Indian Olympiad Qualifier in Junior Science (IOQJS) 2021-2022

conducted jointly by
Homi Bhabha Centre for Science Education (HBCSE-TIFR)
and
Indian Association of Physics Teachers (IAPT)

Part II: Indian National Junior Science Olympiad (INJSO)

Homi Bhabha Centre for Science Education (HBCSE-TIFR)

Date: January 17, 2021

Solutions (April 29, 2022)

For questions requiring detailed solution or reasoning, marks will be awarded for showing the steps/reasoning involved in arriving at the answer, along with the final answer. Any alternative method of solution to questions that is scientifically and mathematically correct, and leads to the same answer will be accepted with full credit. Partially correct answers will gain partial credit. Valid assumptions/ approximations are perfectly acceptable.

Section I (36 marks)

1. D. In the given chemical reaction, Xe is getting oxidized to Xe^{+} and Xe^{2+}, and acting as a reducing agent.

2. B. If some soluble components from soil dissolve in water, then density of water is most likely to change. Other parameters may or may not change significantly.

3. C. With increase in temperature, speed of both free electrons and ions in solids may change, but electrons (main charge carriers in solid silver) slow down significantly due to collisions with heavier ions, but speed of heavy ions (main charge carrier in molten sodium chloride) are relatively less impacted by collisions.

4. C. CaO, NH_4C1, and H_2O (the first two are side products) can be heated together to obtain NH_3 which can be recycled as starting material in the process. The presence of water is important in this process.

5. C. Aluminium being a metal is a good conductor of heat, hence heat flow through conduction cannot be low. Because of highly reflective surface and non-porous nature, heat loss through radiation and convection is low.

6. A. frequency of sound waves will not change due to motion of air.

7. C. The wheels of the cart will move on two concentric circular arcs of radii l and l +10 cm, respectively. The toy cart will change direction by 270° ($3\pi/2$). Thus, the number of rotations of wheels, n is given by $3\pi/2[(l + 10) - l] = n \times 2\pi (2 - 1.5)$. Thus, $n = 15$.

8. C. Since the relative weights of the block and a specific volume of water will remain the same on the Moon also, the block will continue to float with water level remaining the same.

9. D. The mouse that is used in this experiment is heterozygous. So it will carry one functional allele and will produce sperms out of which 50% will be normal. These normal sperms will penetrate the zonapellucida faster, before the mutant sperms could reach. Therefore, the progeny pups will not carry this mutant allele at all.

10. C. Eating more of complex carbohydrate rich food with less physical exercise will accumulate glycogen in body, which can increase performance during the actual event.

11. D.

12. C. The gamete of this tetraploid individual has 26 chromosomes, so the parent cell would contain 52 chromosomes. During metaphase of mitosis, there are two chromatids in the chromosome. Hence 104 chromatids would be present during metaphase of mitosis. During metaphase II of meiosis, only 52 chromatids would be present.

Section II:

13: (**10 marks**)

13.1. S1: NaOH + Water S2. Mixture from S1 + oil/fat S3. Mixture from S2 + sodium chloride (**1.5 marks**)

13.2. Cooling: after S3 Heating: after S2 (**1 mark**)

13.3. NaOH, NaCl, water (**1.5 marks**)

13.4. D. (**1 mark**)

13.5. Water (**0.5 mark**)

13.6.

Moles of NaOH used in saponification = moles of NaOH taken – moles of NaOH remained (& react with HCl)

= (50 - 14) mL × 0.5 M = 18 mmol

Moles of soap saponified (in 5 g) = 1/3 of moles of NaOH saponified = 1/3 × 18 mmol = 6 mmol

Molar mass of glycerol = 92 g

1 kg of vegetable oil will yield: (92) × 1000/5 × 6/1000 = 110.4 g glycerol (**3.5 marks**)

13.7 Amount of glycerol obtained from 1 kg of oil = (10-1)/10 × 110.4 g = 99.36 g (**1 mark**)

14. (12 marks)

14.1- higher density of water than petrol. (**1 mark**)

14.2- I, II (**1 mark**)

14.3. (a) **ii**, **iii**. (b) A, B (**2 marks**)

14.4. **ii**, **iii** (**1 marks**)

14.5 No for both. Water is used as spray in soda acid extinguisher. Water is not miscible with oil, and also settles below oil layer. It cannot be used for electrical fires too because the water or soda mixture is electrically conducting and it will cause electrical short circuits. (**2 marks**)

14.6 Yes for both. It leaves no residue. (**1 mark**)

14.7. (a) All three components get reduced.

i. Fuels, because alkaline solution reacts with oil and forms soap and due to water it also forms foam (which is less flammable than oil).

ii. Oxygen because the foam layers separates air from oil (fuel being burned)

