Multiple Choice Questions

Time : 3 hrs
Marks : 30

Examination Rules

1. You have to sit at your designated desk.
2. Before the examination starts, you must check the stationery and any tools (pen, ruler, calculator) provided by the organizers.
3. You are not allowed to bring any tools except personal medicine or approved personal medical equipment.
4. You have to check the question and answer sheets provided. Raise your hand, if you find any missing sheets. Start tasks after the start whistle is blown.
5. During the examination, you are not allowed to leave the examination room except in an emergency and then you will be accompanied by a supervisor/volunteer/invigilator.
6. You are not to disturb other competitors. If you need any assistance you may raise your hand and wait for a supervisor to come to assist.
7. There will be no discussion about the examination tasks or problems. You must stay at your desk until the examination is over, even if you have finished the examination.
8. At the end of the examination time you will hear a whistle blow. You are not to write anything on the answer sheet after this stop whistle. You must leave the room quietly when asked to do so. The question and answer sheets must be left neatly on your desk.

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READ THE FOLLOWING INSTRUCTIONS CAREFULLY

A. The time available is 3 hours.

B. Check that you have a complete set of the test questions and the answer sheet. The total number of questions is 30.

C. Write down your name, code, country and signature in your answer sheet.

D. Read carefully each problem and choose your correct answer by crossing one of the capital letters in your answer sheet. There is only one right answer for each problem.

Example:

1	~~**A**~~	**B**	**C**	**D**

E. If you want to change your answer, you have to circle the first answer and then cross a new letter as your correct answer. You are only allowed to make one correction per question.

Example:

1	⊗ A	B	C	~~D~~

A is the first answer and D is the final answer

F. Grading rules**:**

(i) Correct answer : + 1 point

(ii) Wrong answer : − 0.25 point

(iii) No answer : 0 point

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1. Which among the following numbers is the largest?

   (A) The number of air molecules in a $3\text{ m} \times 3\text{ m} \times 3\text{ m}$ classroom.

   (B) The number of water molecules in a one-litre bottle filled with water.

   (C) The number of breaths you have taken since your birth.

   (D) The number of seconds which have passed since the origin of the Universe.

2. The Moon was observed near the eastern horizon at the Equator just before sunrise. The shape of the Moon would have been closest to:

(A) 

(B) 

(C) 

(D) 

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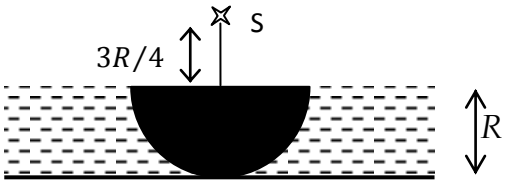
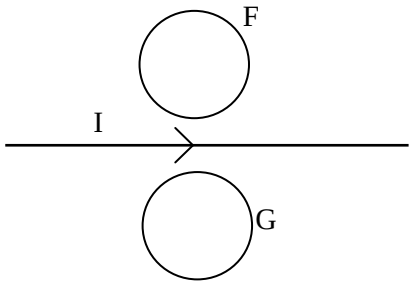
3. An opaque hemisphere of radius R lies on a horizontal plane as shown in the figure below.



On the perpendicular through the point of contact, a point source of light S is placed at a distance $3R/4$ above the centre of the hemisphere. A transparent liquid of refractive index $4/3$ is filled above the plane such that the hemisphere is just covered with the liquid. The area of the shadow on the horizontal plane is

(A) $49\pi R^2/9$ (B) $49\pi R^2/16$ (C) πR^2 (D) $4\pi R^2$

4. Two conducting circular loops F and G are kept in a plane on either side of a straight current-carrying wire as shown in the figure below.



If the current in the wire decreases in magnitude, the induced current in the loops will be

(A) clockwise in F and clockwise in G.
(B) anti-clockwise in F and clockwise in G.
(C) clockwise in F and anti-clockwise in G.
(D) anti-clockwise in F and anti-clockwise in G.

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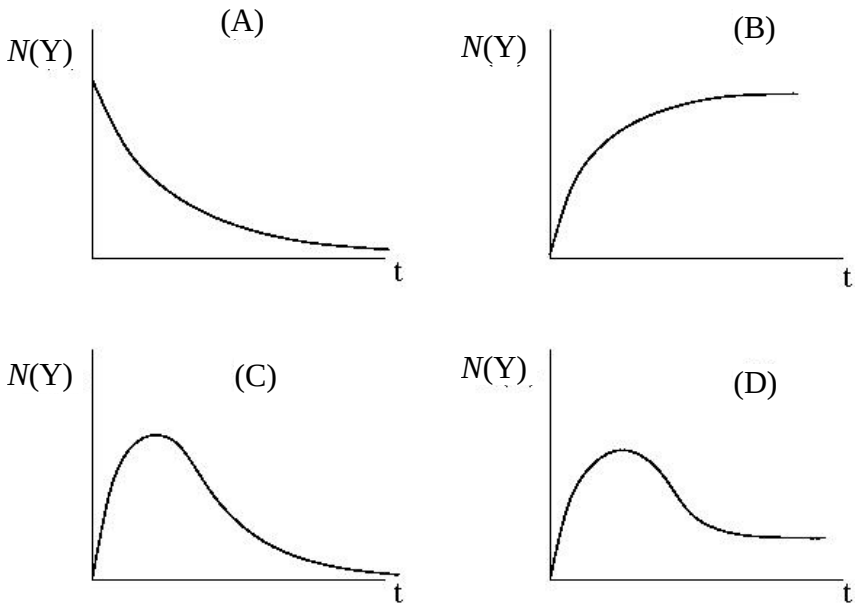
5. The equation of state for one mole of a *real* gas is given, in terms of pressure p, volume V and absolute temperature T, by van der Waals' equation

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT$$

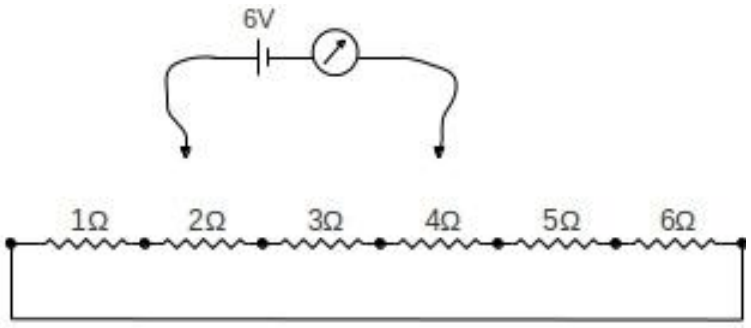
where a has the value α in kg m^5 s^{-2} mol^{-2}, b has the value β in m^3 mol^{-1}, and R = 8.31 J K^{-1} mol^{-1} is the universal gas constant. If the gas is kept in a container with rigid walls of volume 1 m^3, the minimum temperature (in K) that the gas can be cooled to is

(A) $\alpha(1-\beta)/8.31$ (B) $(1-\beta)/8.31$ (C) $\alpha/8.31$ (D) zero

6. The nuclei of a radioactive element decay to nuclei of another element at a rate proportional to the number of nuclei of the first element. Consider that a radioactive element X decays to another radioactive element Y, which further decays to a stable (non-radioactive) element Z. If you start with a sample containing only the element X, a plot of the number of nuclei of Y, *N*(Y), as a function of time, *t*, can look, on a long time scale, like



7. Consider six resistances connected as shown in the figure below. Note that the extreme ends are shorted. A circuit element consisting of a 6 V ideal battery and an ideal ammeter can be connected across any two of the different points marked by dots in the resistance network.



The *minimum* possible value of the current passing through the ammeter would be

(A) 0.29 A

(B) 1.15 A

(C) 1.17 A

(D) 1.41 A

8. Playing with a lens one morning, Rita discovers that if she holds the lens 0.120 m away from a wall opposite to a window, she can see a sharp but upside-down picture of the outside world on the wall. That evening, she covers a lighted lamp with a piece of card on which she has pierced a small hole, 0.005 m in diameter. By placing the lens between the illuminated card and the wall, she manages to produce a sharp image of diameter 0.020 m on the wall. What is the distance between the card and the wall?

(A) 0.450 m

(B) 0.750 m

(C) 0.600 m

(D) 0.300 m

9. Equal amounts of ice at 0^0 C are placed in three containers P, Q and R, which are kept in a constant temperature environment. Identical heating elements are placed inside each container. These heating elements are powered with different voltages: 100 V, 200 V and 300 V in containers P, Q and R, respectively. It was found that it took 20 minutes to melt all the ice in container Q, and it took 4 minutes to melt all the ice in container R. Assuming that at any instant heat is uniformly dissipated in each container throughout its volume, which of the following is correct?

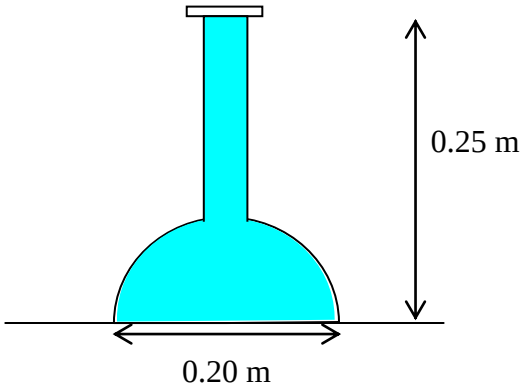
(A) It will take (approximately) 80 min to melt all the ice in container P.

(B) It will take (approximately) 100 min to melt all the ice in container P.

(C) It will take (approximately) 132 min to melt all the ice in container P.

(D) It will not be possible to melt all the ice in container P with the given power source.

10. The figure below shows a glass flask whose hemispherical base is of diameter 0.20 m. The height of the flask is 0.25 m. The flask is filled to the brim with 2.5 litres (1 litre = 10^{-3} m^3) of water and sealed with a glass lid.



What is the approximate magnitude of the total vertical force exerted by the water on the curved surface of the flask? (Take the acceleration due to gravity, *g*, to be 10 ms^{-2}).

(A) 0 N (B) 78.5 N (C) 53.5 N (D) 25.0 N

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11. Consider an element with 7 electrons. In the ground state, these electrons may be arranged in 1*s*, 2*s* and 2*p* orbitals in four different ways.

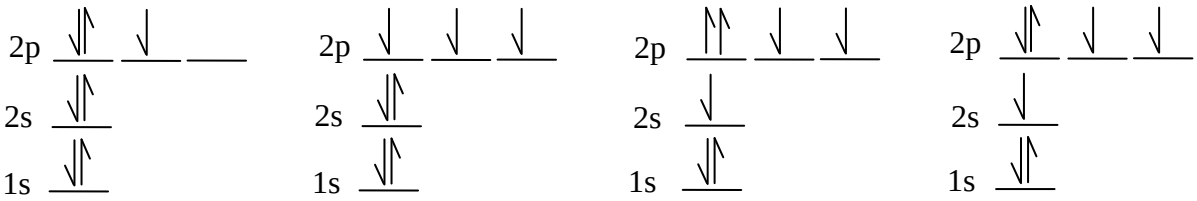
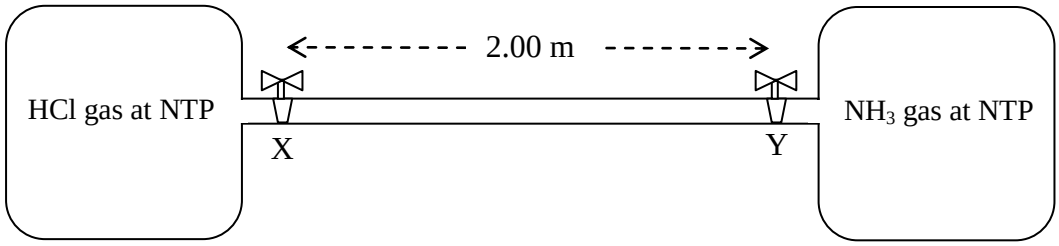


Fig 1 Fig 2 Fig 3 Fig 4

Choose the CORRECT statement from the following.

A. Fig 4 and Fig 2 are correct..
B. Only Fig 2 is correct.
C. Only Fig 1 is correct.
D. Fig 3 and Fig 4 are correct.

12. A glass pipe is connected on either side to gas reservoirs, one containing HCl gas at normal temperature and pressure (NTP) and the other containing NH_3 gas, also at NTP. X and Y are two stop-cocks, separated by 2.00 m, which, when closed, prevent the flow of gas into the glass pipe.



