IOQJS

2021 - 2022

PAPER WITH SOLUTION

मोशन के परिणाम ही है, सफलता का प्रमाण

JEE MAIN 2021 RESULT
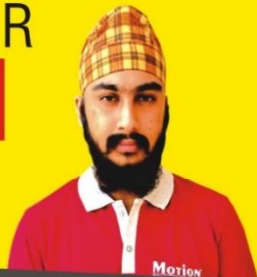
AIR 1 — Guramrit Singh
AIR 11 — Kumar Satyadarshi
AIR 53 — Ayush Agarwal
AIR 90 — Sanket Singh

Students Qualified for **JEE ADVANCED** **2994/4087** = **73.25%**

JEE ADVANCED 2021 RESULT

AIR 26 — Guramrit Singh
AIR 32 — Rudransh Aggarwal
AIR 61 — Harsh Poonia
AIR 88 — Tejas Kumar
AIR 100 — Rajat Golechha

24 Student Under 500
41 Student Under 1000

Motion's Selection **1256/2994** = **41.95%**

NEET 2020 RESULT

AIR 21 — Kartikey Agarwal
AIR 51 — Ronit Singh
AIR 161 — Cyril Joel Deva Asir
AIR 164 — Rahul Yadav

Above 650 Marks **12**
Above 625 Marks **47**
Above 600 Marks **137**

Students Qualified **2663 / 2843** = **93.66%**

PART – 1

1.   The Variation of a certain physical parameter Z with variable u is given by the relation

$Z = A\left(\dfrac{R}{R+u}\right)^3$, where R and A are constants and the maximum value of u<<R. Then to

find R, a student plots a graph of variation of Z (Y-axis) against u (X axis). The graph is
a

(A) straight line passing through origin and slope = $\dfrac{R}{3}$

(B) straight line with intercept $\dfrac{3A}{2}$ and slope = $-\dfrac{R}{3A}$

(C) straight line with intercept A and slope = $-\dfrac{3A}{R}$

(D) straight line with intercept $-\dfrac{A}{2}$ and slope = $-3R$.

Sol.   **Data Missing (Question is Incorrect)**

2.   A submarine S_1 is parked at a depth of 200 m in an ocean on earth. Assume oceans exist on Mars. At about what depth a submarine S_2 has to be parked in an ocean on Mars so that S_2 will experience same pressure as that of S_1? Acceleration due to gravity on Marks is 3.7 m/s². (Assume that sea water density on Earth and Mars is same, $\rho = 1.03 \times 10^3$ kg /m³)

(A) 158 m   (B) 435 m   (C) 530 m   (D) 616 m
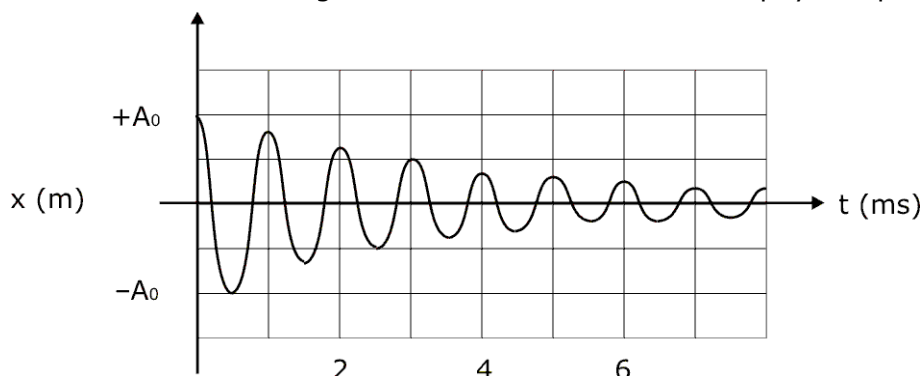
Sol.   **(C)**

$\rho g_1 \, h_1 = \rho g_2 h_2$

$1.03 \times 10^3 \times 9.8 \times 200 = 1.03 \times 10^3 \times 3.7 \times h_2$

$h_2 = 530\,m$

3.   In an oscillating system, damping results in dissipation of the stored energy. The following figure shows the variation of displacement x with time t for an oscillating system. Which of the following statements best describes this physical phenomenon.


(A) Oscillatory motion of an object without damping

(B) Oscillatory motion of an object with damping such that time measurement was started when the system was at the mean position.

(C) Oscillatory motion of an object with damping with decreasing time period.

(D) Oscillatory motion of an object with damping such that time measurement was started when the system had maximum potential energy.

Sol. **(D)**

It is starting from maximum displacement from mean position ($+A_0$)

So, that potential energy will be maximum at start and according to the graph displacement is decreasing with time, so that it is the damped oscillation.
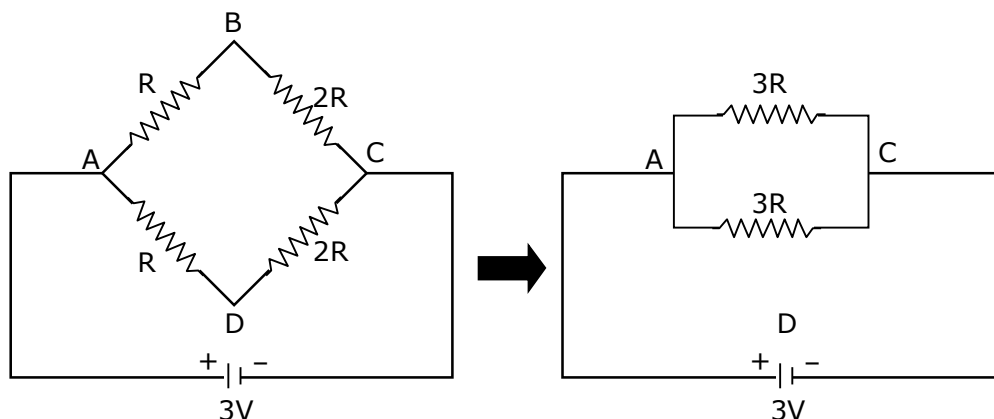
4. In the adjacent circuit, the galvanometer G does not show any deflection. If R = 2Ω, the current drawn from the cell is:
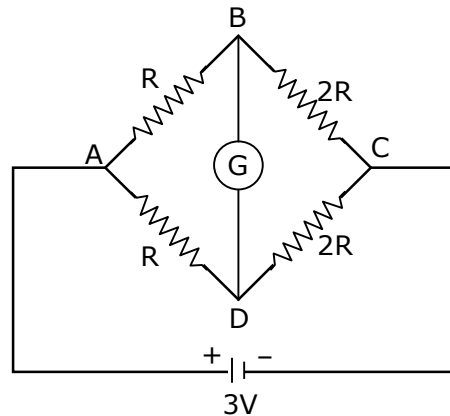
(A) 1 A   (B) 9 A   (C) 4 A   (D) $\dfrac{9}{4}$ A

Sol. **(A)**

Thus the equivalent resistance of the network is = $\dfrac{3R}{2}$ = 3Ω.

By using Ohms Law I = $\dfrac{V}{R} = \dfrac{3}{3} = 1\,A$.

5. 'Gear' is a mechanical system used to transfer mechanical and rotary motion from one mechanical system to another. As shown in the figure below the driving wheel A drives the driven wheel B without slipping and thus forms the gear system. The wheel A has 16 teeth and B has 24 teeth. Wheel B has a projection (shown by white ring in Fig. 1 and also in the side view of Fig. 2) of radius $\dfrac{14}{11}$ cm.
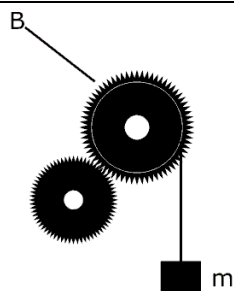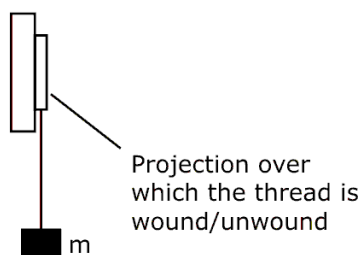
Fig. 1   Fig. 2

A long massless, inextensible string can be would/ unwound over this circular projection. A mass m is attached to the free end of this long string. If the wheel A makes 6 revolutions per second in the clockwise direction, without slipping, then in $\frac{1}{2}$ second the potential energy of the mass m in CGS unit

(A) Increases by 32 mg   (B)decreases by 32 mg
(B) Increases by 16 mg   (D) decreases by 16 mg

Sol. **(C)**

According to the question, wheel A makes 6 revolutions per second in clockwise direction.

Thus, wheel B makes 4 revolutions per second in anticlockwise direction (because wheel B has 24 teeth and A has 16 teeth.

Thus in $\frac{1}{2}$ sec. wheel A makes 3 revolutions and B makes 2 revolutions.

Thus, wheel B move upward by = $2 \times 2\pi r = 2 \times 2 \times \frac{22}{7} \times \frac{14}{11} = 16$

Thus, wheel B move upward by 16 cm thus potential increases by 16 mg.