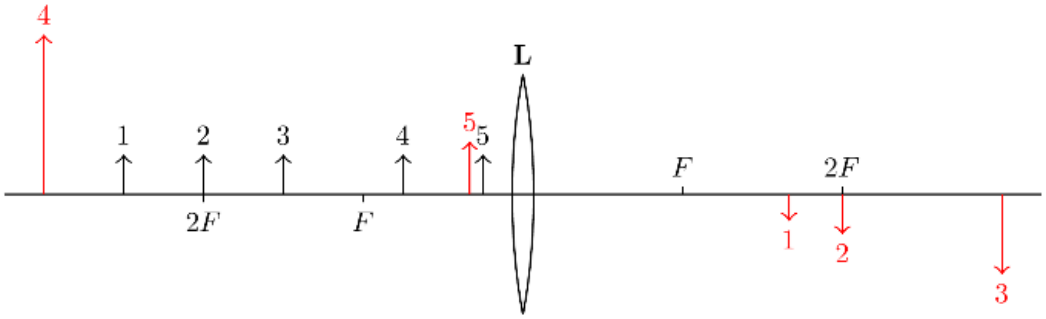
iii. Heat because water removes some of the heat being a part of foam, and cools down the mixture.

(b)- **I**, **II** **(4 marks)**

15. **(10 marks)**

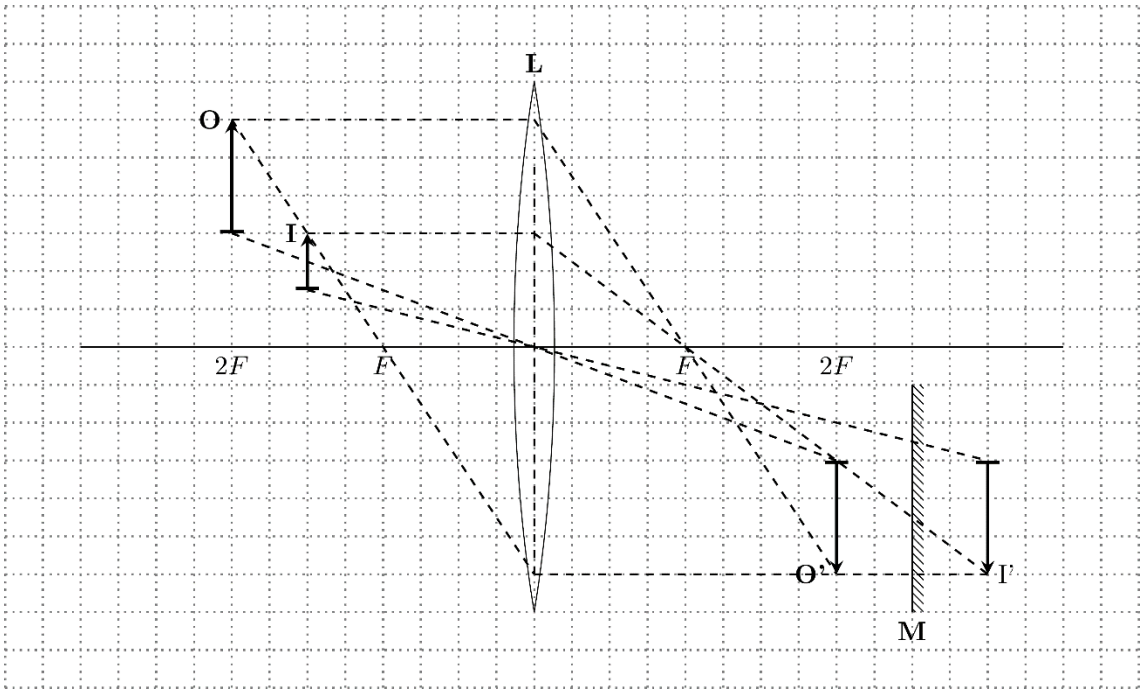
(a) As far as the ray diagram is concerned, it does not matter which arrow is the object and which one is the image due to the principle of reversibility of light. Either of the arrows can be identified as an object, and the other as its (real) image.

Let us assume that the bigger arrow is the object. Size and position of the image using a convex lens at different locations of the object is shown below. The black arrows represent objects and the red arrows are their respective images.



As apparent from the above figure, if the object is placed within the focal distance of the lens (arrows 4 and 5), an object-image pair similar to the one given in the question (smaller-bigger) may be produced. But this image formation cannot involve any use of the mirror and also, the resultant image will be virtual. So the possibilities of 4 and 5 as the object are ruled out. Thus the object (O) must be beyond the focus (cases 1, 2 or 3) so that a smaller and inverted image (O') will be formed by the lens alone on the right side of the lens.

The mirror then forms the secondary image I' of O' which acts as a virtual object for the lens that forms a final real image I on the left side of the lens.



The lens equation for the primary object-image pair will be

$$\frac{1}{v_1} = \frac{1}{f} + \frac{1}{u_1}$$

where the symbols have their usual meanings.

Take the object distance u_1 to be – 4 cm (Cartesian sign convention) in the lens equation to obtain v_1 in terms of focal length f. Let the distance between the first image O' and the mirror M be d. The object distance now will be $-v_1 - 2d$ (reversed Cartesian sign convention). Use the lens equation again to obtain v_2 in terms of f and d. Also, magnifications can be written in terms of object and image distances. Solving these equations together, we get f = 2 cm and d = 1 cm.

Hence the correct answer for this part is: Focal length of the lens = 2 cm.