It was observed that when the stop-cocks X and Y were opened simultaneously, then white fumes first appeared at a point P inside the glass pipe between X and Y. The distance of the point P from the stop-cock X is nearly

(A) 1.00 m (B) 1.19 m (C) 0.81 m (D) 0.62 m

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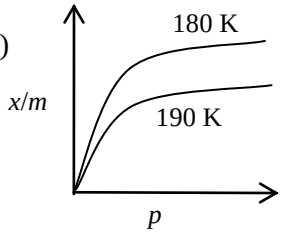
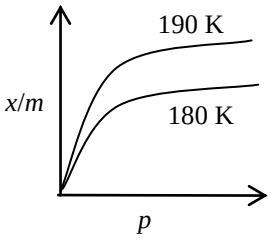
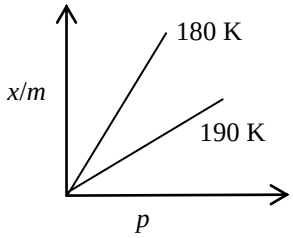
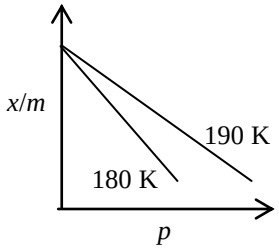
13. The physical adsorption of x grams of neon gas on m grams of activated charcoal adsorbent at pressure p is correctly represented by

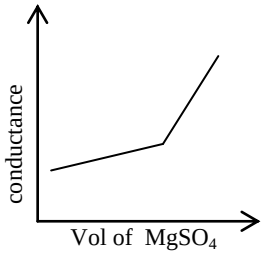
(A)


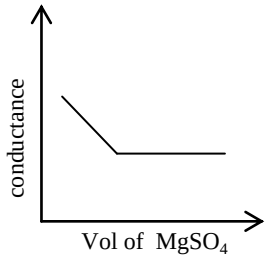
(B)


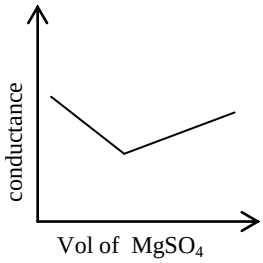
(C)


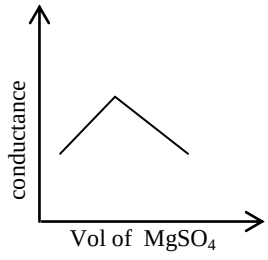
(D)


14. In a conductometric titration experiment, a solution of 0.1 M $Ba(OH)_2$ is titrated against a solution of 0.1 M $MgSO_4$, and the conductance of the mixture is continuously measured. The correct variation of conductance of the reaction mixture with the titration volume of $MgSO_4$ is best represented by

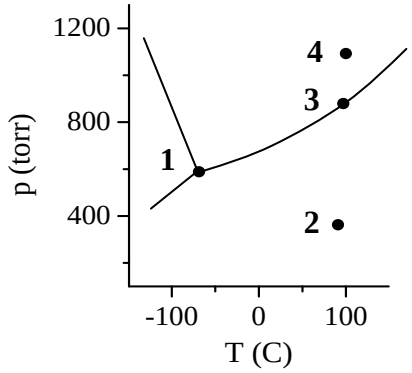
(A)


(B)


(C)


(D)


15. The phase diagram (pressure against temperature) for a substance S is given below.



Consider the following statements for the substance S:

(i) at point **1**, solid S can spontaneously convert to gaseous S but not to liquid S.

(ii) at point **2**, liquid S can be in equilibrium with gaseous S.

(iii) at point **3**, liquid S can start boiling to gaseous S.

(iv) at point **4**, S is in liquid state.

Which of the following is correct for the substance S?

(A) Statements (ii) and (iv) are correct.

(B) Statements (i) and (ii) are correct.

(C) Statements (i) and (iii) are correct.

(D) Statements (iii) and (iv) are correct.

16. In the pharmaceutical industry, a chemical analysis of aspirin involves the following reaction

$$5\,Br^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O\,(liquid)$$

In one such analysis it was found that the rate of formation of Br_2 at a particular instant was 0.25 mol s^{-1}. This indicates that the rate of disappearance of Br^- (in mol s^{-1}) would be

(A) 0.50 (B) 0.42 (C) 0.15 (D) 0.83

17. Corrosion of iron pipes occurs in the presence of water. To prevent such corrosion, iron pipes are normally coated with an element like magnesium using electroplating.

Which of the following statements is correct?

(A) During corrosion of an un-plated iron pipe, water is oxidized; during electroplating, iron acts as anode.

(B) During corrosion of an un-plated iron pipe, oxygen is reduced; during electroplating, iron acts as cathode.

(C) During corrosion of an un-plated iron pipe, iron is oxidised; during electroplating, magnesium is deposited on the anode.

(D) During corrosion of an un-plated iron pipe, iron is reduced; during electroplating, magnesium is deposited on the cathode.

18. HCl (acid) and NaOH (base) dissociate in water (H_2O) as:

$$HCl \rightarrow H^+ + Cl^- \qquad NaOH \rightarrow Na^+ + OH^-$$

and neutralize by the reaction $H^+ + OH^- \rightarrow H_2O$.

Now consider the following statements about the analogous reaction of NH_4Cl and KNH_2 in liquid NH_3 as solvent.

(i) NH_4Cl acts as an acid and KNH_2 acts as a base.

(ii) NH_4Cl acts as a base and KNH_2 acts as an acid.

(iii) The reaction of NH_4^+ and NH_2^- is a neutralization reaction.

(iv) The reaction of K^+ and Cl^- is a neutralization reaction.

Which of the following statements is correct?

(A) (i) and (iii) (B) (ii) and (iii)

(C) (i) and (iv) (D) (ii) and (iv)

19. The solubility product of $PbBr_2$ is $K_{sp} = 6.3 \times 10^{-6}$ at room temperature. If 50 ml of 0.02 M $Pb(NO_3)_2$ are mixed with 50 ml of 0.01 M $CaBr_2$, then

(A) $PbBr_2$ will precipitate and excess Br^- will remain in solution.

(B) $Ca(NO_3)_2$ will precipitate.

(C) $PbBr_2$ will precipitate and excess Pb^{2+} will remain in solution.

(D) no precipitate will form.

20. Consider the three molecules NH_3, PH_3 and AsH_3. Which of the statements below is INCORRECT?

(A) Each of the 3 molecules has a pair of unshared valence electrons.

(B) Each of the molecules is polar.

(C) Each of the molecules contains three sigma bonds.

(D) Each of the molecules is planar and triangular.

21. Nucleic acids can be double stranded (ds) or single stranded (ss). The following table gives the composition of bases in four different nucleic acid samples.

	Amount of base (%)				
	A	**T**	**G**	**C**	**U**
Sample 1	40	40	10	10	0
Sample 2	10	40	40	10	0
Sample 3	40	0	40	10	10
Sample 4	40	0	20	10	30

Using the information given above, it may be deduced that the samples 1, 2, 3, 4 are

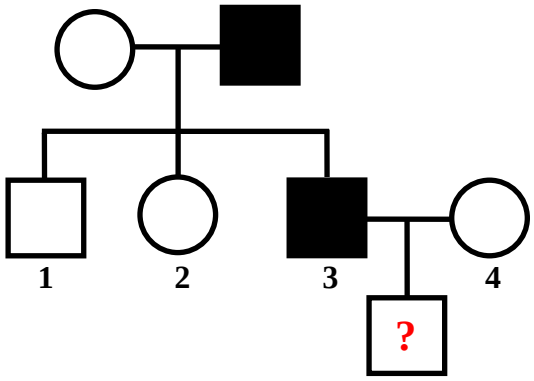
(A) 1 : dsDNA, 2 : ssDNA, 3 : ssRNA, 4 : ssRNA.

(B) 1 : dsDNA, 2 : ssRNA, 3 : dsDNA, 4 : ssDNA.

(C) 1 : ssDNA, 2 : dsDNA, 3 : ssRNA, 4 : dsRNA.

(D) 1 : dsDNA, 2 : ssRNA, 3 : ssDNA, 4 : ssDNA.

22. The following is the pedigree of a family from a marriage between first cousins. Males are represented by squares and females by circles. The family has a very rare X-linked trait. Out of their progeny (individuals 1, 2, 3 in the figure), individual 3, who expressed this trait, married outside the family to individual 4, who is not a carrier of this trait.



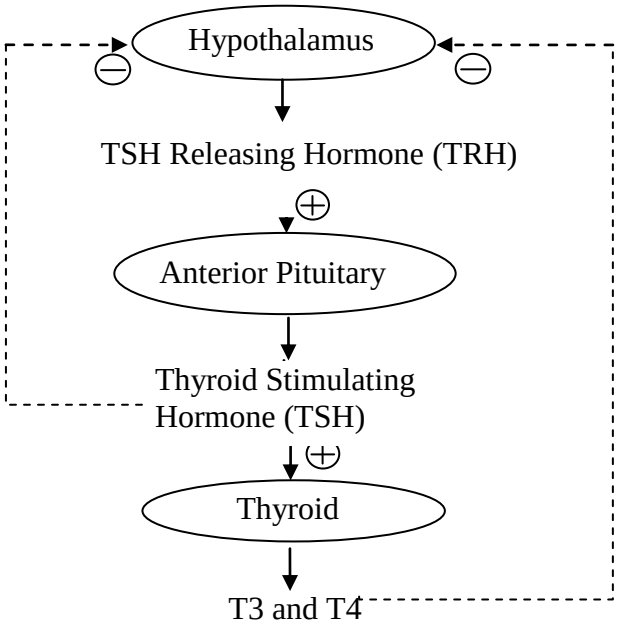
Consider the following statements regarding the above trait:

(i) The trait is recessive.
(ii) The trait is dominant.
(iii) The probability that the daughter (individual 2) is a carrier is 0.
(iv) The probability that the daughter (individual 2) is a carrier is 1.
(v) The probability that a son born to individuals 3 and 4 will express the trait is 0.
(vi) The probability that a son born to individuals 3 and 4 will express the trait is 0.5.

Which of the above statements are correct?

(A) (i), (iii) and (vi)
(B) (i), (iv) and (v)
(C) (ii), (iii) and (vi)
(D) (ii), (iv) and (v)

23. The following flow chart represents the feedback loops that regulate secretion of thyroid hormones (T3 and T4). Such secretion essentially regulates the basic metabolism rate in mammals. The '+' and '—' signs represent positive and negative regulation, respectively.



Three disease conditions are being studied where (x) the anterior pituitary fails to produce TSH, (y) the thyroid fails to produce T3 and T4 and (z) the hypothalamus fails to secrete TRH. In the Table below, match the hormone levels in column A with the disease conditions in column B.

Column A		Column B	
(i)	Low TRH, Low TSH and Low T3, T4	(x)	Anterior pituitary fails to produce TSH
(ii)	High TRH, High TSH and Low T3, T4	(y)	Thyroid fails to produce T3 and T4
(iii)	High TRH, Low TSH and Low T3, T4	(z)	Hypothalamus fails to secrete TRH

Which of the following is the correct match for the above?

(A) (i) – (x) ; (ii) – (y) ; (iii) – (z)

(B) (i) – (z) ; (ii) – (y) ; (iii) – (x)

(C) (i) – (y) ; (ii) – (x) ; (iii) – (z)

(D) (i) – (z) ; (ii) – (x) ; (iii) – (y)

24. DNA replicates in a semi-conservative manner in which each individual strand is copied to form a new molecule of DNA. The two strands can be labelled with isotopes using substrates that contain either normal ^{14}N or its heavy isotope ^{15}N. In an experiment, one strand of DNA was labelled with ^{14}N and the other with ^{15}N (hybrid DNA). The hybrid DNA was then allowed to replicate in the presence of the ^{14}N-labelled substrate. If one started with a single molecule of hybrid DNA and allowed it to replicate over 4 cycles, what would be the proportion of double-stranded DNA molecules labelled with ^{15}N?