6. Canopus is the second brightest star in the night sky. It is about 300 light years away. The energy is produced inside the star through nuclear reaction. If we receive 5.0×10^{-8} W/m^2 energy from Canopus, how much mass does it lose per second?

(A) 1.70×10^{-6} kg   (B) 1.91×10^{9} kg   (C) 5.62×10^{13} kg   (D) 6.34×10^{31} kg

Sol. **(C)**

Distance of star = 300 light year = $300 \times 9.46 \times 10^{15}$ m.

Energy received is 5×10^{-8} W m/s^2.

By using energy mass relation.

$\underline{\Delta E} = \frac{\Delta mc^2}{A^2} = \frac{\Delta m \times 9 \times 10^{16}}{4\pi \times (28.38 \times 10^{17})^2}$

On solving,

$\Delta m = \frac{5 \times 4 \times 3.14 \times 805.42 \times 10^{34} \times 10^{-8}}{9 \times 10^{16}} = 5.62 \times 10^{13}$ kg.

7. An average human adult radiates about 100W energy mainly in infra-red region of the electromagnetic spectrum 50 persons are sitting in a hall with an air conditioning system which is 50% efficient. How much electricity must be used to maintain temperature of the hall at 25°c for 4 hours?

(A) 5 units   (B) 10 units   (C) 20 units   (D) 40 units

Sol. **(D)**
Energy radiates by 1 human is 100W
Thus energy radiates by 50 human are = 50 × 100 = 5 kW.
Thus, energy consumed is = $P \times t = 5 kW \times 4 H$

= 20 kWH
AC is 50% efficient thus electricity used will be 20× 2 = 40 kWH.

8. Which of the following is not a function of mature RBCs?
(A) Help in classifying blood in different blood groups
(B) Help in transport of gases
(C) Synthesis of immunoglobulins
(D) Help in maintaining acid base balance in the body

Sol. **(C)**
Because synthesis of immunoglobins is mainly done by WBC'S (B cells)

9. In which of the following classes of vertebrates there are groups of animals without limbs?
(A) Fish, reptiles and mammals   (B) Reptiles only
(C) Reptiles and Amphibians   (D) Amphibians only

Sol. **(C)**
IN GROUP OF ANIMALS – Reptiles and Amphibians have limbless organisms.

10. Which of the following groups have only one pair of wings?
(A) Honey bee, beetle, ant   (B) Butterfly, housefly, fruitfly
(C) Dragonfly, butterfly, fruitfly   (D) Housefly, fruitfly, mosquito

Sol. **(D)**
Following insects have two pairs of wings
HONEY BEE -2 PAIR
BEETLE -2 PAIR
ANT-2 PAIR
DRAGONFLY-2 PAIR

11. During an expedition to planet 'Imagitica', scientists analysed the genetic material of the organisms found there and noted the following features:
i. Amount of purines and pyrimidines is unequal
ii. Absence of thymine
iii. Unstable genetic material, with high frequency of mutation
iv. Rapid degradation at pH above 12
From the above data, what genetic material might the Imagitica inhabitants contain?
(A) ssDNA   (B) dsDNA   (C) ssRNA   (D) dsRNA

Sol. **(C)**
As amount of purines and pyrimidines is unequal so it indicate ssRNA

12. Which to the following is most likely to show aerenchyma?
(A) Leaf base of mango   (B) Petiole of water hyacinth
(C) Seta of moss   (D) Stem of *Opuntia*

Sol. **(B)**
Arenechyma is present in water hyacinth and they are aquatic floating plants.

13.   Given below are three statements about bryophytes:

i. Bryophytes are lower plants with plant body differentiated into root, stem and leaves.

ii. Bryophytes are devoid of xylem and phloem.

iii Bryophytes require water for completion of their life cycle.

Which of the above statement/s is/are true with respect to bryophytes?

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

Sol.   **(D)**

In Bryophytes plant body is not well differentiated.

14.   Carbon fixation in most of the succulent plants takes place through which pathway?

(A) Calvin cycle

(B) Glycolate pathway

(C) Crassulacean acid metabolism pathway

(D) Hatch-Slack pathway

Sol.   **(C)**

As succulent plants follow CAM pathway that allows carbon fixation pathway that evolved in some plants as an adaptation to arid conditions that allows a plant to do photosynthesis during day but only exchange gases at night.

15.   If a flower is large, wide-mouthed, white, showing anthesis after sunset, and emitting fruity or musky fragrance, it is most likely to be pollinated by:

(A) Birds   (B) Bats   (C) Insects   (D) Baboons

Sol.   **(B)**

In the tropics and deserts, bats are often the pollinators of nocturnal flowers such as agave, guava and morning glory. The flowers are usually large and white or pale-coloured so that they can be distinguished from their dark surroundings at night.

16.   Coal is a common fossil fuel. It contains 0.2 to 5.0 percent sulphur which on burning produces a gas responsible for acid rain. The number of atoms in one mole of this gas is-

(A) 6.02×10^{23} (B) 1.81×10^{23} (C) 1.81×10^{24} (D) 1.21×10^{24}

Sol.   **(C)**

$S + O_2 \rightarrow SO_2$
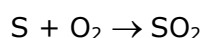
1 mole SO_2 = 3 mole of atom

total no. of atom = $3 \times 6.022 \times 10^{23}$

= 18.066×10^{23}

= 1.8066×10^{24}

17.   The stomach fluid in human contains HCl, KCl and NaCl. The stomach fluid is highly acidic and plays and important role in the digestion of food as well as killing or bacteria. The increased acidity may lead to abdominal pain, nausea, bloating, and heartburn. Such a patient is prescribed antacid tablet which mainly contains aluminium hydroxide (Mol. Wt 78). If the concentrations of HCl, KCl and NaCl are 0.01M each and the stomach fluid volume is 2 litre, the amount of $Al(OH)_3$ required to neutralize the fluid will be-

(A) 0.52 g   (B) 1.08 g   (C) 0.81 g   (D) 2.16 g

Sol.   (A)

concentrate HCl = 0.01 M

no. of millimoles HCl = 2000 × .01

= 20 millimoles

1 moles HCl required 1 mole Al(OH)$_3$ for complete neutrilization

20 millimoles HCl = 20 millimoles of Al(OH)$_3$

Weight of Al(OH)$_3$ = 20 × 78 = 1.56 gm

Minimum weight required is 1.56 gm. So answer is (D).

18.   A 0.500 g mixture of calcium carbonate and calcium oxide was strongly heated to produce a non-combustible gas. If the weight of the residue obtained on heating is found to be 0.434 g, the percentage of calcium oxide in the mixture is-

(A) 70%   (B) 30%   (C) 35%   (D) 60%

Sol.   (A)

CaCO$_3$ +   CaO

(0.5–x)   x

CaCO3 $\rightarrow$ CaO + CO$_2$

Weight of CaO formed

$x + \left(\dfrac{0.5-x}{100}\right) \times 56 = .434$

$x + (0.5 - x).56 = .434$

$x + .28 - .56x = .434$

$.44x = .154$

$x = .35$ gm

CaO $\rightarrow$ .35 gm

CaCO$_3$ $\rightarrow$ .5 − .35 = .15

Percentage of CaO is $= \dfrac{.35}{.5} \times 100 = 70\%$

19.   Arrange the following in the increasing order of their metallic character Na, C, O, Li, Be

(A) C < O < Na < Li < Be   (B) O < C < Be < Na < Li

(C) O < C < Be < Li < Na   (D) C < O < Be < Li < Na

Sol.   (C)

O < C < Be < Li < Na

non-metallic character increases as we move left to right in period.

Metallic character increases as we move top to bottom in group.

20.   A 50 mL of 0.1 M acetic acid solution is taken in a beaker and two wires are dipped in it as shown in following figure.

When electric supply is switched on, the bulb glows, To this solution, distilled water is added slowly till the volume doubles. During the addition of water, the intensity of the bulb-
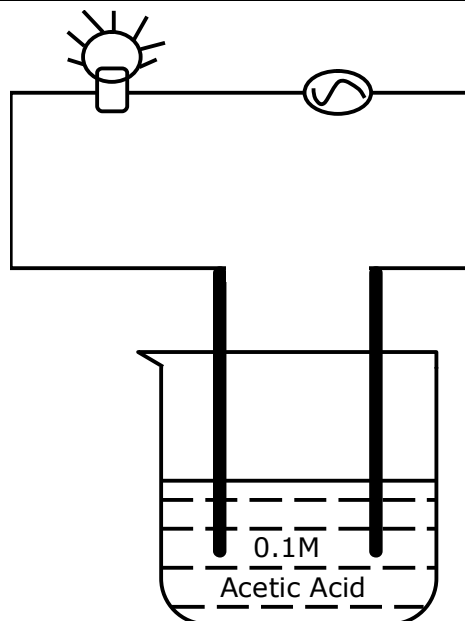
(A) Remains unchanged

(B) Goes on decreasing

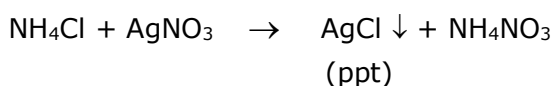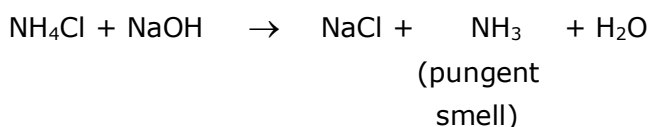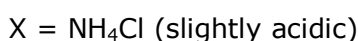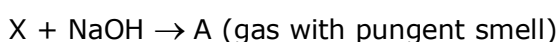(C) Goes on increasing

(D) Suddenly becomes zero

Sol. **(C)**

On dissolution the degree of dissolution increases

So number of ions increases, so more charge will pass which increase the intensity.