Location of the mirror l = 5 cm to the right of the lens.

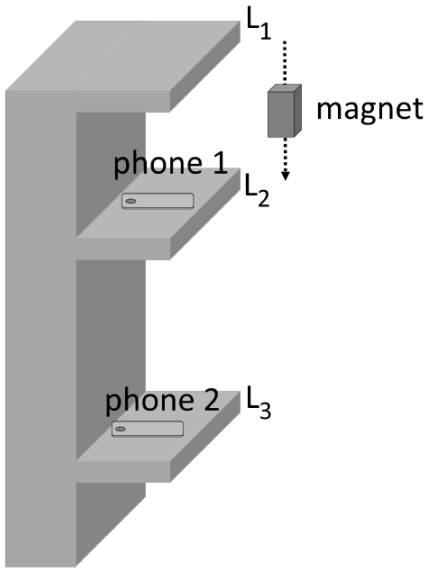
Note that alternate methods of the correct solution exist and will be accepted.

(b) The values of f and l obtained above from the solution of the equations are unique. For the given location and magnification characteristics, only two configurations are possible by interchanging the object and the image. However, this interchange will lead to the same solutions for f and l (guaranteed by the principle of reversibility of light).

16. (**10 marks**)

Procedure

1. Activate the magnetometer sensors of both the phones simultaneously by pressing the switches.
2. Place the two phones on the bottom two shelves, L_2 and L_3.
3. Align the magnet with the top shelves, L_1.
4. Drop the magnet from rest.
5. Record the timing of magnetic field peaks in the top (say t_1) and bottom (say t_2) phones.



Calculation of g:

Let the magnet's speed when it crosses the top phone be v. Also, let $\Delta t = t_2 - t_1$. Then,

$$v^2 = 2gS_1 \quad (1)$$

$$S_2 = v\Delta t + g(\Delta t)^2/2 \quad (2)$$

$$= \left(\sqrt{2S_1}\Delta t\right)\sqrt{g} + \left(\frac{1}{2}(\Delta t)^2\right)(\sqrt{g})^2 \quad (3)$$

The above equation is a quadratic in $\sqrt{g}$, the solution of which will give

$$\sqrt{g} = \sqrt{2}\left[\frac{\sqrt{S_1+S_2}-\sqrt{S_1}}{\Delta t}\right] \quad (4)$$

$$g = \frac{2}{(\Delta t)^2}\left[\sqrt{S_1+S_2}-\sqrt{S_1}\right]^2 \quad (5)$$

With the known values of S_1, S_2 and measurement of Δt, one can determine g.

Possible sources of errors:

1. Reaction time will play an important role when the two phones are started simultaneously to record the magnetic field.
2. The magnet may pick up some velocity when it starts descending and leave Padma's hand.
3. If the magnet is not aligned properly with L_1, an error will be added to S_1.

17. (9 marks)

17.1. A. When serum of an infected person is added, it will contain the viral antigen too. Therefore in well **X**, both the unlabeled as well as labeled antigens will bind to the antibodies. In well **Y**, only the labeled antigens will bind and same situation will be there in control. Hence, label/ colour from **X** will always be less than in **Y** and control. (**2 marks**)

17.2 A. The antibody concentration increases in about a week and then steadily goes down and a basal level is maintained for a longer period (days). (**2 marks**)

17.3 **X** = i / iii **Y** = i and ii / iii and ii / iv and I (**5 marks**)
P = vi / viii **Q** = ix / v

18. (**3 marks**)

Surface area of single microvillus A = surface area of cylinder – area of base

$$= 2\pi rh + \pi r^2$$

Surface area of a healthy microvillus = $2 \times \frac{22}{7} \times 0.05 \times 1 + \frac{22}{7} \times 0.05^2 = 0.322$

Surface area of a shortened microvillus = $2 \times \frac{22}{7} \times 0.05 \times 0.34 + \frac{22}{7} \times 0.05^2 = 0.1147$

The loss in total surface area available for absorption = (0.322 - 0.115) / 0.322 = 0.6438

Thus, about 64.4 % of the surface area of intestines would be lost in the given genetic condition.

19. (**10 marks**)

19.1 (a) B, C, D; 2015, 2016 , 2017, 2018, 2019

(b) A, B (in case of A, 3 year rotation is planned. in case of B, same rows are used for planting different crop)
(c) Soybeans and **pea plants** are leguminous plants used in intercropping.
(d) D (Most of the legumes have symbiotic nitrogen-fixing bacteria in structures called root nodules. For that reason, they play a key role in crop rotation. Legumes or crop or land rotation is not practiced in D)
(e) C.

(**6 marks**)

19.2 (a) True (chemical attractants and plant leaf size decide whether the trap plant can be a good host for pest insects)
(b) True (Mixed cropping provides physical barrier to pest flight and attack, insect repellent volatiles, and promotes growth of natural pest enemies)
(c) False (Improved biodiversity because of introduction of mixed cropping would encourage growth of natural enemies of insect pests)
(d) False (push and pull is a prevention strategy cannot rescue already infected plant)

(**4 marks**)