(A) 1/4

(B) 1/8

(C) 1/16

(D) 1/32

25. Assimilation of CO_2 by photosynthesis in cacti growing in arid regions occurs in two stages. In stage 1, CO_2 uptake and fixation occurs at night and CO_2 is stored in the form of malate in vacuoles. In stage 2, during the day the malate moves to the chloroplast where it is decarboxylated, and the released CO_2 is re-fixed by RuBP carboxylase. The main reason for this is:

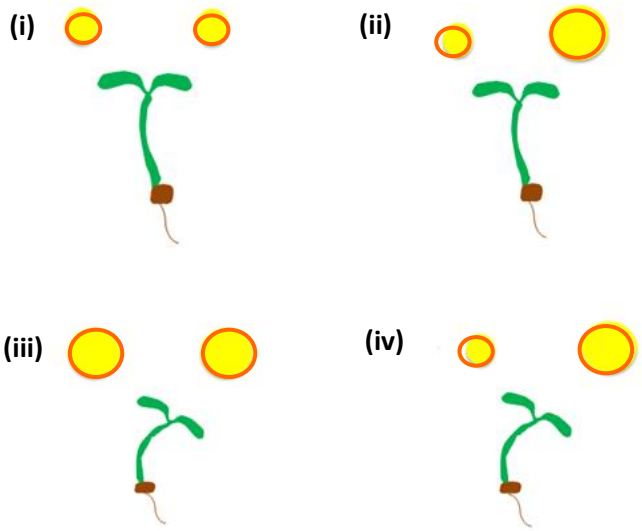
(A) Cacti require light for RuBP carboxylase activity.

(B) Cacti close their stomata during the day, so availability of CO_2 for RuBP carboxylase activity is low during the day.

(C) Cacti can fix CO_2 only at an acidic pH that is provided by malate.

(D) Cacti have chloroplasts that are impermeable to CO_2 but are permeable to malate.

26. Charles Darwin observed that seedlings grow towards light. He called this response 'phototropism.' In an experiment two light sources are used to illuminate each seedling. Each source is indicated by a yellow circle in the diagrams below. The larger yellow circle represents a light source with twice the illumination than the light source represented by the smaller yellow circle.



Which of the above responses would be observed?

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

27. In an eukaryotic cell, mitochondria and chloroplasts are thought to have originated through endosymbiosis, a process in which an organism engulfs another and the two continue to exist in a mutually beneficial arrangement. Which of the following observations best supports this theory?

(A) These organelles exchange metabolites with other cellular compartments.
(B) These organelles are capable of independent existence outside the cell.
(C) These organelles have their own genetic material.
(D) These organelles provide energy in the form of ATP to the cell.

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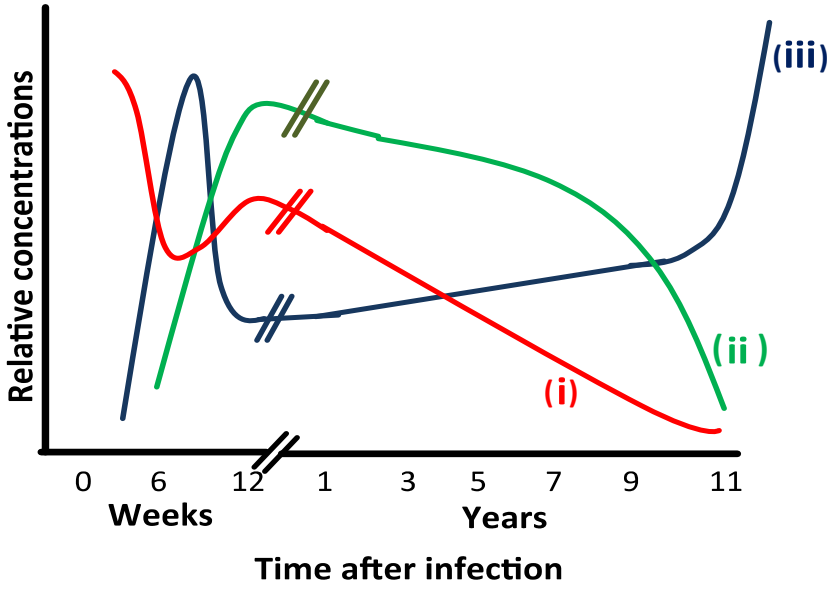
28. The Human Immunodeficiency Virus (HIV) can cause the disease AIDS. The HIV infects lymphocytes, the T-cells, that help in the production of antibodies. The following graph shows how the concentrations of HIV, T-cells, and antibodies against HIV develop in time in an untreated AIDS patient.



In the above graph, the lines marked (i), (ii) and (iii), respectively, represent

(A) HIV, T-cells and antibodies.

(B) T-cells, HIV and antibodies.

(C) T-cells, antibodies and HIV.

(D) Antibodies, T-cells and HIV.

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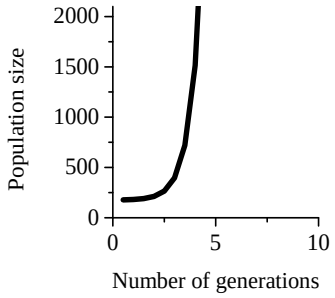
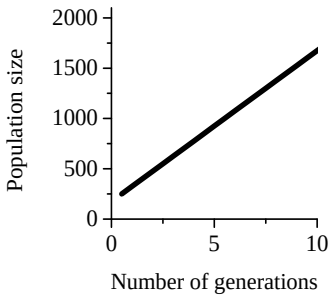
29. Consider a hypothetical population, where all members have access to abundant food and they are free to reproduce at their physiological capacity. Which one of the following curves best represents the population growth expected under such conditions?

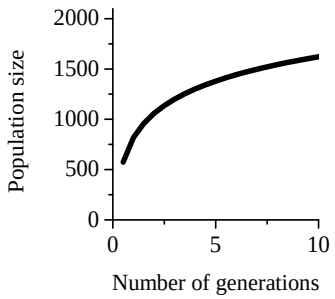
(A)



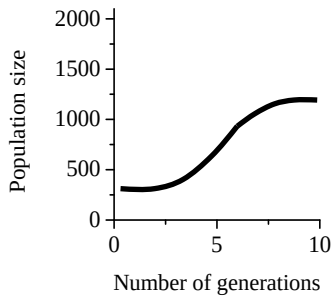
(B)



(C)



(D)



30. Ammonia, urea and uric acids are toxic, nitrogenous waste products produced by break down of protein and nucleic acids. These waste products have to be excreted. Ammonia is highly toxic and has a high solubility in water. Urea is less soluble and less toxic than ammonia. Uric acid is least toxic and has low solubility. Excretion of nitrogenous waste from a frog and a tadpole would primarily be as

(A) Urea in tadpole and ammonia in frog.

(B) Ammonia in tadpole and urea in frog.

(C) Urea in both tadpole and frog.

(D) Uric acid in tadpole and urea in frog.

Time : 3 hrs Marks : 30

Multiple Choice Questions

1) Answer : A **Solution :** a: 27m3 / 22.4 lt = 10^3 moles = 10^26 molecules

b: 1000/18 = 50 moles = 10^25 atoms

c: 5 seconds for 1 breath => 10^8 breaths

d: 14 billion years => 10^17 seconds

2) Answer : A **Solution: The sun is just below the horizon. The Moon is just above the horizon. This implies crescent moon. Since the illumination is from below, answer is A.**

3) Answer: B Solution :

$$m = \frac{\sin i}{\sin r}$$

$$\sin r = \frac{\sin i}{m} = \frac{R/\sqrt{1+(3/4)^2}R}{\frac{4}{3}} = \frac{3}{5},$$

$$\cot r = \frac{4}{3} = \frac{R}{R - R}$$

$$R = \frac{7}{4}R$$

Area of shadow = $\frac{49}{16}\pi R^2$

4) Answer B**. Solution:** The magnetic field above the wire is out of the plane. This flux is decreasing and should be compensated by the current in the loop F and so the current in loop F will be anti- clockwise. For loop G the situation is opposite

5) Answer A**: Solution : (a) corresponds to p = 0. Then solve for T and put V = 1, a = α, b = β**

6) Answer C

7) Answer B

8) Answer B: **Solution :** We assume the sign convention where distance measured in the direction of light propagation are positive, and in opposite direction, negative. For the morning experiment, since the image of the outside world (object distance $u \approx$ inf) is real, sharp and

inverted, the lens must be converging one, and the image distance (v) is equal to the focal length (f) of the lens. Thus f = 0.120m. for the evening experiment, the hole in the card serves as the object of size 0.005m. The image size on the wall is 0.020m.

- Distance between the lens and the card $u = -uc$ ($uc > 0$)
- Distance between the lens and the wall $v = +vc$ ($vc > 0$)
- Distance between the lens and wall (question) $d = uc + vc$
- Magnification = $vc/-uc$ = 0.020 / -0.005 = -4 (real images by converging lenses always have negative magnification, i., inverted image).

Thus, applying the lens formula

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

$$\frac{1}{vc} + \frac{1}{uc} = \frac{1}{f}$$

$$\frac{1}{4uc} + \frac{1}{uc} = \frac{1}{f}$$

$$\frac{5}{4uc} = \frac{1}{f}$$

$$uc = 5f / 4 = 5 \text{ x } 0.120\text{m}/4 = 0.150\text{m}$$

$$vc = 4\,uc - 4 \text{ x } 0.150\text{m} = 0.600\text{m}$$

Therefore, the distance between the lens and the wall is

$$d = uc + vc = (0.15\,0 + 0.600)\text{m} = \mathbf{0.750m}$$

Multiple Choice Questions

9) Answer D **:Solution:**

$V_1 = 300$ V $\quad t_1 = 5$ min

$V_2 = 200$ V $\quad t_2 = 20$ min

$V_3 = 100$ V $\quad t_3 =$? min

Rate of heat supplied by heating container = $\frac{V^2}{R}$

For first and second container (resistance R is same)

$$\frac{t_1}{t_2} = \frac{1}{4} \neq \frac{V_1^2}{V_2^2} = \frac{4}{9}$$

Second container should take 2.25 times that of container one but it is taking four times that of container one. There is some heat loss (P_{loss}) to the environment which is at lower temperature than ice temperature (0^0 C).

Same amount of heat is being melt in both containers, that means amount of heat supplied is same.

$$\left(\frac{V_1^2}{R} - P_{loss}\right)_1 = \left(\frac{V_2^2}{R} - P_{loss}\right)_2$$

which gives $P_{loss} R = \frac{5}{3} \times 10^4 = V_{loss}^2 > V_3^2 = 10^4$.

Container will loose all heat given by 100 V power supply and ice will cool down instead of melting.

Additional:

Say outside temp is T_0 and final temperature of ice is T_f .

$$k(0 - T_0) = 10^4 \times \frac{5}{3}$$

$$k(T_f - T_0) = 10^4 \times 1$$

which gives $T_f = \frac{2}{3} T_0$

Multiple Choice Questions

10) Answer C:
Force at the bottom : F_b
Weight of water : W
Downward vertical force of curved surface on water is : F_g

Then $F_b = W + F_g$
=> $F_g = F_b - W$
=> $P_b.A - V\rho g$
$F_g = \rho ghA - V\rho g$
$F_g = \rho g (hA - V)$
$= 10^3 \times 10 \times [\ 0.25 \times 3.14 \times (0.20)^2/4 - 2.5 \times 10^{-3}]$ N

$= 10^4 \times [7.85 - 2.50] \times 10^{-3}$ N
$= 53.5$ N
By 3rd law, F_g = vertical force of water on glass

11) Answer **B : Fig 2 violates Pauli's exclusion principle and Hund's rule.**

12) Answer C: **Solution :** Grahams law of diffusion

13) Answer A : **Frendlich isotherms: (lower the temp higher is the adsorption)**

14) Answer C: **Solution :** The conductivity that is measured in an electrolyte solution depends on the type and concentration of the ions. As long as the reaction is taking its course the conductivity drops, when the standard solution is in surplus the conductivity rises again

15) Answer D: **Statements (i) and (iii) are correct**

16) Answer B:

17) Answer B: **Iron acts as the cathode and oxygen is reduced.**

18) Answer A: **A) I and III are correct**

19) Answer D: Solution:

$[Pb^{+2}] = 1 \times 10^{-3}$

$[Br^-] = 5 \times 10^{-4}$

Ionic product = $[Pb^{+2}] [2Br^-]^2$

Ionic product = $[1 \times 10^{-3}] [2x5 \times 10^{-4}]^2$

10^{-3+2-8}

10^{-9} As K_{sp} > ionic product, **no precipitate will form.**

20) Answer D: **each of the molecules is planar and triangular.**

21)Answer A: **Solution:** T is present only in DNA, while U is present only in RNA. If A≠T or U it is single stranded. If A = T it is most likely to be double stranded. Sample 1 could possibly be single stranded. However, it is not one of the choices in the correct answer (A).