21. A compound X when heated with NaOH solution produces a pungent gas that turns red litmus blue. When an aqueous solution of X is treated with $AgNO_3$ solution, a white precipitate Y is obtained which on keeping in sunlight turns grey liberating pale yellowish green gas. The aqueous solution of compound X is -

(A) neutral   (B) slightly acidic   (C) slightly alkaline   (D) strongly acidic

Sol. **(B)**

X + NaOH $\rightarrow$ A (gas with pungent smell)

X(aq.) + $AgNO_3$ $\rightarrow$ Y $\downarrow$

X = NH_4Cl (slightly acidic)

NH_4Cl + NaOH $\rightarrow$ NaCl + NH_3 + H_2O

                                                     (pungent

                                                       smell)

NH_4Cl + $AgNO_3$ $\rightarrow$ AgCl $\downarrow$ + NH_4NO_3

                                    (ppt)

22. Equal masses of two gases among N_2, NO, O_2, CO, CO_2 and SO_2 occupy same volume at STP. These two gases are :

(A) N_2 and O_2 (B) CO and NO

(C) SO_2 and CO_2 (D) N_2 and CO

Sol. **(D)**

Equal mass of two gas contain equal volume at STP have the same molecular weight.

23. When a solution and the pure solvent are separated by a semipermeable membrane, the solution exerts a pressure on the membrane called as osmotic pressure. The osmotic pressure increases with increase in number of particles (ions or molecules) in the solution. If 10 milimoles of each of the sulphate salts of sodium, magnesium and aluminium are dissolved in 1.0 litre of water in three different beakers labelled as P, Q and R respectively, the osmotic pressure follows the order -

(A) P < Q < R   (B) Q < P < R   (C) P > Q > R   (D) P > R > Q

Sol. **(B)**

10 millimoles of Na_2SO_4

10 millimoles of $MgSO_4$

10 millimoles of $Al_2(SO_4)_3$ contains

10 millimoles of Na_2SO_4 Contain 20 Na^+ millimoles & 10 SO_4^{2-} millimoles

Similarly in $MgSO_4$ contains

20 Mg^+ millimoles

20 SO_4^{2-} millimoles

$Al_2(SO_4)_3$ 20 Al^{+3}

   30 SO_4^{2-}

If total no. of ions increases, osmotic pressure also increases

So   R > P > Q

24. The axes of a coordinate system S_2 are inclined at an angle θ to those of another coordinate system S_1. The origins of both the systems are coinciding. A particle P_1 at rest in system S_1, starts from point $(-2, 0)$ and travels along positive direction of X_1 axis with uniform acceleration of 1.25 m/s^2 for 4s and stops. In system S_2, particle P_2, starts from rest from the origin and travels for 2s along positive direction of X_2 axis with uniform acceleration 5m/s^2 and stops. If the final distance between P_1 and P_2 is 6m, then the angle between $+Y_1$ axis and $+X_2$ axis is -

(A) 36.8º   (B) 53.2º   (C) 106.8º   (D) 126.8º

Sol. **(B)**
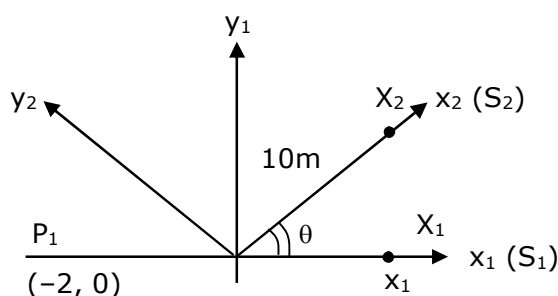
$X_1 = -2 + \dfrac{1}{2} \times 1.25 \times 4^2 = -2 + 10 = 8$

$X_2 = \dfrac{1}{2} \times 5 \times 2^2 = 10$ m

100 cos θ = 8 $\Rightarrow \theta = 37°$

Angle b/w X_2 and Y_1 = 53°

25. According to Einstein's theory, light can be assumed to be in the form of a large number of discrete energy packets called 'photons'. In case of light of frequency ν, each photon carries energy $E = h\nu$. In a certain surgical procedure a surgeon uses LASER beam of wavelength 650 nm is pulses of 30.0 ms duration. The average power of each pulse is 0.6W. Here h is Planck's constant. Then

(A) the frequency of this LASER photon is 4.6×10^{14} Hz

(B) the energy in each pulse is 1.1×10^{17} eV

(C) energy of one photon is 3.1×10^{-19} J

(D) number of photons in each pulse is 5.9×10^{16}

Sol. **(A,B,C,D)**

Given, $\Delta t = 30$ ms

$\lambda = 650$ nm

$P = 0.6$ W $= \dfrac{E}{t}$

$h = 6.63 \times 10^{34}$ J/sec.

(A) $V = \lambda f$
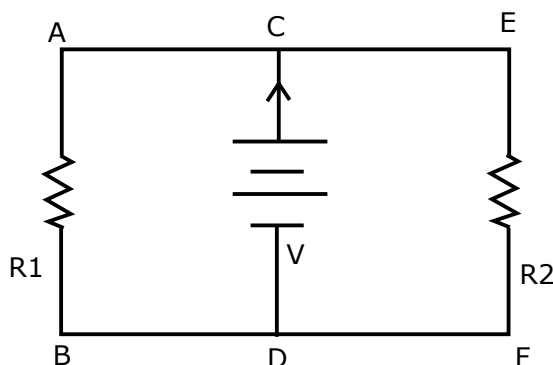
$f = \dfrac{3 \times 10^8}{650 \times 10^{-9}} = 4.6 \times 10^{14}$ Hz

(B) Energy in each pulse is $= E = P \times t = 0.6 \times 30 \times 10^{-3}$ J in eV $= 1.1 \times 10^{17}$ eV.

(C) Energy of 1 photon $= h\nu = 6.63 \times 10^{-34} \times 4.6 \times 10^{14} = 3.4 \times 10^{-14}$ J

(D) Number of photons $= \dfrac{E}{h\nu} = 5.9 \times 10^{16}$

26. In the following circuit, $R_1 = 6\ \Omega$, $R_2 = 12\ \Omega$, $V = 16$ V. The currents I_1 and I_2 flow through the resistances R_1 and R_2 respectively.

(A) power generated across R_1 is 42.6 watt

(B) the ratio of $\dfrac{I_1}{I_2} = 2$

(C) total current drawn from the cell is 4 ampere

(D) as $R_2 = 2 R_1$, the voltage across R_2 will be twice the voltage across R_1

Sol. **(A,B,C)**
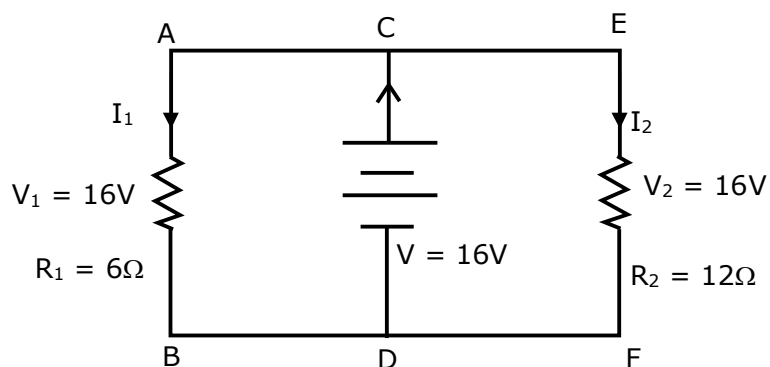
R_1 and R_2 are connected in parallel combination with 16V supply.

That's why voltage across R_1 and R_2 will be same. That is 16 V as shown in figure.

