200\ gm.$

The remainder is potassium carbonate i.e. the weight of K_2CO_3 is $1000 - 200 - 102 = 698\ gm$

Hence the composition of the original mixture is: 10.2% chlorate, 20% bicarbonate and 69.8% carbonate.

39.

As both the projectiles have the same horizontal range, their angles of projection must be complementary. $\therefore sin\theta_2 = cos\theta_1$

Time of flight, $T = \frac{2usin\theta}{g} \quad \therefore T_1 = \frac{2usin\theta}{g}$ and, $T_2 = \frac{2ucos\theta}{g}$

Horizontal range, $R = (ucos\theta)T = \frac{u^2 \sin 2\theta}{g} = \frac{g}{2} \times \frac{2usin\theta}{g} \times \frac{2ucos\theta}{g} = \frac{g}{2} \times T_1 \times T_2$

$$(T_1 - T_2)^2 = T_1^2 + T_2^2 - 2T_1T_2$$
$$\therefore (T_1 - T_2)^2 = \frac{4u^2}{g^2} - \frac{4R}{g}$$
$$\therefore u^2 = g\left[\frac{g}{4}(T_1 - T_2)^2 + R\right] = 2500$$

$$\therefore u = 50 \text{ m/s}$$

Alternate solution:

$t_1 = \frac{2u.sin\theta}{g}$ $\quad t_2 = t_1 - 6 = \frac{2u.cos\theta}{g}$

$160 = \frac{2u^2.cos\theta.sin\theta}{g} = \frac{2}{g} \times \frac{gt_1}{2} \times \frac{g(t_1-6)}{2}$

Forming and solving quadratic equation in t_1, we get $t_1 = \sqrt{41} + 3$ & $t_2 = \sqrt{41} - 3$

Using $sin\theta$ and $cos\theta$ from the expressions of t_1 & t_2 in $(sin^2\theta + cos^2\theta = 1)$, we get $u^2 = 2500$

$\therefore u = 50$ m/s

40.

I)

P1 nuclei

P2 mitochondria

P3 Membrane Fraction

P4 ribosome particles

40. II.

P1. Hematoxylin

P2. Redox dyes

P3. Lipophilic stains

40. III.

In animal cells: Mitochondria In plant cells: Mitochondria and chloroplast

40. IV.

Smooth Endoplasmic Reticulum

41.

I. (i) P

II. (i) P

III. (iii) R

IV. (iii) O_2 , H_2O and temperature

V. (ii) Increase in germination frequency

42.

I. (ii) Water

II. (ii) active transport of salts from ascending tubule to interstitial fluid.

III. (iii) It will excrete large amount of dilute urine.

IV. (i) Aquatic

V. (i) semipermeable, isotonic, passive