22) Answer B: **B) (i), (iv) and (v)**

Solution:

- If trait is dominant then daughter would show the trait as it would inherit the father's X-chromosome. Since son shows the trait, X chromosome inherited from the mother carried the recessive trait (carrier).
- As the daughter would inherit the father's X-chromosome the daughter is bound to be a carrier.
- As the trait is RARE, marriage outside the family ensures that the mother is likely to not carry the trait. Hence the son will have '0' probability of inheriting the trait as the X-chromosome will come from the mother.

23) Answer B: **(i) and (z); (ii) and (y); (iii) and (x)**

Solution: It based on analysis. No prior knowledge is needed.

- In case of 'x' level of T_3 and T_4 will be low. As T_3 and T_4 has a negative effect on TRH levels, there will be an increase in the levels of TR . Thus 'x' matches with 'iii'
- In case of 'y' T_3 and T_4 is low, so TRH levels are high (as explained above). As TRH positively regulates TSH, TSH levels will increase. Thus 'y' matches with 'ii'

- In case of 'z' TRH levels are low, thus TSH levels will be low and finally T_3 and T_4 levels will be low. Thus 'z' matches with 'i'.

24) Answer C: **C) 1/16**

Solution: ^{14}N: ^{15}N (start); after 1 cycle two molecules of DNA, ^{14}N: ^{15}N and ^{14}N: ^{14}N; after 2 cycle four molecules of DNA, one ^{14}N: ^{15}N and three ^{14}N: ^{14}N; after 3rd cycle we will have 8 molecules of DNA, one ^{14}N: ^{15}N and rest 7 ^{14}N: ^{14}N. Finally after the 4th cycle there will be 16 molecules of DNA of which only one will be hybrid ^{14}N: ^{15}N in nature.

25) Answer B:

B) Cacti close their stomata during the day, so availability of CO_2 for RuBP carboxylase activity is low during the day.

Solution: To conserve water during the hot days, cacti close stomata during the day. This reduces the CO_2 concentration in the leaf, which cannot support RuBPcase activity.

26) Answer D: **D) i and iv**

Solution: 'i' has equal illumination so the seedling does not bend. In 'iv' the seedling bends towards the higher illumination.

27) Answer C: **C) These organelles have their own genetic material.**

Solution: A and C are correct but only C supports the concept of endosymbiosis. B is possible only for a short duration.

28) Answer C: **C) T-cells, antibodies and HIV**

29)Answer A**: Solution:** Population increase under these ideal conditions is called exponential population growth, giving rise to what is called a J-shaped growth curve. Curve presented in D is based on logistic model of population growth. B and C are just created as wrong answers.

Comment: Typical growth-curves for populations is a topic mentioned in the syllabus under Systems – Ecology. See Chapter on Population Ecology in Biology 7th Edition, Campbell and Reece for clarification on growth curves.

30)Answer B: **B) Ammonia in tadpole and urea in frog.**

Solution: As ammonia has maximum solubility in water, thus tadpole has evolved the mechanism to generate ammonia as the waste. On the other hand a land animal would generate urea or uric acid. Frog makes urea.

Very Important Instruction

The first 30 minutes are to be used ONLY for reading the question paper.

You MAY NOT write anything during this period, even on the Question Paper.

After 30 minutes, you will be given the answer sheets and a signal to start writing.

You will then have a further 3 hours to complete the examination.

Examination Rules

1. You have to sit at your designated desk.
2. Before the examination starts, you must check the stationery and any tools (pen, ruler, calculator) provided by the organizers.
3. You are not allowed to bring any tools except personal medicine or approved personal medical equipment.
4. You have to check the question and answer sheets provided. Raise your hand, if you find any missing sheets. Start tasks after the start whistle is blown.
5. During the examination, you are not allowed to leave the examination room except in an emergency and then you will be accompanied by a supervisor/volunteer/invigilator.
6. You are not to disturb other competitors. If you need any assistance you may raise your hand and wait for a supervisor to come to assist.
7. There will be no discussion about the examination tasks or problems. You must stay at your desk until the examination is over, even if you have finished the examination.
8. At the end of the examination time you will hear a whistle blow. You are not to write anything on the answer sheets after this stop whistle. You must leave the room quietly when asked to do so. The question and answer sheets must be left neatly on your desk.

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

A. The time available is 3 hours.

B. Check that you have a complete set of the test questions and the answer sheets. The total number of questions is 5 (19 pages).

C. Write down your ID code on each page of your answer book.

D. Write your final answer in the smaller box provided. Write the steps clearly in the larger box.

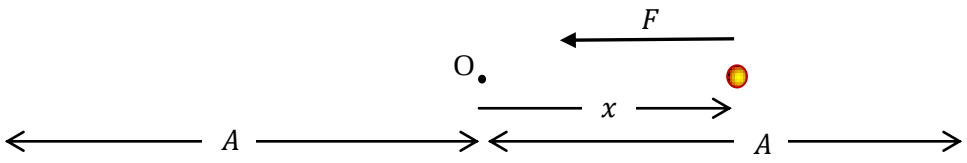
Question 1

1. Oscillations, or periodic motions, pervade our Universe. One starts from the concept of a *linear restoring force*, i.e. the force F on a body of mass m at a distance x from its equilibrium position is given by

$$F = -kx$$

where k is a *positive* constant known as the *force constant*;

The negative sign $(-)$ in the equation indicates that the force is directed towards the position O of equilibrium at $x = 0$:



Under the action of such a force, a body will execute *simple harmonic motion* (SHM), i.e. to-and-fro motion about the equilibrium position (O), with a time period

$$T = 2\pi\sqrt{\frac{m}{k}}$$

and frequency

$$\nu = \frac{1}{T}$$

The maximum displacement A of the body from its equilibrium position is called the *amplitude* of the oscillation, as shown in the figure above.

(a) Consider the Moon as a uniform solid sphere with

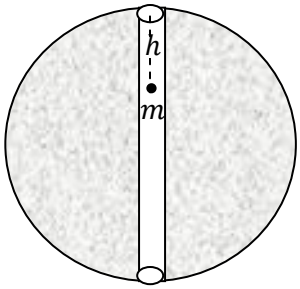
radius $R = 1.7 \times 10^6$ m,

mass $M = 7.3 \times 10^{22}$ kg, and

acceleration due to gravity at the surface $g = 1.6$ m s^{-2}.

It is known that for a spherically symmetric mass distribution, the gravitational force at a distance r from the centre is only due to the mass enclosed within a sphere of radius r with the same centre.

Now imagine the following situation. A straight narrow tunnel is dug through the Moon, passing through its centre, as indicated in the figure, and a small mass m is dropped into it from one end.



(i) The magnitude of the gravitational force experienced by the mass m at a depth h from the surface (see figure) will be

[0.5]

(A) $mg\left(1-\frac{h}{R}\right)$ (B) $mg\left(1+\frac{h}{R}\right)$

(C) $mg\frac{h}{R}$ (D) $mg\frac{h}{R-h}$

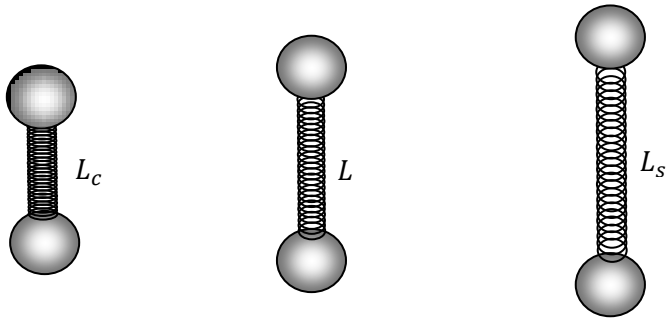
(ii) In the grid provided on your answer sheet, plot a graph of $F(r)/mg$, where $F(r)$ is the force on the mass m at a distance r from the centre of the Moon, as a function of r/R, as r varies from 0 to $2R$.

[1.0]

(iii) If $m = 0.10$ kg, what is the minimum time (in seconds) it will take, from the moment the mass m is dropped through the hole at the surface, for it to reach the centre of the Moon?

[1.0]

(b) A molecule like O_2 consists of two identical atoms held together by covalent bonding. We can think of such molecules as two identical spheres of mass m, held together by a spring that provides a linear restoring force F, with force constant k. This causes SHM of the masses along the line joining them. As a result, the molecule changes periodically from a compressed state (where the separation between the masses is minimum at L_c) to a stretched state (where the separation is maximum at L_S). In between, the force F is zero when the masses are separated by the equilibrium length L.



Obviously $L_c < L < L_s$ as the figure shows.

(i) The oxygen molecule O_2 has a force constant, $k = 1150$ N m^{-1}. The equilibrium bond length is $L = 1.5 \times 10^{-10}$ m and the change in the bond length when it is fully stretched is 6.0% of L. Calculate the vibrational energy, that is the sum of kinetic and potential energies per mole of oxygen (in kJ mol^{-1}). **[1.5]**

(Avogadro's number, $N_A = 6.023 \times 10^{23}$)

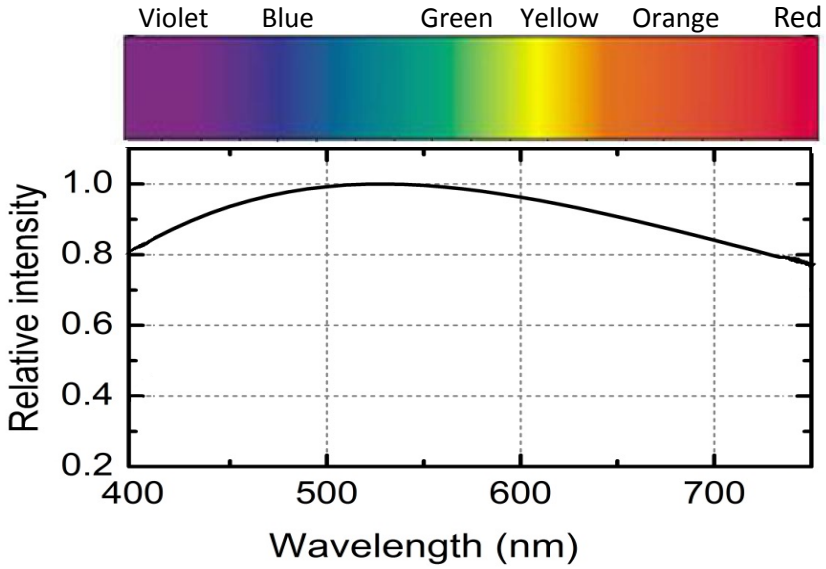
(ii) The atomic weights of the halogen elements listed in the periodic table are:

F	**Cl**	**Br**	**I**
19.0	35.5	79.9	126.9

Two halogen elements, X and Y, form diatomic molecules X_2 and Y_2 with force constants $k_X = 325.0$ N m^{-1} and $k_Y = 446.0$ N m^{-1} respectively. The vibration frequencies are measured to be $\nu_X = 16.7 \times 10^{12}$ Hz and $\nu_Y = 26.8 \times 10^{12}$ Hz. Identify the halogen elements X and Y by writing their symbols. Write your answer in the form X = _____ , Y = _____ in the answer sheets. **[1.0]**

Question 2

2. Sunlight, the most important source of illumination on the Earth, contains all of the visible wavelengths, which the human eye perceives as the different colours of the spectrum. However, sunlight does not contain all wavelengths with equal intensity, as shown in the graph below. The maximum intensity is for blue-green light of wavelength about 525 nm (1 nm = 10^{-9} m).



Our perception of the colours of objects around us results mainly from the wavelength-dependent scattering or absorption of sunlight by these objects. If an object scatters/reflects back sunlight with exactly the same intensity distribution of wavelengths as above, it will appear to our eye as pure white. Any deviations from this intensity pattern in the light scattered/reflected from an object is perceived as that object having a colour.

(a) The scattering of light by particles which are much smaller than the wavelength of light, e.g. air molecules, was independently studied in the UK by Lord Rayleigh and in India by Sir C.V. Raman. They showed that if we define a *scattering efficiency* $\eta_s = I_s/I_i$, where I_i and I_s are the intensities of the incident and the scattered light respectively, then $\eta_s(\lambda) \propto \lambda^{-4}$, where λ is the wavelength of the incident light. Later, the German physicist Gustav Mie showed that if the particle sizes are comparable to the wavelength, then η_s is typically 40 times higher and is independent of the wavelength λ. Thus, one distinguishes between wavelength-dependent *Rayleigh scattering* and wavelength-independent *Mie scattering*.