By using Ohm's Law

Current in $R_1 = \dfrac{V_1}{R_1} = \dfrac{16}{6}$ A

Current in $R_2 = \dfrac{V_2}{R_2} = \dfrac{16}{12}$ A

Total current I = $I_1 + I_2$ = 4A

Power generated across R_1 (P_1) = V_1 (I_1) = 42.6W

27. A glass plate of uniform thickness t and refractive index μ is as shown in the diagram. AB is the incident ray and FG is the emergent ray. The angles of incidence and refraction are i and r respectively. The perpendicular distance FC = x between the incident and the emergent rays is called the lateral shift. Then
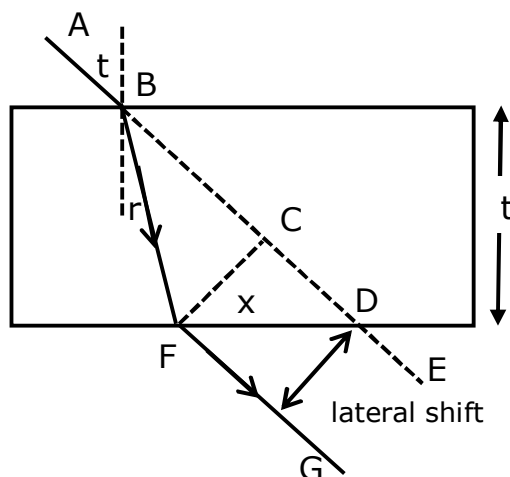
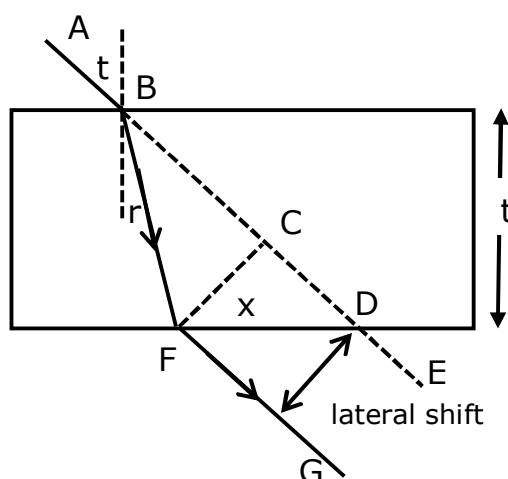
(A) $x = t\left(\sin i - \dfrac{\cos i \sin r}{\cos r}\right)$

(B) x depends on refractive index μ

(C) x is independent of the wavelength λ of light

(D) Maximum value of x = t when *i* is close to 90º

Sol. **(A,B,D)**

(A)   Lateral shift is given by $x = t\left(\sin i - \dfrac{\cos i \sin r}{\cos r}\right)$

(B)   Lateral shift depends on refractive index (on increasing refractive index lateral shift also increases).

(C)   Lateral shift is also depends on wavelength of light (on increasing wavelength lateral shift decreases).

(D)   When i is close to 90°, then lateral shift will be maximum.

28.   Given below are four statements about viruses. Which of the following statement/s is/are incorrect?

(A) All known viruses contain RNA as the genetic material

(B) During viral multiplication, a complementary DNA is produced in riboviruses

(C) Viruses are the smallest, freely living cells found on the planet

(D) DNA containing viruses are more susceptible to mutations when compared to RNA containing viruses and hence show a very rapid evolution

Sol.   **(ACD)**

DNA viruses (adenovirus) are more stable than RNA viruses, viruses do not follow cell theory.

29.   During a race, Ramesh was thrown off the horse back and suffered an injury in the front part of head. Upon thorough examination, Ramesh was found to have injury to the front part of the head. Which of the following can be the possible outcome/s of this injury?

(A) Trouble in speaking properly   (B) Inability to smell

(C) Inability to walk on a narrow path   (D) Inability to maintain blood pressure

Sol.   **(AC)**

Frontal lobe will be affected which includes function of speech and motor.

30.   Which of the following molecules are primarily responsible for structural support and motility?

(A) Actin   (B) Tubulin alpha   (C) Lamins   (D) Desmin

Sol.   **(AB)**

Actin- cellular processes includes muscle contraction, cell motility, cell division and cytokinesis

Alpha/beta tubulin – mitotic spindle

Laminins- major component of basal lamina, a protein network foundation for most cells and organs.

Desmin is found in heart (cardiac) muscle and muscles used for movement (skeletal muscle). Within muscle fibres, desmin proteins are important to help maintain the structure of sarcomeres, which are necessary for muscles to tense.

31. The types of bonding found in dry ice is/are

(A) Covalent   (B) Ionic   (C) Metallic   (D) Vander Wall forces

Sol. **(A, D)**

Dry ice is CO_2

$O = C = O$

In CO_2 both covalent & Vander Waal bonding is present.

32. The compound/s that raise/s the temperature of water (from room temperature) on dissolving in it is/are-

(A) Ammonium chloride   (B) Potassium hydroxide

(C) Glucose   (D) Conc. HCl

Sol. **(A, B, D)**

Hydration and dilution are exothermic process so on dilution(ionization) and hydration heat energy evolved.

33. Soap and detergents are common agents used in laundry industry. They are long chain hydrocarbons with ionic terminals of cationic or anionic nature. A 1% (w/v) soap solution X and 1% (w/v) detergent solution Y were prepared in distilled water. Each of the solutions was divided in two equal parts and labelled as X_1, X_2, Y_1 and Y_2. 1g NaCl was added to X_1 and Y_1 each while 1g $CaCl_2$ was added to X_2 and Y_2 each. Which of the following observations is/are correct?

(A) X_1 shows slimy precipitate   (B) X_2 shows slimy precipitate

(C) Y_1 shows slimy precipitate   (D) Y_2 shows slimy precipitate

Sol. **(B)**

Soap – salts of carboxylic acid

Detergent $\rightarrow$ Salts of sulfonate group

Calcium salt of carboxylic acid show ppt

So X_2 & Y_2 show ppt

SECTION I

1.   Neil Bartlett reacted molecular oxygen (O_2) with PtF_6 to get a compound $O_2^+ PtF_6^-$. He repeated the experiment with xenon (Xe) in place of O_2 to get another substance which was found to be a mixture of compounds with two of them being $XeF^+ PtF_6^-$ and $Xe^+ PtF_6^-$.
     Based on the above information, the statement that is true is
     (A) Second ionization potential of Xe is much lower than its first ionization potential
     (B) First ionization potential of Xe is much lower than first ionization potential of O_2
     (C) Xe makes ionic bond with F in one of the above compounds
     (D) Ze acts as reducing agent in above reactions

Sol.   **(D)**

2.   A student took a sandy soil sample from a desert area, put it in a bucket and poured tap water on it. After some time, the soil settled down in the bucket. She wanted to know if the sample had any soluble substances in it. Comparison of which of these properties between supernatant bucket water and the original tap water will most likely answer her question definitively.
     (A) pH   (B) density
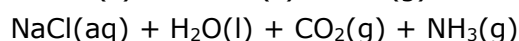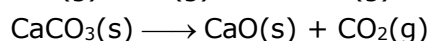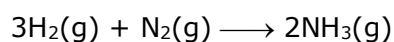   (C) temperature   (D) light scattering in identical containers

Sol.   **(A)**

3.   When silver metal is heated, its electrical conductivity decreases. But the electrical conductivity of molten sodium chloride increases with temperature because-
     (A) specific heat of molten sodium chloride is higher than that of silver metal
     (B) average speed of charge carries increases in both cases
     (C) at a given temperature, collisions decrease the average velocity of electrons much more than that of ions
     (D) density of charge carries in silver is less than that in sodium chloride

Sol.   **(C)**

4.   An industrial process uses NaCl, $CaCO_3$, H_2 and N_2 as raw materials to obtain $NaHCO_3$, using the following processes involving heat and catalysts
     $3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$
     $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
     $NaCl(aq) + H_2O(l) + CO_2(g) + NH_3(g)$
     Of the following substances present in this system, those which can be heated together in another separate chamber to reduce consumption of primary raw material in this process are
     (A) H_2, $CaCO_3$ (B) NH_2Cl, H_2
     (C) CaO, NH_4, H_2O (D) $CaCO_3$, NH_4Cl

Sol.   **(D)**

5. A thin aluminium foil is often placed on a bowl of food to keep the food warm. The foil does this by preventing heat flow through

(A) radiation only   (B) convection only

(C) radiation and convection only   (D) radiation, conduction, and convenction

Sol. **(C)**

Conduction cannot be avoided as aluminium is conductor.

6. On a windy day, standing on your balcony, you hear the whistle of a stationary train at a distance. Which among the velocity and frequency of the sound is/are affected by the wind?

(A) only velocity   (B) only frequency

(C) both velocity and frequency   (D) neither velocity nor frequency

Sol. **(A)**

As source and observer both are at rest so frequency does not change and velocity change.

7. Madhav assembled a toy cart with two wheels which were unequal in size. The left wheel was 4 cm in diameter and the right wheel was 3 cm in diameter. The wheels were connected to the opposite ends of an axle of length 10 cm. he set the cart in motion on the floor, pointing due north. Assume that the wheels roll without slipping. Approximately after how many rotations of the wheels will the cart be pointing due west?

(A) 5   (B) 10   (C) 15   (D) 20

Sol. **(C)**

$\tan \theta$ is same

$$\frac{1.5}{x} = \frac{2}{x + \ell}$$

$1.5x + 1.5\ell = 2x$

$1.5\ell = 0.5x$

$\boxed{x = 3\ell}$

$= 3 \times 10$

$= 30$ cm.