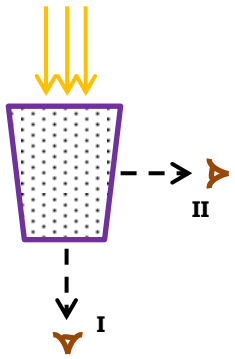
(i) If sunlight is shone through a transparent container (with walls of negligible thickness) filled with nitrogen gas, what will be the ratio of the scattered light intensity for colours corresponding to wavelengths 400 nm and 650 nm respectively? **[1.0]**

(ii) The *visibility range* R_v^0 for pure air is about 300 km for the wavelength corresponding to the blue-green colour. However, if the air is polluted by suspended materials (like smoke and dust), these scatter sunlight more efficiently than air molecules and the visibility is considerably reduced. For polluted air, the visibility range is given by

$$R_v = \frac{R_v^0}{\beta_s}$$

in terms of the *scattering loss factor* β_s, which satisfies $\beta_s \propto \eta_s C$, where C is the concentration of the scattering material and η_s is its scattering efficiency. Obviously, for pure air $\beta_s = 1$. If, after a dust storm, dust particles of size 520 nm are added to the air at 10% concentration, what will be the visibility range R_v (in km) for the blue-green colour of light? **[1.5]**

(iii) Milk is a *colloidal solution* in which droplets of liquid fat, of size around 100 nm, are suspended in water. These droplets scatter light more strongly than the water molecules, causing normal milk to appear white rather than transparent.



Consider the following experiment. A few drops of milk are added to a glass of water illuminated from above by a beam of sunlight, as shown in the figure on the right. The water turns cloudy, but some sunlight still passes through, since the concentration of milk is small. The glass is now viewed (I) from below, and (II) from the side, as shown in the figure.

When compared to the emerging light viewed from below (I), the emerging light viewed from the side (II) will appear **[0.5]**

(A) bluish (B) orange (C) reddish (D) the same

(iv) Which of the following atmospheric phenomena is mainly governed by Mie scattering of light?

[0.5]

(A) red sunset

(B) white clouds

(C) blue sky

(D) rainbow

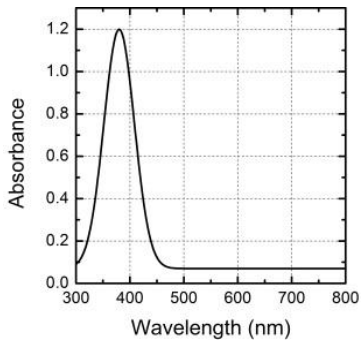
Images taken from:
(A) http://bostern.wordpress.com (B) http://www.kaneva.com
(C) http://lisathatcher.wordpress.com (D) http://www.freefoto.com

(b) Plants absorb sunlight and store the energy in chemical form, combining water and CO_2 into carbohydrate molecules by a complex process called *photosynthesis*. The discovery of photosynthesis is a long and fascinating story, starting with the Dutch physician Jan van Helmont in the 17th century. Some of the pioneering research on the physiology of photosynthesis was carried out in the 1920's by the Indian scientist, Sir J. C. Bose. A few of the details are even now under study.

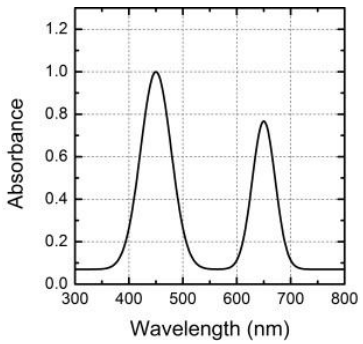
(i) The green colour of leaves and shoots of plants is usually due to the presence of chlorophyll, the compound mainly responsible for photosynthesis. Which of the following graphs depicts the correct absorbance spectrum of chlorophyll?

[1.0]

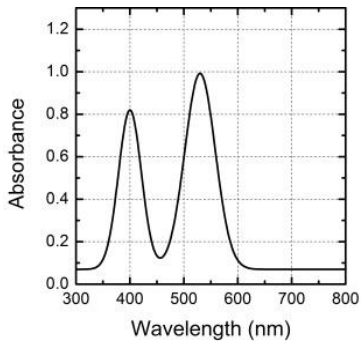
(A)



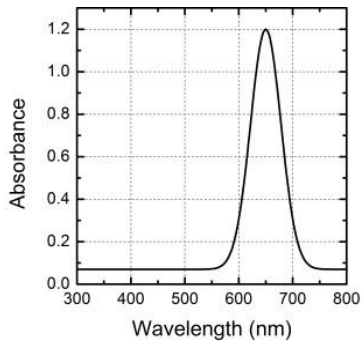
(B)



(C)



(D)



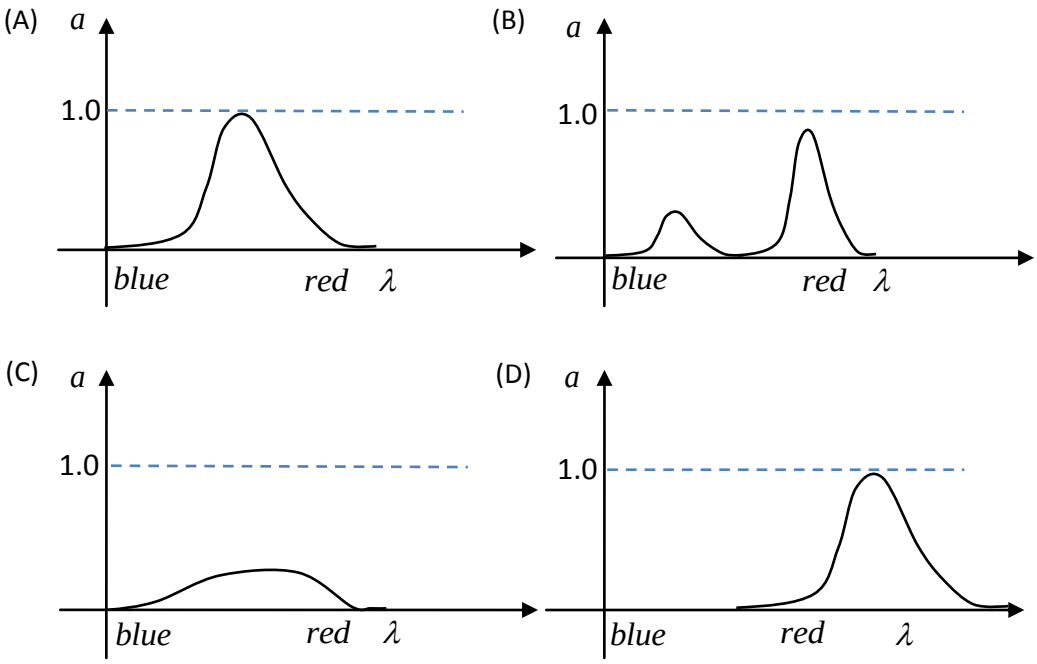
(ii) Assuming that the rate of photosynthesis is proportional to the amount of light absorbed (see above figure), what will be the wavelength (in nm) corresponding to the maximum photosynthesis rate in green plants?

[0.5]

(iii) For a long time it was believed that only plants are able to absorb solar energy and convert it into usable form. However, with the invention of solar cells, we now have artificial devices that, just like photosynthesis, also convert light into another form of energy for use in various devices.

The four graphs below represent the characteristic absorbance (a) spectra of four different materials that can potentially be used in solar cells. If these cells are designed to work in sunlight, which material will exhibit the highest conversion efficiency of sunlight into electricity?

[1.0]



Question 3

3. Maintenance of proper pH in blood and in intercellular fluids is absolutely crucial in living organisms. This is primarily because the functioning of enzymes that catalyze these processes are normally pH-dependent, and small changes in pH values may lead to serious illnesses. The pH value of human blood plasma is 7.4. The presence of CO_3^{2-}, HCO_3^- and CO_2 in body fluids helps in stabilizing pH of blood despite the addition or removal of H^+ ions by other biochemical reactions in the body.

(a) The dissociation of H_2CO_3 in blood occurs in two steps. Write down balanced equations for these two steps.

[0.5]

(b) Let the equilibrium constants for these reactions be K_1 and K_2 respectively. The values of these constants at the body temperature of 37 ^{0}C are : $K_1 = 2.2 \times 10^{-4}$ and $K_2 = 4.8 \times 10^{-11}$.

(i) Calculate the concentration of H^+ in a solution at 37 ^{0}C, and hence its pH value, if H_2CO_3 and HCO_3^- are present in equal concentrations in mol/l in that solution.

[0.5]

(ii) Calculate the ratio of HCO_3^- and CO_3^{2-} concentrations required to maintain the pH of blood at 7.4.

[1.0]

(c) Usually in the human body, H_2CO_3 is in equilibrium with the CO_2 dissolved in the blood.

$$CO_2(\text{dissolved}) + H_2O\,(\text{liq}) \overset{K_3}{\rightleftharpoons} H_2CO_3(\text{dissolved})$$

At 37^0 C, $K_3 =$ 5.0 x 10^{-3}.
Calculate the total equilibrium constant, K' for the reaction

$$CO_2(\text{dissolved}) + H_2O\,(\text{liq}) \overset{K'}{\rightleftharpoons} HCO_3^-(\text{aq}) + H^+(\text{aq})$$

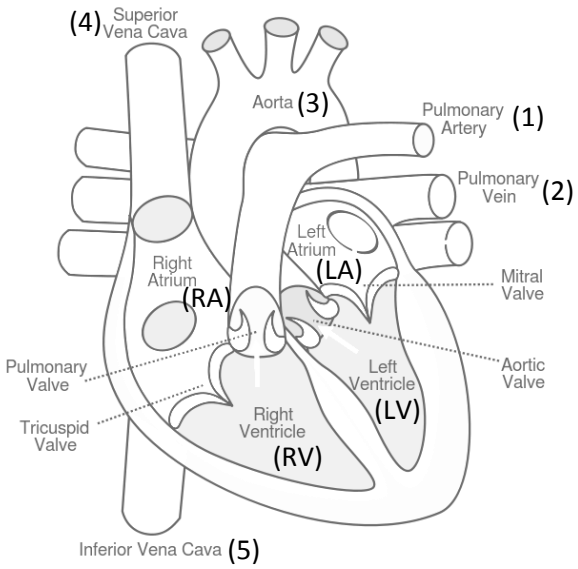
[0.5]

(d) Blood plasma contains a total carbonate buffer pool, which is a mixture of HCO_3^- and CO_2 with a total concentration of 3.4×10^{-2} M at 38 ^{0}C. At this temperature the value of the equilibrium constant K' is 1.3×10^{-6}. The concentration of the H_2CO_3 is negligible. Calculate the ratio of concentrations of CO_2(dissolved) and HCO_3^-, and their individual concentrations, in this blood sample at pH 7.4.

[1.5]

Question 4

4. The human heart has four chambers — the *left atrium*, the *right atrium*, the *left ventricle* and the *right ventricle*. These four chambers and the various blood vessels connected to the heart are shown in the diagram below.



Major blood vessels to and from the heart	**Heart Chambers**
1. Pulmonary artery	RA) Right Atrium
2. Pulmonary vein	RV) Right Ventricle
3. Aorta	LA) Left Atrium
4. Superior Vena Cava	LV) Left Ventricle
5. Inferior Vena Cava	

.

(a) Which of the above carry de-oxygenated blood?

[1.0]

(b) The table below shows the volume of blood V in the left ventricle of an individual at different times t during one cardiac cycle.

[0.5]

t (s)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
V (cm^3)	80	89	75	60	48	47	70	80	89

What would be the individual's heart rate (in beats/minute) as calculated from the table?

(c) At different times during the cardiac cycle the various valves are open or closed so as to direct the flow of blood. Considering the data given in the above table in 4(b), what would be the correct positions of the Mitral valve and the Aortic valve at 0.2 s and 0.6 s, respectively? Fill the table provided in the answer sheet appropriately. (O = open, C=closed).

[1.5]

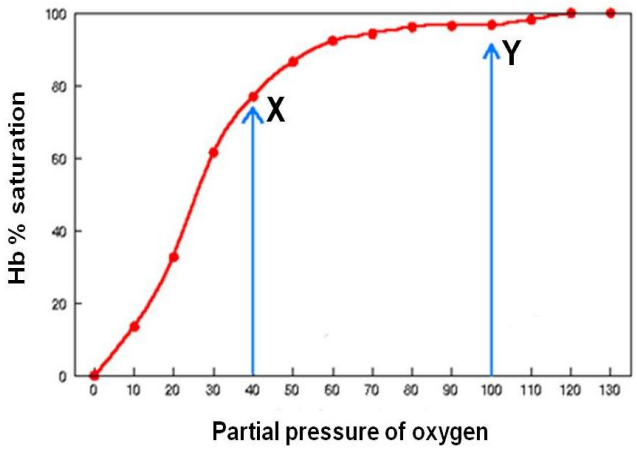
Time	Mitral valve	Aortic valve
0.2 s		
0.6 s		

(d) Blood flows from the heart into the aorta during a cardiac cycle. If the diameter of the aorta is approximately 2.4 cm, then, using the table in 4(b) calculate the average speed (in cm s^{-1}) of blood flowing into the aorta in one full cardiac cycle.

[1.0]

(e) Blood flows from the aorta and its major arteries into arterioles and fine-walled capillaries. If all the major arteries in the body have a total cross-sectional area of about 7.0 cm^2 calculate the average speed (in cm s^{-1}) in the major arteries which have the same volume of blood as the aorta flowing through them. **[0.5]**

(f) The degree of haemoglobin (Hb) saturation with oxygen may be determined by measuring the partial pressure of oxygen in various tissues of the body. The graph below shows the haemoglobin saturation level corresponding to different partial pressures of oxygen. Two such points have been marked as X and Y on the graph.



Considering the above graph, correlate the percent Hb saturation at points X and Y with approximate partial pressure of oxygen in the following areas of the body. Fill the table given in the answer sheets using X and Y as appropriate.

[1.0]

Aorta	Renal vein	Alveolar space in lungs	Pulmonary artery

Question 5

5. A cheetah is a wild cat, now extinct in India, but still found in some other parts of the world. Its most prominent feature is its high running speed and fast acceleration. It can accelerate from rest to its maximum running speed of about 30 m s^{-1} in just 3.0 s. (For comparison, a fast sports car like a Porsche takes about 4.0 s to attain the same speed).

Image taken from: http://www.vimeo.com

Though the cheetah can accelerate and run very fast, it cannot run a long distance at its maximum speed because it quickly gets tired. Thus, if it cannot catch its prey within that limit, it has to forgo the hunt.

(a) Consider a cheetah with mass 50 kg. It starts from rest and accelerates for 3.0 s to reach its maximum speed of 30 m s^{-1}. It then continues to run for 20 s at this speed.

(i) Calculate the average acceleration of this cheetah required to reach its maximum speed.

[0.5]

(ii) Calculate the distance travelled during the first 3.0 s, assuming that the acceleration is uniform.

[0.5]

(iii) The cheetah has to do work against friction, mostly due to air. Assume that this frictional force is always 100 N. Calculate the total mechanical work done by the cheetah during the first 23.0 s of its motion.

[1.0]

(b) During the first 23.0 s, the body temperature of the cheetah rises from 38.5 ^{0}C to 40.0 ^{0}C. Take the specific heat of the body of the cheetah to be 4.2 kJ kg^{-1} K^{-1}.

(i) If the rise in body temperature is linear during this time, calculate the total heat generated by the cheetah's metabolism. Neglect any heat loss to the surroundings.

[1.0]

(ii) Assume that some of the energy generated by the cheetah's body increases its temperature and the rest corresponds to the mechanical work done. Calculate the fraction of the total generated energy that is converted to kinetic energy.

[**1.0]**

(c) When the cheetah starts running, it generates its energy initially by aerobic respiration, where glucose is oxidised in the presence of oxygen, resulting in generation of ATP. In this process, each mole of glucose generates 36 moles of ATP, and 1130 kJ energy is released when all these ATP molecules are utilised. Running at high speeds increases the demand for oxygen, resulting in the increased breathing rate of 150 breaths per minute.

(i) Write down the balanced chemical reaction for aerobic respiration.

[1.0]

(ii) If the cheetah requires 400 kJ of energy, calculate the volume of oxygen required if all this energy is to be obtained by aerobic respiration. Take the molar volume of oxygen gas to be 24.5 litres.

[1.0]

(iii) The cheetah extracts oxygen from the air while breathing. The inhaled air (about 500 ml per breath) contains 20.0 % oxygen (by volume), while the exhaled air is assumed to contain 15.0 % oxygen (by volume). Calculate the volume of oxygen that the cheetah can use during the 23.0 s of its run, at a breathing rate of 150 breaths per minute.

[1.0]

(d) It should be clear from the answers to the above that the energy requirement of the cheetah's muscles is not met only by aerobic respiration. ATP must then be produced by anaerobic respiration, but in this only two moles of ATP are generated per mole of glucose.

(i) Anaerobic respiration converts the energy from glucose into ATP. If glucose were to be completely burnt up, one mole would release 2872 kJ of energy. What is the efficiency of anaerobic respiration compared to complete combustion of glucose?

[1.0]

(ii) If all the 400 kJ required by the cheetah for its run were to be produced by anaerobic respiration, calculate the total amount of glucose (in kg) that would be required.

[1.5]

(i) The magnitude of the gravitational force experienced by the mass m at a depth h from the surface (see figure) will be

[0.5]

(A) $mg\left(1-\frac{h}{R}\right)$ (B) $mg\left(1+\frac{h}{R}\right)$

(C) $mg\frac{h}{R}$ (D) $mg\frac{h}{R-h}$

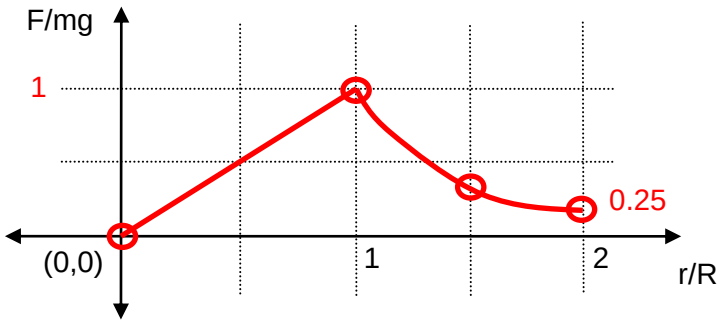
Correct answer: (A) **[0.5]**

$g(r) = GM(r)/r^2$ $M(r) = (4/3)\rho\pi r^3$ $\rho = M/(4/3)\rho\pi R^3$

$g(r) = (GM/R^2)(r/R) = gr/R$ $F = [mg/R]r = mg(1-h/R)$

(ii) In the grid provided on your answer sheet, plot a graph of $F(r)/mg$, where $F(r)$ is the force on the mass m at a distance r from the centre of the Moon, as a function of r/R, as r varies from 0 to $2R$.

[1.0]



(iii) If $m = 0.10$ kg, what is the minimum time (in seconds) it will take, from the moment the mass m is dropped through the hole at the surface, for it to reach the centre of the Moon?

[1.0]

Correct answer: T = 1619 s **[1.0]**

Substitute mg/R as k in the formula for the frequency, Time period = 6476 s, time take to reach the centre = 1619 s.

$\nu_0 = 1/2\pi(k/m)^{0.5}$

Time taken to reach the centre, $T = 2\pi/4(m/k)^{0.5}$

$T = \pi/2(R/g)^{0.5}$ $T = 1619$ s

(iv) The oxygen molecule O_2 has a force constant, $k = 1150$ N m^{-1}. The equilibrium bond length is $L = 1.5 \times 10^{-10}$ m and the change in the bond length when it is fully stretched is 6.0% of L. Calculate the vibrational energy, that is the sum of kinetic and potential energies per mole of oxygen (in kJ mol^{-1}). **[1.5]**

(Avogadro's number, $N_A = 6.023\times10^{23}$)

Vibrational energy per mole = UN_0 = 28.052 kJ/mole **[1.5]**

$L_s = 1.59 \times 10^{-10}$ m [0.5]

Vibration energy is the work done in changing the separation from equilibrium position to the fully stretched position [1.0].

Force, $F = k(L_s-L)$ Work, $W = 0.5k(L_s-L)^2$

$U = 0.5k(L_s-L)^2$

Vibrational energy per mole = $UN_0 = 28.052$ kJ/mole [0.5]

(v) The atomic weights of the halogen elements listed in the periodic table are:

F	Cl	Br	I
19.0	35.5	79.9	126.9

Two halogen elements, X and Y, form diatomic molecules X_2 and Y_2 with force constants $k_X = 325.0$ N m^{-1} and $k_Y = 446.0$ N m^{-1} respectively. The vibration frequencies are measured to be $\nu_X = 16.7 \times 10^{12}$ Hz and $\nu_Y = 26.8 \times 10^{12}$ Hz. Identify the halogen elements X and Y by writing their symbols. Write your answer in the form X = _____ , Y = _____ in the answer sheets.

[1.0]

Correct answer: X = Cl and Y = F **[1.0]**

The ratio of the vibration frequencies is 0.623.Only X = Cl and Y = F are the elements such that the ratio of the square roots of the masses $(m_y/m_x)^{0.5} \sim 0.64$.

Question 2

(i) If sunlight is shone through a transparent container (with walls of negligible thickness) filled with nitrogen gas, what will be the ratio of the scattered light intensity for colours corresponding to wavelengths 400 nm and 650 nm respectively? **[1.0]**

Ratio of the scattered intensities = 6.2 **[1.0]**

Correct ratio of the light intensity = 0.9 [0.5] or

Correct ratio of the scattered light intensity without taking into account solar spectrum [0.5].

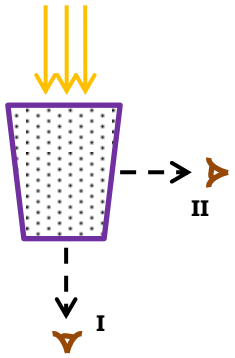
The ratio of the intensity of 400 nm and 650 nm light in the sunlight is 0.9.
$\eta_s(400)/\ \eta_s(650) = (650/400)^4 * 0.9 = 6.2$ [0.5].

Visibility range for polluted air 60 x 10^3 m or 75 x 10^3 m **[1.5]**

Scattering losses due to the pollutants will be proportional to 0.1*40 = 4 times larger compared to pure air. [0.5]

Pollutants act as additional scattering hence the visibility range reduces by 5 times (**60 x 10^3 m**)

(ii) Milk is a *colloidal solution* in which droplets of liquid fat, of size around 100 nm, are suspended in water. These droplets scatter light more strongly than the water molecules, causing normal milk to appear white rather than transparent.



Consider the following experiment. A few drops of milk are added to a glass of water illuminated from above by a beam of sunlight, as shown in the figure on the right. The water turns cloudy, but some sunlight still passes through, since the concentration of milk is small. The glass is now viewed (I) from below, and (II) from the side, as shown in the figure.

When compared to the emerging light viewed from below (I), the emerging light viewed from the side (II) will appear **[0.5]**

(A) bluish (B) orange (C) reddish (D) the same

Correct answer: (A) **[0.5]**

Shorter wavelengths are scattered much more than the longer wavelengths, hence blue will be scattered more along the direction (II) compared to direction (I)

(iii) Which of the following atmospheric phenomena is mainly governed by Mie scattering of light?

[0.5]

(A) red sunset

(B) white clouds

(C) blue sky

(D) rainbow

Images taken from:
(A) http://bostern.wordpress.com (B) http://www.kaneva.com

(C) http://lisathatcher.wordpress.com (D) http://www.freefoto.com

Correct answer: (B) white clouds [0.5]

(a) and (c) are due to Rayleigh scattering (wavelength dependent), (d) is due to wavelength dependent refraction and dispersion through water droplets.

(i) The green colour of leaves and shoots of plants is usually due to the presence of chlorophyll, the compound mainly responsible for photosynthesis. Which of the following graphs depicts the correct absorbance spectrum of chlorophyll?

[1.0]

Correct answer: (B) [1.0]

For green colour the absorption is minimum and hence is reflected or scattered the most

(ii) Assuming that the rate of photosynthesis is proportional to the amount of light absorbed (see above figure), what will be the wavelength (in nm) corresponding to the maximum photosynthesis rate in green plants?