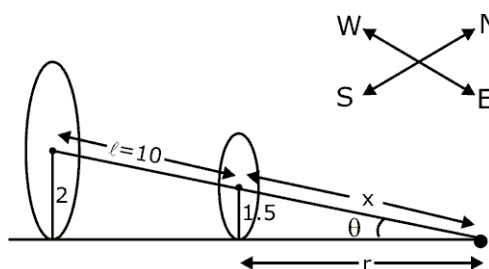$r = \sqrt{x^2 + 1.5^2}$

$= \sqrt{(30)^2 + (1.5)^2}$

$r = 30.03$

No. of rev. $= \dfrac{\dfrac{3\pi}{2}r}{2\pi(1.5)}$

$= \dfrac{3}{4} \times \dfrac{30}{1.5} = 15.015$

8. A wooden block is floating, partially submerged in a cup of water. If the setup is taken to the Moon and assuming the set-up is such that the water does not evaporate,
(A) the block will still float but the water level in the cup will rise
(B) the block will still float but the water level in the cup will go down
(C) the block will still float with the water level in the cup remaining the same
(D) the block will sink and the water level in the cup will rise

Sol. **(C)**
Effect of gravity will remain the same in both cases.
So, the level will not change and the block will still float with the same water level.

9. A mutation has been found in gene X of mice. The expression of this gene is testis specific. The mutation alters acrosome reaction (penetration of egg membrane by the sperm) during the process of fertilization. The sperms with the mutation in gene X are slower to penetrate the membrane as compared to normal healthy sperms. A heterozygous mouse carrying this mutation is allowed to mate with a normal healthy female. In spite of having this mutation, the mouse was able to produce the progeny from this cross. What will be the percentage of the progeny that will have this mutation?
(A) All the progeny pups will have this mutation
(B) 50% of the pups will carry this mutation
(C) 25% of the pups will carry this mutation
(D) It is unlikely that the progeny pups will carry this mutation

Sol. **(B)**

10. The muscular endurance of an athlete is his/her ability to perform certain physical exercise for longer period of time without getting exhausted. To achieve this high muscular endurance, most of them follow 'Carbo Loading' practice. Generally, while preparing for certain event, they increase overall exercise and conduct rigorous workout for a week or two. Then, 3-4 days just before the actual event, they reduce the training and include complex carbohydrate rich food in their diet. How this can be helpful for their performance?
(A) The diet helps in building extra muscle tissue needed for strength
(B) It increases the blood glucose level necessary for immediate raised performance
(C) Excessive glycogen can be synthesized, which can be stored and utilized during the event
(D) The complex carbohydrate gets stored into fats which can provide more ATPs for strenuous performance

Sol. **(C)**

11. The following observations were recorded after studying some organisms:

Character	Organisms W	Organisms X	Organisms Y	Organism Z
Water essential for fertilization	–	+	–	+
Formation of filament from germinating spore	–	–	–	+
Plant body sporophytic, differentiated in root, stem and leaves	+	+	+	–
Male and female sex organs arranged compactly in cone	+	+	–	–
Female gametophyte enveloped by single layered covering		–	–	–
Triploid tissue observed in zygote	–	–	+	–

On the basis of the data, identify the group of organisms:
(A) W-pteridophytes, X-bryophytes, Y-angiosperms, Z-gymnosperms
(B) W-angiosperms, X-gymnosperms, Y-pteridophytes, Z-bryophytes
(C) W-angiosperms, X-bryophytes, Y-gymnosperms, Z-pteridophytes
(D) W-gymnosperms, X-pteridophytes, Y-angiosperms, Z-bryophyte

Sol. **(D)**

12. If the gamete of a tetraploid plant contains 26 chromosomes, the number of chromatids in cells of the plant during metaphase of mitosis and metaphase II of meiosis will be, respectively,
(A) 104 and 104   (B) 52 and 26   (C) 104 and 52   (D) 26 and 26

Sol. **(C)**

SECTION II

13. **(10 Marks)** Glycerol is formed in large quantities as the by-product in the soap making industry. Saponification reaction is the hydrolysis of fat and oils (triglycerides) with excess alkali resulting in two products: soap and glycerol. The common raw materials required for preparing soap are: oil/fat, caustic soda (NaOH solid), sodium chloride, and water.

13. 1. In which order should these materials be mixed to obtain soap? Indicate the mixing order in 3 steps S1 – S3. [Note that mixing of caustic soda and water produces a lot of heat.]

Sol S-1: oil /Fat $\rightarrow$ NaOH $\rightarrow$ Soap solution + Glycerol.

S-2: Soap solution + NaCl $\rightarrow$ Precipitation of soap

S-3: Filtration $\rightarrow$ Soap (s) + Glycerol (aq.)

13. 2. Cooling the mixture is helpful after one of the mixing steps while heating the substance is helpful after another of the mixing steps. Identify the two steps (from S1 – S3).

Sol.   S-1 : Step-1 is exothermic so cooling is helpful.

S-2: During precipitation slight heating is required.

13. 3. After soap is formed and separated, what components of the reaction mixture are left behind apart from glycerol?

Sol   By products are salt solution and Glycerol

13. 4. Glycerol cannot be distilled at atmospheric pressure. It is removed from the reaction mixture by distillation under very low pressure. Based on this information, estimate the range in which boiling point of glycerol at atmospheric pressure is likely to lie. Given: Boiling point of Ethanol: 78 °C.

A. 25–75 °C   B. 75–110 °C   C. 90–110 °C   D. above 110 °C

Sol   **(D)**

above 110º C

13. 5. The glycerol obtained in this process is not pure. What is the predominant impurity in the distilled glycerol obtained?

Sol   We get a mixture of Salt, Fat and Soap.

13. 6. During the saponification process three molecules of soap and one molecule of glycerol are formed by the reaction of one molecule of oil with alkali. When 5 g of an oil was completely saponified with 50.0 ml of 0.5 M NaOH solution, the resultant mixture was titrated with 0.5 M HCl and it required 14.0 ml of the acid to reach equivalent point. Calculate the amount of glycerol that can be obtained from 1 kg of this vegetable oil. Glycerol may decompose to from acrolein at higher temperatures as shown below:
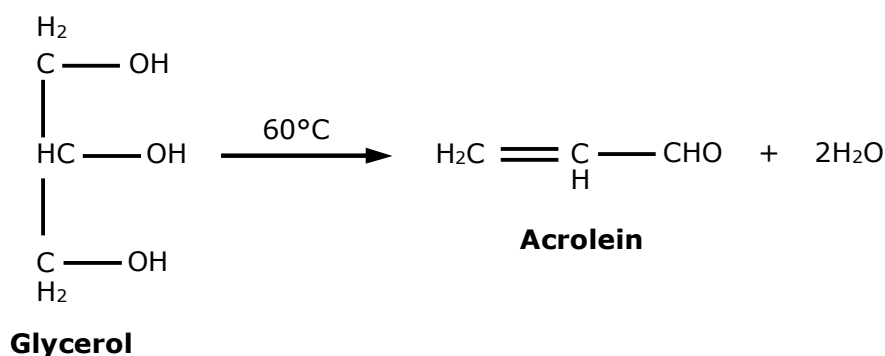
Sol   Oil   + NaOH → 3 Soap + Glycerol

5gm

NaOH reacted with oil = Total NaOH − vol. of HCl used

= (50 ml × 0.5 m) − (14ml × 0.5 m)

= 36 ml × 0.5 m

moles of NaOH reacted with oil $= \dfrac{36 \times 0.5}{1000} = 0.018$ moles

Stoichiometry

1 mole NaOH = 1 mole oil = 1 mole glycerol produced

0.018 mole = 0.018 mole = 0.018 mole glycerol

∵ 5 gm of oil producer = 0.018 mole glycerol

= 92 × 0.018 gm glycerol

= 1.656 gm glycerol

∴ 1000 gm oil producer = $\dfrac{1.656 \times 1000}{5}$ = 331.2 gm glycerol formed.

13. 7. If under the soap making conditions described in **13.6**, 1 out of 10 glycerol molecules formed decompose to acrolein, calculate the amount of glycerol that can be obtained per kg of oil.

14. **(12 Marks)** Most fires require three components to sustain the combustion:

i. fuel

ii. oxygen

iii. heat to initiate and sustain the combustion

To control unwanted/accidental fire, various methods are used to extinguish fire depending on the nature of the material(s) being burnt.

Consider different kind of fired being fuelled by the following materials:

I. Paper stacks

II. Stack of clothes

III. Vegetable oil spill

IV. Petrol in drums

V. Electrical wiring with plastic insulation

Different kind of fire-fighting strategies are effective for different fires. Here we look at four common strategies.

First strategy is of spraying water over the fire.

14.1. Spraying water cannot extinguish fires due to petrol. Which property of water and petrol prevents water from extinguishing petrol fire?

Sol. Petrol is having low density than water, Petrol layer exposed into air so fire cannot be extinguished by water.

14.2. Among the fires sustained by materials **I - V,** which can be extinguished by spraying water?

Sol. Fires sustained by material I and II are in the category of general fire which can be extinguished by water.

14.3. (a) Which of the three components of fire **(i – iii)** is/are reduced immediately by water spraying?

(b) The property/ies of water responsible for the role mentioned in 14.3 (a) is/are (identify the correct option(s)):

A. high latent heat of vapourization

B. high specific heat

C. low thermal conductivity

D. high electrical conductivity

E. its property to dissolve carbon dioxide

Another fire-fighting strategy involves use of CO_2-based extinguishers. A soda acid fire extinguisher was first patented in 1866 by Francois Carlier and then modified in 1881 in U.S. by Almon M Granger. The extinguisher contains a solution of sodium bicarbonate ($NaHCO_3$) with sulphuric acid contained in a sealed vial (labelled Ac in diagram). When the nozzle is pressed, the seal is broken and acid falls into sodium bicarbonate solution. As a result carbon dioxide and carbonic acid water is sprayed on the fire.
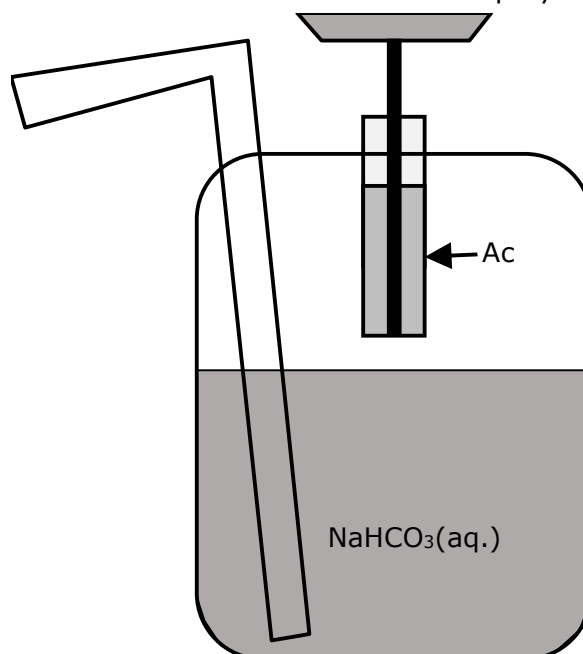
Sol.   (a) component (iii) heat to initiate and sustain the combustion, can be reduced immidiately by spraying water.

(b) B

14.4. Which of the three components of fire **(i - iii)** does soda acid suppresses in fire?

Sol.   (ii) soda acid suppresses the oxygen supply.

14.5. Should a soda acid extinguisher be used reduce petrol fires and/or fires in electrical wiring? Give reason for your answer.

Another version of CO_2 based extinguisher was developed in 1920s contains only compressed CO_2, which is released at high pressure by pressing a nozzle.

Sol.   Soda acid extinguisher is used to reduce the fire in electrical wiring because it releases CO_2.

$NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO2 \uparrow$

Because we cannot use water to extinguish the fire in electrical wiring.

14.6. Can a CO_2 extinguisher be used to reduce petrol fires and/or electrical fires?

A third type of fire extinguisher is used specifically for vegetable oil fires. These fire extinguishers spray a fine spray of alkaline potassium carbonate or potassium acetate on burning oil. This fine spray causes formation of foam on the oil surfaces.

Sol.   Yes.

14.7. (a) In this case, which of the three components of fire (i - iii) get reduced? Write one sentence for each of the component(s) explaining reduction mechanism(s).

(b) Which of the other kind of fires **(I, II, IV, V)** can be extinguished using this extinguisher?

Sol.   **(-)**

(a) (ii) this reduces the oxygen supply.

(b) (iv) - fire due to petrol can be reduced by foam based extinguisher.

15.   **(10 marks)** The figure below shows a partial drawing of an optical system. The system consists of an object, a real image of that object (both shown by the pair of arrow), a thin converging lens L, and plane mirror placed to the right of the lens (not shown in the drawing). It is not explicit that which arrow represent the object. All elements are parallel to each other. Consider the centre of the lens to be at (0 cm, 0 cm). assume each small box on the dotted grid is 0.5 cm × 0.5 cm is size.
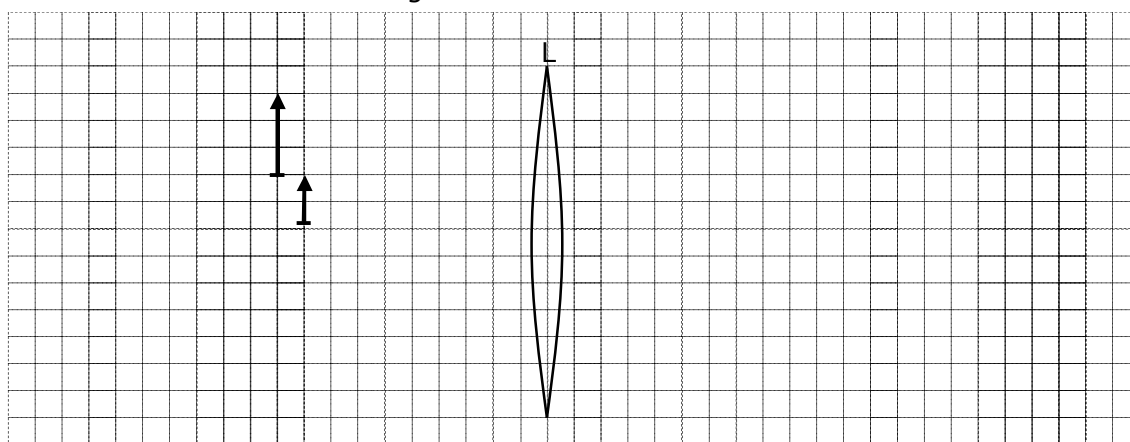
(a) Draw a ray diagram showing all the elements (including the mirror) of the optical system so that the given object-image pair is produced. you are not allowed to change the size or position of any of the elements shown. Also state the values of the focal length of the lens f, and the location of the mirror l (both in centimeters).

(b) With the given object/image pair, are there any other values of f and l possible? Justify your answer.

Sol.   (a) $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$
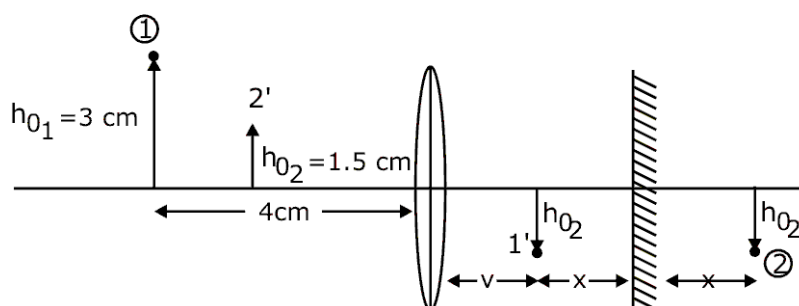
$\dfrac{1}{v} + \dfrac{1}{4} = \dfrac{1}{f}$ ...(1)

$\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

$\dfrac{1}{3} + \dfrac{1}{v + 2x} = \dfrac{1}{f}$ ...(2)

From (1) and (2) $\dfrac{1}{v} + \dfrac{1}{4} = \dfrac{1}{3} + \dfrac{1}{v+2x}$

$\dfrac{1}{v} - \dfrac{1}{v+2x} = \dfrac{1}{3} - \dfrac{1}{4}$

$\dfrac{v+2x-v}{v(v+2x)} = \dfrac{1}{12}$ …(3)

$\dfrac{v}{u} = \dfrac{h_I}{h_0}$ (for first refraction)

$\dfrac{v}{-4} = \dfrac{-h_{I_1}}{3}$

$v = \dfrac{4}{3} h_I$ …(4)

For 2nd refraction, $\dfrac{v}{u} = \dfrac{h_I}{h_0}$

$\dfrac{3}{-(v+2x)} = \dfrac{1.5}{(-)h_{I_1}}$

$h_{I_1} = \dfrac{v+2x}{2}$ …(5)

$v = \dfrac{4}{3} \times \dfrac{(v+2x)}{2} = \dfrac{2v}{3} + \dfrac{4}{3}x$

$\dfrac{v}{3} = \dfrac{4}{3}x \Rightarrow v = 4x$ …(6)

From (3) and (6)

$\dfrac{2x}{16x^2 + 2 \times 4x \times x} = \dfrac{1}{12}$

$6 = 6x$

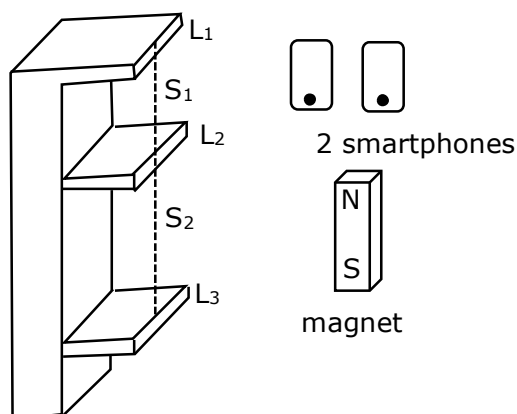$\boxed{x = 1\,cm}$

$\therefore v = 4x$

$V = 4 \times 1$

$\boxed{v = 4\,cm}$

$\dfrac{1}{4} + \dfrac{1}{4} = \dfrac{1}{f}$

$f = 2$ cm

Distance of mirror = $\boxed{v + x = 5\,cm}$

16. **(10 marks)** Padma wants to devise an experiment to determine the acceleration due to gravity, g. All she had is a wooden shelf with three levels, two identical smartphones, and one small magnet.