[0.5]

450 nm [0.5]

Maximum absorption in Fig. b is at 450 nm.

[1.0]

Correct answer: (A) **[1.0]**

Larger absorbance where the solar spectrum has a maximum intensity.

Question 3

(a) The dissociation of H_2CO_3 in blood occurs in two steps. Write down balanced equations for these two steps.

[0.5]

$H_2CO_{3\,(aq.)} \rightleftharpoons H^+_{(aq.)} + HCO_3^-{}_{(aq.)}$ **[0.25]**

$HCO_3^-{}_{(aq.)} \rightleftharpoons H^+_{(aq.)} + CO_3^{2-}{}_{(aq.)}$ **[0.25]**

(i) Calculate the concentration of H^+ in a solution at 37 ^{0}C, and hence its pH value, if H_2CO_3 and HCO_3^- are present in equal concentrations in mol/l in that solution.

[0.5]

$[H_2CO_3] = [HCO_3^-]$ $K_1 = [H^+]$

$[H^+] = 2.2 \times 10^{-4}$ M **[0.25]**

pH = 3.65 **[0.25]**

(ii)

[1.0]

$pH = 7.4 \Rightarrow [H^+] = 3.98 \times 10^{-8}$ **[0.5]**

$$K_2 = \frac{[H^+][CO_3^{-2}]}{[HCO_3^-]} = 4.8 \times 10^{-11} = \frac{3.98 \times 10^{-8}[CO_3^{-2}]}{[HCO_3^-]}$$

$$\frac{[CO_3^{-2}]}{[HCO_3^-]} = \frac{4.8 \times 10^{-11}}{3.98 \times 10^{-8}} = 1.2 \times 10^{-3}$$

$$\therefore \frac{[HCO_3^-]}{[CO_3^{-2}]} = \frac{1}{1.2 \times 10^{-3}} = 833$$ **[0.5]**

(b) Usually in the human body, H_2CO_3 is in equilibrium with the CO_2 dissolved in the blood.

K_3

$$CO_2\,(\text{dissolved}) + H_2O\,(\text{liq}) \rightleftharpoons H_2CO_3(\text{dissolved})$$

At 37^0 C, $K_3 = 5.0 \times 10^{-3}$.

Calculate the total equilibrium constant, K' for the reaction

K'

$$CO_2\,(\text{dissolved}) + H_2O\,(\text{liq}) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$$

[0.5]

$$K_1 = \frac{[H^+][HCO_3^{-2}]}{[H_2\,CO_3]} \quad , \quad K_3 = \frac{[H_2\,CO_3]}{[CO_2]}$$

$$K' = \frac{[H^+][HCO_3^{-2}]}{[CO_2]}$$

$$(5.0 \times 10^{-3})(2.2 \times 10^{-4}) = 1.1 \times 10^{-6}$$ **[0.5]**

(c) Blood plasma contains a total carbonate buffer pool, which is a mixture of HCO_3^- and CO_2 with a total concentration of 3.4×10^{-2} M at 38 ^{0}C. At this temperature the value of the equilibrium constant K' is 1.3×10^{-6}. The concentration of the H_2CO_3 is

negligible. Calculate the ratio of concentrations of CO_2 (dissolved) and HCO_3^-, and their individual concentrations, in this blood sample at pH 7.4.

[1.5]

pH = 7.4 $\Rightarrow [H^+] = 3.98 \times 10^{-8}$

$$K_2 = \frac{[H^+][HCO_3^-]}{[CO_2]} = \frac{1.3 \times 10^{-6}}{3.98 \times 10^{-8}}$$

$\frac{[HCO_3^-]}{[CO_2]} = 32.6$ or $\frac{[CO_2]}{[HCO_3^-]} = 0.0306$ **[0.5]**

$$32.6[CO_2] + [CO_2] = 3.4 \times 10^{-2}$$

$[CO_2] = \frac{3.4 \times 10^{-2}}{32.6} = 0.10 \times 10^{-2}$ **[0.5]**

$[HCO_3^-] = 32.6[CO_2] = 3.29 \times 10^{-2}$ **[0.5]**

Question 4

.

(a) Which of the above carry de-oxygenated blood?

[1.0]

1,4,5, RA and RV

(b)

[0.5]

What would be the individual's heart rate (in beats/minute) as calculated from the table?

Heart rate: 60/0.7 = 85.7 beats/min **[0.5]**

(c)

[1.5]

Time	Mitral valve	Aortic valve
0.2 s	C	O
0.6 s	O	C

(d) Blood flows from the heart into the aorta during a cardiac cycle. If the diameter of the aorta is approximately 2.4 cm, then, using the table in 4(b) calculate the average speed (in cm s^{-1}) of blood flowing into the aorta in one full cardiac cycle.

[1.0]

Speed = Volume/(cycle time*Area) **[0.5]**
Speed = 42/4.52 = 60/4.52
Speed = 13.26 cm/s (for cycle time of 0.7 s) or 23.23. cm/s (for cycle time of 0.4 s)
[0.5]

(e) Blood flows from the aorta and its major arteries into arterioles and fine-walled capillaries. If all the major arteries in the body have a total cross-sectional area of about 7.0 cm^2 calculate the average speed (in cm-s^{-1}) in the major arteries which have the same volume of blood as the aorta flowing through them. **[0.5]**

V2 = 8.56 cm/s (13.26 cm/s), V2 = 14.99 cm/s (23.23 cm/s)
A1V1 = A2V2

FULL [0.5] Credits to be given for the correct value.
HALF [0.25] Credits to be given for the formula even if the value is wrong.

[1.0]

Aorta	Renal vein	Alveolar space in lungs	Pulmonary artery
Y	X	Y	X

Question 5

(i) Calculate the average acceleration of this cheetah required to reach its maximum speed.

[0.5]

Average acceleration, $a = \frac{v}{t}$ **[0.25]**

$a = \frac{30}{3} = 10 ms^{-2}$ **[0.25]**

(ii) Calculate the distance travelled during the first 3.0 s, assuming that the acceleration is uniform.

[0.5]

Distance travelled during the acceleration phase , $d^1 = \frac{1}{2}at^2$ **[0.25]**

$d^1 = \frac{1}{2} \times 10 \times 3^2 = 45m$ **[0.25]**

(iii) The cheetah has to do work against friction, mostly due to air. Assume that this frictional force is always 100 N. Calculate the total mechanical work done by the

cheetah during the first 23.0 s of its motion.

[1.0]

Work done in
Change in kinetic energy, $K = \frac{1}{2}mv^2 - 0$ **[0.25]**

$K = \frac{1}{2} \times 50 \times 30^2 = 22.5kJ$ **[0.25]**

Overcoming friction due to air, $W_d = F_a \times (d + d^1)$ **[0.25]**

$W_d = 100 \times (600 + 45) = 64.5kJ$

Total work done $W = K + W_d$

$W = 22.5 + 64.5 = 87kJ$ **[0.25]**

(a) During the first 23.0 s, the body temperature of the cheetah rises from 38.5 ^{0}C to 40.0 ^{0}C. Take the specific heat of the body of the cheetah to be 4.2 kJ kg^{-1} K^{-1}.

(vi) If the rise in body temperature is linear during this time, calculate the total heat generated by the cheetah's metabolism. Neglect any heat loss to the surroundings.

[1.0]

Heat generated in the body of the Cheetah, $H = Sm\Delta t$ **[0.5]**

$H = 4.2 \times 50 \times (40 - 38.5) = 315kJ$ **[0.5]**

(vii) Assume that some of the energy generated by the cheetah's body increases its temperature and the rest corresponds to the mechanical work done. Calculate the fraction of the total generated energy that is converted to kinetic energy.

[**1.0**]

Total energy generated in the body of Cheetah, $E = H + W$ **[0.5]**

$E = 315 + 87 = 402kJ$

Fraction $= \frac{22.5}{402} = 0.06$ **[0.5]**

(viii) Write down the balanced chemical reaction for aerobic respiration.

[1.0]

The balanced reaction: $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$

(ix) If the cheetah requires 400 kJ of energy, calculate the volume of oxygen required if all this energy is to be obtained by aerobic respiration. Take the molar volume of oxygen gas to be 24.5 litres.

[1.0]

Number of glucose molecules required to produce 400kJ of energy is

$$n_g = \frac{400\ kJ}{U}$$

$$n_g = \frac{400\ kJ}{U1130\ kJ} = 0.35\ mol$$ **[0.25]**

Number of mol of O_2 is $n_O = 6n_g$

$n_O = 6 \times 0.35 = 2.1\ mol$ **[0.25]**

Volume of O_2 required, $V = 24.5 \times n_O = 24.5 \times 2.1 = 52\ l$ **[0.5]**

(x) The cheetah extracts oxygen from the air while breathing. The inhaled air (about 500 ml per breath) contains 20.0 % oxygen (by volume), while the exhaled air is assumed to contain 15.0 % oxygen (by volume). Calculate the volume of oxygen that the cheetah can use during the 23.0 s of its run, at a breathing rate of 150 breaths per minute.

[1.0]

Amount of O_2absorbed by the lungs per breath is $V^1 = 5\%\ of\ 500ml = 25ml$

[0.5]

Total number of breaths during its entire motion,

$$n = \frac{N}{60} \times total\ duration\ of\ motion$$

$n = \frac{150}{60} \times 23 = 57.5 \approx 58$ **[0.25]**

Thus the amount of intake of O_2, $V_a = n \times V^1 = 58 \times 25 = 1.45l$ **[0.25]**

(xi) Anaerobic respiration converts the energy from glucose into ATP. If glucose were to be completely burnt up, one mole would release 2872 kJ of energy. What is the efficiency of anaerobic respiration compared to complete combustion of glucose?

[1.0]

Energy generated in production of one mol of ATP due to oxidation of glucose is

$U^1 = \frac{U}{36} = \frac{1130}{36} = 31.4kJ$ **[0.5]**

Efficiency of the anaerobic respiration, $\eta = \frac{U_g}{U^1}$ **[0.25]**

$\eta = \frac{2 \times 31.4}{2872} = 0.022$ **[0.25]**

(xii) If all the 400 kJ required by the cheetah for its run were to be produced by anaerobic respiration, calculate the total amount of glucose (in kg) that would be required.

[1.5]

Amount of glucose of required, $N = \frac{400}{2U_g}$

$N = \frac{400}{62.8} = 6.4\ mol$ **[0.5]**

Approximate molecular mass of glucose,

$M = 6 \times 12 + 12 \times 1 + 6 \times 16 = 180g$ **[0.5]**

$m = 180 \times 6.4 = 1.2\ kg$ **[0.5]**

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

Very Important Instructions

The first 15 minutes are to be used ONLY for reading the question paper and planning of the experimental tasks.

You MAY NOT write anything during this period, even on the Question Paper.

After 15 minutes, you will be given the answer sheets and a signal to start the experiments.

You will then have a further 3 hours to complete the examination.

Task: A Pendulum (14 marks for this task)

Examination Rules:

1. You are not allowed to bring any tools **except** any personal medicine or any personal medical equipment.
2. You must sit at your designated table.
3. Before the examination starts, you must check the stationery and any tools (pen, ruler, calculator) provided by the organizers.
4. You must check the question paper and answer sheet. Raise your hand, if you find any missing sheets. You may start only when given the signal by the organizers.
5. During the examination, you are not allowed to leave the examination room except in an emergency and for that the examination supervisor/volunteer/invigilator will accompany you.
6. You are not to disturb any other competitor or disrupt the examination. In case any assistance is needed, you may raise your hand and the nearest supervisor will come to help.
7. You may not question or discuss the examination problems with anyone other than your team members. You must stay at your table until the time allocated for the examination is over, even if you have finished the examination or you do not want to continue working.
8. A signal will indicate the end of the allotted time for the examination. You are not allowed to write anything on the answer sheet after the allocated time is over. You must leave the room quietly after all the answer sheets have been collected.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

Read the following instructions carefully:

1. While you are in the examination hall, you should wear safety spectacles at all times. While doing your experimental task, always wear your lab coat, safety goggles, and hand gloves.
2. Handle each and every apparatus and chemicals with care.
3. Do not try to taste or smell any chemical substance.
4. Chemicals are very safe if handled and disposed of properly.
5. Ensure that you keep the answer sheet and question paper away from liquids.
6. Place all waste papers and used material in the waste basket provided.
7. Immediately report all accidents, injuries, however minor they may be, to the invigilator/supervisor/volunteer present.
8. Eating of any kind of food is strictly prohibited during the experimental task.
9. You are expected to work safely, to behave socially, and to keep the equipment and work environment clean. When carrying out discussions with your teammates, keep your voice low.
10. Do not leave the examination hall until you have permission to do so. Ask an invigilator/supervisor/volunteer if you need to use the bathroom.
11. You may start working only when the start signal is given.
12. You have 3 hours to complete the experimental tasks and to record your results on the yellow answer sheets. You must stop your work immediately after the stop command is given.
13. Be sure that your team has a complete set of the question paper (3 copies) and 2 types of answer sheets (1 white copy for rough work and 1 yellow copy for final answers). **ONLY YELLOW ANSWER SHEETS WILL BE EVALUATED.**
14. Use only the pen and calculator provided.
15. ID code must be written on every page of the final (yellow) answer sheets. Each team member must sign on the front page of the final (yellow) answer sheets.