She knows the distances S_1 and S_2 between the levels (L_1, L_2, L_3) of the shelf. She came to know that smartphones have a magnetometer sensor and there are apps which is use it and display the magnetic field nearby. She experimented with an app and noticed that when a magnet passes within the close vicinity of the phone, the magnetometer in the phone shows the change in magnetic field graphically (as seen at t = 15.37 sec in graph below).
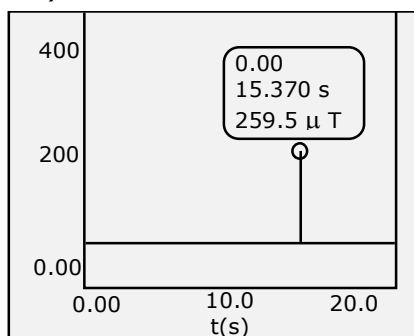
Clocks in the two phones are not synchronized but the time in the app is measured from the time the sensor is activated by pressing a switch in the app. She found that she can manually start the apps in the two phones simultaneously by pressing the start buttons in each together. However, synchronization of dropping the magnet and starting the app is very difficult, and introduces a large error in the measurement. The formula for change of magnetic field B with distance is not known to her.

Describe the experiment that she should perform to determine g as accurately as possible. You must clearly describe the setup and the procedure of measurement, as well as derive the formula for determination of g from the measures quantities. Also, list the possible sources of errors.

Sol. Magnet dropped at t = T

```
┌─── Mg
│
│S₁
├─── Sp(1)
│
│S₂
└─── Sp(2)
```
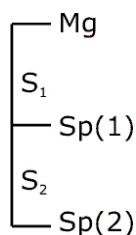
It will pass Sp(1) at

$$t_1 = T + \sqrt{\frac{2S_1}{g}}$$

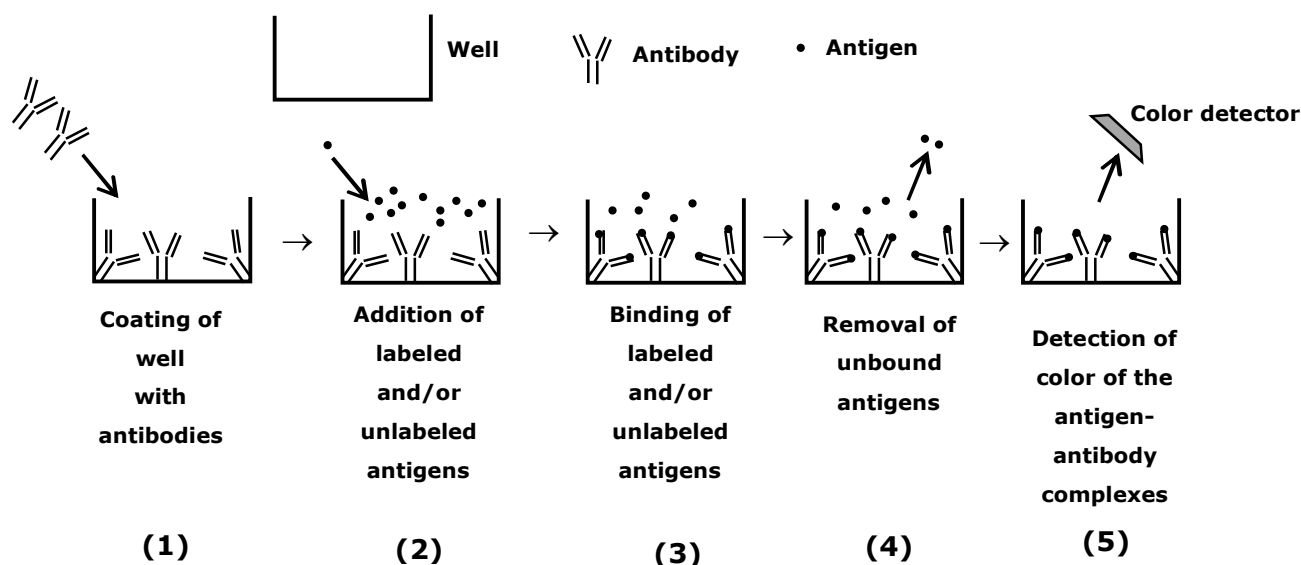$$SP_2 \text{ at } t_2 = T + \sqrt{\frac{2(S_1 + S_2)}{g}}$$

$$t_2 - t_1 = \sqrt{\frac{2(S_1 + S_2)}{g}} - \sqrt{\frac{2S_1}{g}}$$

$$\left(\frac{\sqrt{2(S_1 + S_2)} - \sqrt{2S_1}}{(t_2 - t_1)} \right)^2$$

17. **(9 Marks)** When an infectious agent enters the body of a person, the cells of the immune system recognize it as a foreign object and initiate immune reaction against it. The antigen-antibody reaction is one of the many mechanisms of action of our immune system to fight infection. In this, the immune system starts to form more of the cells that produce antibodies specific to the newly encountered antigen. These cells then multiply to produce large quantities of the required antibody. In a few days time, these antibodies starts eliminating the infectious agent from the body and continue to do so till the number of infectious agent becomes almost zero.

When a person is infected by any pathogen for the first time, the immune system develops antibodies and keeps the memory for variable durations depending upon the pathagon. When there are subsequent attacks by the same pathogen before the memory period is over, the immune system takes less time to initiate a response and the response generated is usually stronger than the first response.

The specificity of the antigen-antibody interactions is used as a tool for detection of the infectious agent or its parts in the body fluids/tissues. One such technique is depicted in the diagram shown below.

(1) Coating of well with antibodies **(2)** Addition of labeled and/or unlabeled antigens **(3)** Binding of labeled and/or unlabeled antigens **(4)** Removal of unbound antigens **(5)** Detection of color of the antigen-antibody complexes

The system is developed in such a way that if the antigens are labeled, when they bind to the antibodies, they form complexes that are coloured and can be detected. The process of labeling involves chemically attaching a coloured molecule to the antigen. If the antigens are not labeled, then the complex remains colorless.

17.1   Suppose that this test is used for detection of a virus from circulating blood. The labeled antigens have the same capacity as that of the actual antigen to bind to the antibodies. The serum from an infected and a non-infected person are added as shown in the table below.
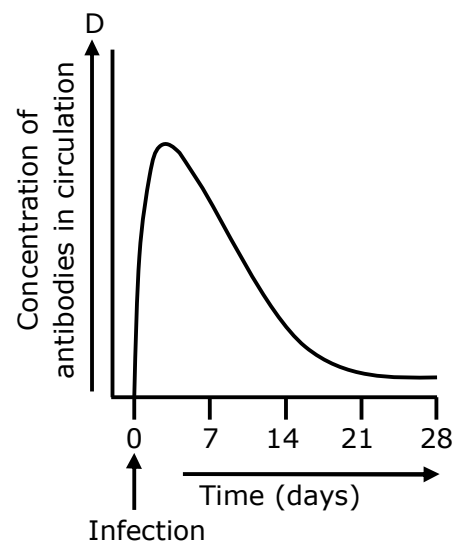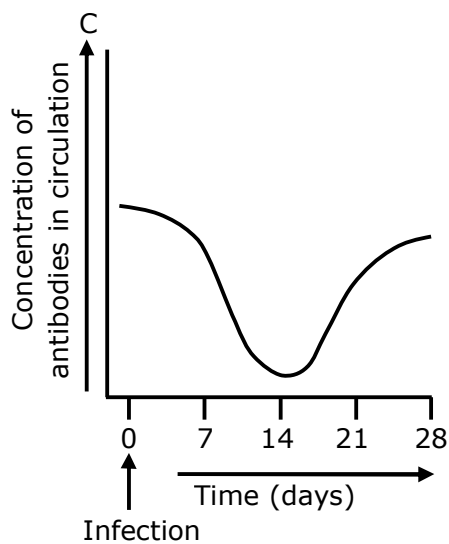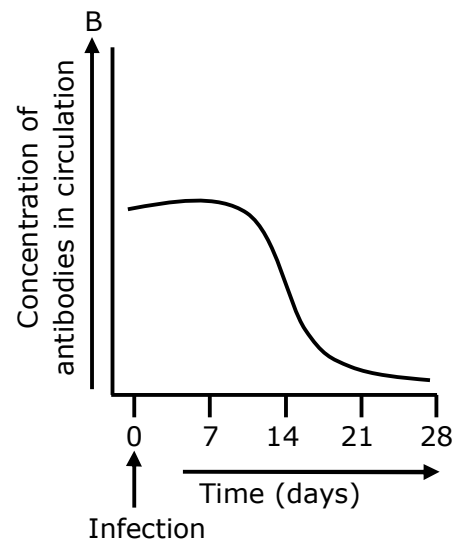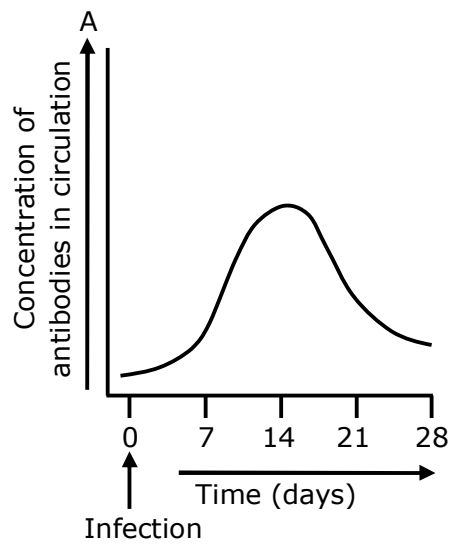
Well	Components added after antibody coating
1. Control	Labeled antigens only
2. X	Labeled antigens + serum of an infected person
3. Y	Labeled antigens + serum of a non-infected person

After allowing the antigens to bind with the antibodies, the supernatant containing unbound antigens is removed and intensity of the color of the antigen-antibody complexes, if there are any, is detected and quantified. Based on this experimental set up, which of the following statements is CORRECT ?

(A) Intensity of the color detected from X is less than that from the control well.

(B) Intensity of the color detected from X is more than that from the control well.

(C) Intensity of the color detected from X is less than that from the control; but is more than that from Y.

(D) Intensities of the color detected from X and Y are equal to each other as well as with that from the control.

Sol.   **(B)**

17.2   Considering the facts regarding entry of pathogen and production of antibodies, choose the correct option that depicts the response of the immune system in form of antibody production following the first time infection by a new pathogen(not encountered before) in an adult healthy human being.

A

Concentration of antibodies in circulation

0   7   14   21   28
Time (days)

Infection

B

Concentration of antibodies in circulation

0   7   14   21   28
Time (days)

Infection

C

Concentration of antibodies in circulation

0   7   14   21   28
Time (days)

Infection

D

Concentration of antibodies in circulation

0   7   14   21   28
Time (days)

Infection

Sol.   (A)

17.3 Vaccine-mediated immune protection depends on antigen-antibody reactions. Most of the traditional vaccines are killed/weakened or inactivated pathogens, which are unable to cause the disease by themselves, but are able to trigger antibody production.
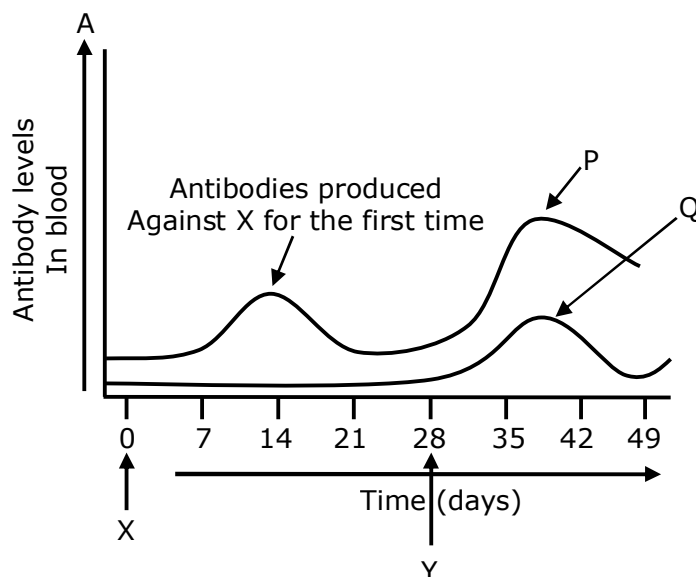

Considering these facts and the graph shown above, identify possibilities for labels X, Y, P and Q from the list given below.

(i)   Entry of new pathogen into the body

(ii)   Second/repeat encounter of a pathogen

(iii)   Vaccine administration

(iv)   Administration of booster dose of vaccine

(v)   Antibody levels upon entry of a new pathogen

(vi)   Antibody levels upon second/ repeated entry of a pathogen

(vii)   Antibody levels upon administration of any vaccine

(viii) Antibody levels upon administration of booster dose of the same vaccine

(ix)   Antibody levels upon administration of vaccine developed against a different pathogen.

Sol.   (i)-X, (ii)-Y, (iii)-Q, (iv)-P, (v)-Q, (vi)-P, (vii)-Q, (viii)-P, (ix)-Q

18.   **(3 marks)** There are about 1.2×10^{10} microvilli per square centimeter of sub mucosa in gastrointestinal track of humans. Each microvillus – a rod like structure present on epithelial cell of sub mucosa – is 1 μm in length and 0.1 μm in diameter.
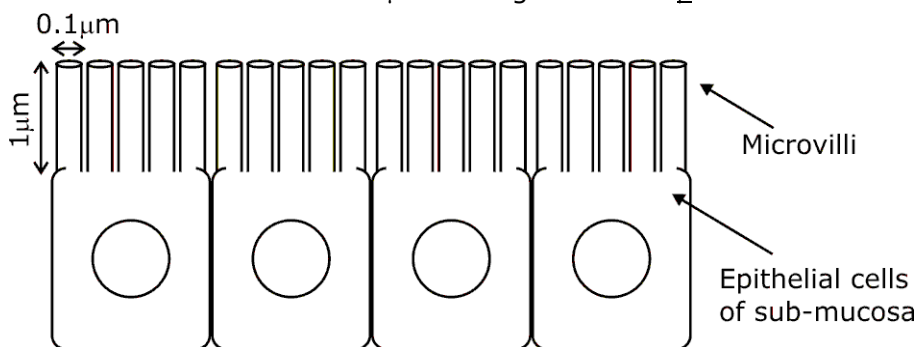
In a particular genetic condition associated with intractable diarrhea, the average length of the microvillus is found to be reduced by 66% (though the cross section remains almost the same).

Assume that absorption is happening predominantly on the microvilli surfaces. Calculate, in terms of percentage, how much would be the loss in total surface area available for absorption in small intestine in that genetic condition. Note that answer without calculations/explanation will not be considered.

Sol. Given:

Length of microvilli = 1 μm

Diameter of microvilli = 0.1 μm

Average length reduced = 66%

During normal condition = 0.341 × 10^{-8} m

After disease = 0.34 m times.

34% would be the loss in total surface area available for absorption in small intestine.

19. **(10 marks)** Four farms from similar geographic location, A, B, C and D of equal size are divided into 7 lanes spatially – 1, 2, 3, 4, 5, 6 and 7. The table represents plantation strategy of farmer for the four farms in five consecutive years.

Farm name	Plantation	Kharif season of the Year				
		2015	2016	2017	2018	2019
A	Wheat	1,2,3,4,5,6,7			1,2,3,4,5,6,7	
	Soyabean		1,2,3,4,5,6,7			1,2,3,4,5,6,7
	Rice			1,2,3,4,5,6,7		
B	Wheat	1,3,5,7	2,4,6	1,3,5,7	2,4,6	1,3,5,7
	Soyabean	2,4,6	1,3,5,7	2,4,6	1,3,5,7	2,4,6
	Rice	0	0	0	0	0
C	Maize	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
	Pea Plant	3,5	3,5	3,5	3,5	3,5
	Trap plant/grass	1,7	1,7	1,7	1,7	1,7
D	Maize	3,5,6,7	3,5,6,7	3,5,6,7	3,5,6,7	3,5,67
	Wheat	2,4	2,4	2,4	2,4	2,4
	Trap plant/grass	1	1	1	1	1

19.1 For items (a – e), write appropriate answer(s) in the answer sheet, based on the above table.

(a) Intercropping is practiced in farm/s _____ in the year(s) _____.

(b) Crop rotation is practiced in the farm/s _____.

(c) Rice / Maize / Wheat / Pea plant / Trap grass may replace Soyabean in Farm B, without affecting yield/acre or plantation strategy to a great extent. (Identify the correct option(s)).

(d) The farm that is likely to provide least yield/hector to the farmer in the year 2019 is _____.

(e) One of the efficient farming strategies termed 'push pull technology' involves planting insect attractant forage grass trap or 'pull' – plant at the border of field, and insect repellent leguminous 'push' plant in between the main crop. The farm/s using this strategy is/are _____.

Sol.   (a) B,C,D, 2015 to 2019

(b) A, B

(c) Pea plant

(d) D

(e) C, D

19.2   State true or false.

(i)   Chemical and visual cues given by plant will be important while choosing it as a trap crop.

(ii)   Monoculture of maize in a farm would be more susceptible to any new pest infestation over farm/s. A, B and C.

(iii)   Mixed cropping/intercropping would discourage growth of natural enemies of insect pests compared to monocropping.

(iv)   Pest infested cereal crop can be rescued by using push and pull technology.

Sol.   (i) True

(ii) True

(iii) True

(iv) True

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