16. All results must be written in the designated boxes on the **yellow answer sheets**. **Data written elsewhere will not be evaluated.**
17. After completing the task, put all the equipment back to its original place. Make sure you clean your work place.
18. After the stop command is given, put all papers inside the envelope kept on the desk. Wait for the volunteer to check and collect it.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

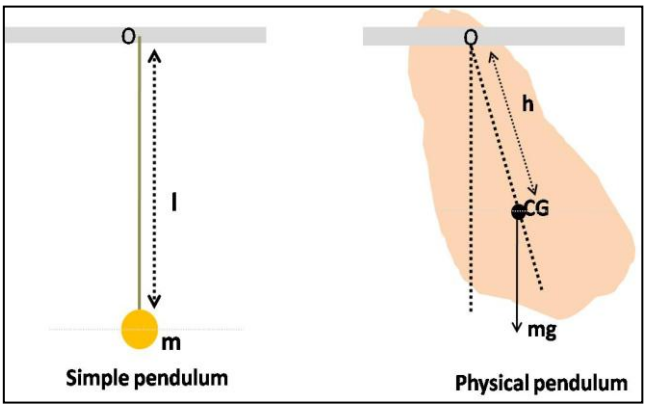
Task **A:** This task is divided into three parts:

A1: To determine the centre of gravity of a triangular plate, A.
A2: To record the time period of oscillation for different suspension points for the plate.
A3: To analyze the above data and results.

A *simple pendulum* consists of a point mass m suspended from a string of fixed length l and negligible mass, the other end of which is fixed to a rigid support O. For small displacements from the equilibrium position (shown in the figure below), the point mass m executes simple harmonic motion with time period, T (time taken for one oscillation):

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where g is the acceleration due to gravity.



A much wider variety of situations that involve small oscillations may be described in terms of a *physical pendulum*, also called a "compound pendulum". Using this concept, we can describe the motion of a rigid body of mass m, of arbitrary shape and size. It is pivoted at O (called the "point of suspension", as shown in the above figure). For small displacements, such a physical pendulum executes simple harmonic motion, with time period

$$T = 2\pi\sqrt{\frac{I_0}{mgh}}$$

Here I_0 is the *moment of inertia* about an axis passing through the point of suspension, h is the distance of the point of suspension from the *centre of gravity* (CG)**,** and g is the acceleration due to gravity.

Moment of inertia (I_0) is a quantity measuring the resistance offered by a body against its rotational motion. It is always referred to with respect to an axis of rotation and it depends on the body's shape. For a point mass m**,** the moment of inertia I_0 is given by $I_0 = mr^2$, where r is the distance of the point mass from the axis of rotation.

In this experiment we consider a triangular plate of mass m which oscillates in its own plane. Its moment of inertia about an axis passing through its point of suspension O is given by:

$$I = m(K^2 + h^2)$$

where K is called the radius of gyration.

The time period of oscillation of the physical pendulum is therefore

$$T = 2\pi\sqrt{\frac{K^2 + h^2}{gh}}$$

The time period can also be written as $T = 2\pi\sqrt{\frac{L}{g}}$

where $L = \frac{K^2}{h} + h$ is called the length of an equivalent simple pendulum.

A point S, on the other side of the CG and at a distance of $h' = \frac{K^2}{h}$ from the CG (along the line joining O and CG) is called the "point of oscillation". The oscillations with the point of suspension O are then equivalent to having all the mass concentrated at S.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

You are supplied with the following:

	Quantity
Clamp Stand	1
Triangular plate	1
Fulcrum rod with knife edge for suspension	1
Plumb line	1
Ruler	1
Stop watch Same stopwatch to be used for Task B	1

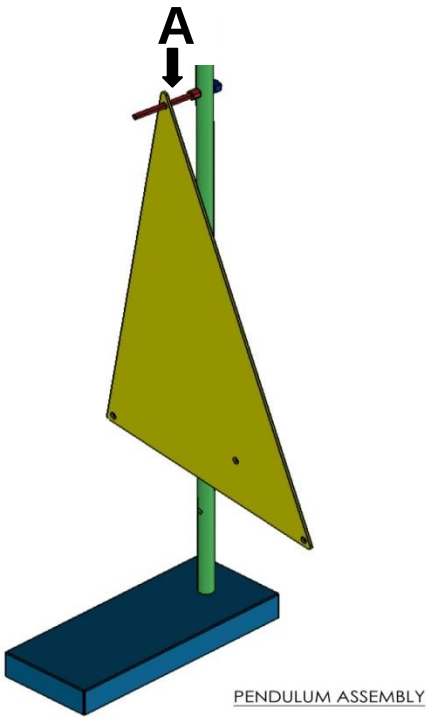
Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

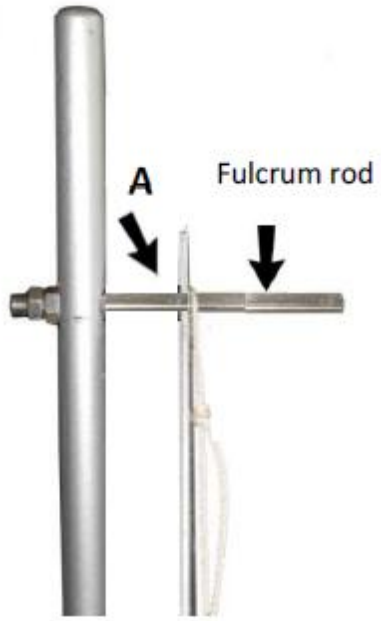
A1 To determine the centre of gravity (CG) of triangular plate, A.

Procedure:

1. Suspend the triangular plate **A** from the fulcrum rod (mounted on the clamp stand) by one of the three holes provided at the three corners of the triangle (see the figure below).



PENDULUM ASSEMBLY



2. Ensure that the suspended plate is stationary. Pass the loop of the string on the rod and hang the plumb line through the fulcrum rod (as shown in the figure above). Using a ruler and pencil, mark a straight line on the plate along the string.

3. Repeat the same procedure by suspending the plate through a different hole. The intersection of the two lines gives the CG. Use a pencil to mark it as 'X' on the plate.

   Mark the two lines and the point 'X' also on the large sized sheet of paper (provided to you) with a drawing of the triangular plate on it. Label it as **Sheet 1**.

   Please write ID codes of all team members and the Country Code on **Sheet 1**.

   [A.Q1: 1.0 mark]

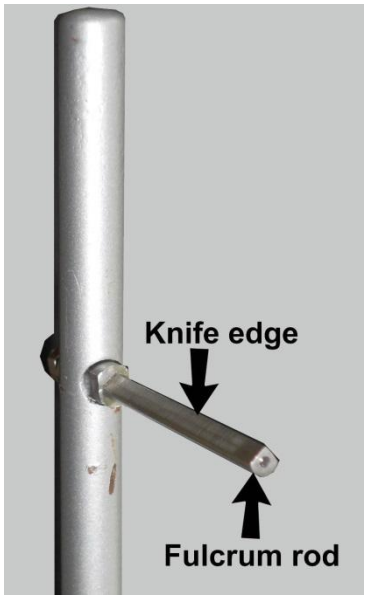
4. Suspend the plate through a different hole and repeat steps 1 and 2. This line should also pass through the CG. Show the line on **Sheet 1** also.

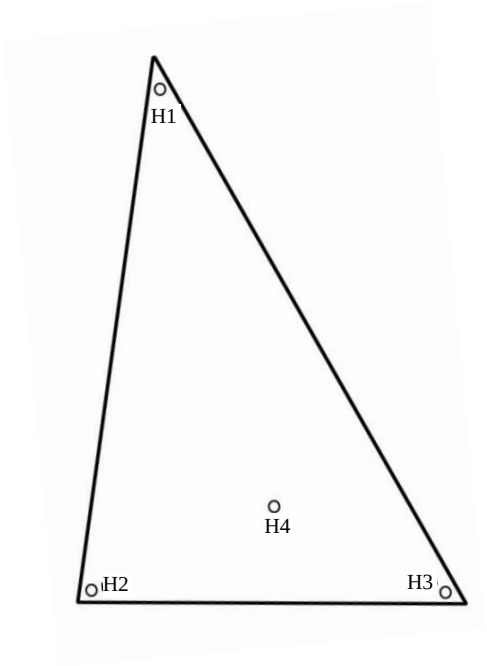
Note: The correct determination of CG is very important as any error here will introduce a corresponding error in the measurement of h, which will be used later.

A2 To record the time period of oscillation for different suspension points for the plate.

Procedure:

1. Suspend the plate from hole **H1** using the fulcrum rod. Ensure that the plate is almost at the centre of the fulcrum rod and resting on the knife edge (see the figure below). This is important to reduce damping of the oscillations and, hence, to minimize error in determining the time period of oscillations.





Note: Measure all distances from the top end of all the holes.

2. Measure the distance **h** between hole **H1** and the **CG** you marked in the previous part of the experiment. (Measure the distance from the top end of hole **H1**). Write it in **Table A.1 in the yellow answer sheet**.

3. Set the plate into oscillation (with small amplitude) and ensure that these oscillations occur mostly in the plane of the plate.

4. Using the stop watch, measure the time taken for 50 oscillations. Repeat three times and write each reading in **Table A.1 in the yellow answer sheet.**

5. Repeat the above steps for holes **H2**, **H3**, and **H4.**

[A.Q2: 4.0 marks]

A3 To analyze the above data and determine

a) the acceleration due to gravity
b) the radius of gyration of the plate about an axis passing through its CG normal to the plane of the triangle;
c) the positions of the corresponding points of oscillation from the CG for two points of suspension; and
d) the lengths of the equivalent simple pendulum for these two points of suspension.

Procedure:

1. Using the data in **Table A.1**, plot a graph of hT^2(y-axis in ms^2) versus h^2 (x-axis in m^2) on the grid provided in the answer sheet (**Grid 1**).

[A.Q3: 2.0 marks]

2. Draw a straight line through the points (best fit) and determine the slope s and the y-intercept c.

   Using these values of s and c, and the expression for the time period of a physical pendulum, determine the values of g in ms^{-2} and K in units of metres. Enter the values of s, c, g, and K in **Table A.2 in the yellow answer sheet.**

[A.Q4: 3.0 marks]

3. For holes **H1** and **H4**, calculate the positions of the corresponding points of oscillation from the CG (h'). Write it in **Table A.3 in the yellow answer sheet**. On the large sized sheet of paper (**Sheet 1**), mark the positions of the points of oscillation **J1** and **J4** corresponding to the holes **H1** and **H4, respectively.**

[A.Q5: 3.0 marks]

4. Determine the length (L) of the equivalent simple pendulum when the plate is suspended from **H1** and **H4**. Write your answer in **Table A.4 in the yellow answer sheet.**

[A.Q6: 1.0 mark]

Space for rough work

Country | Team

ID Code: 1) | 2) | 3)

International Junior Science Olympiad,
Pune, India

Time : 3 hrs
Marks :40

Experimental Tasks A + B + C

Task: A This task is divided into three parts. **Total marks: 14**

A1: To determine the centre of gravity of a triangular plate, A.
A2: To record the time period of oscillation for different suspension points for the plate.
A3: To analyze the above data and results.

A.Q1 Determination of CG: **[1.0 mark]**

Mark "X" on **Sheet 1** at the appropriate position to denote the CG (large sized sheet).

CG within 5 mm [1.0]
CG within 10 mm [0.5]

A.Q2 Table A.1: Oscillation measurements: **[4.0 marks]**

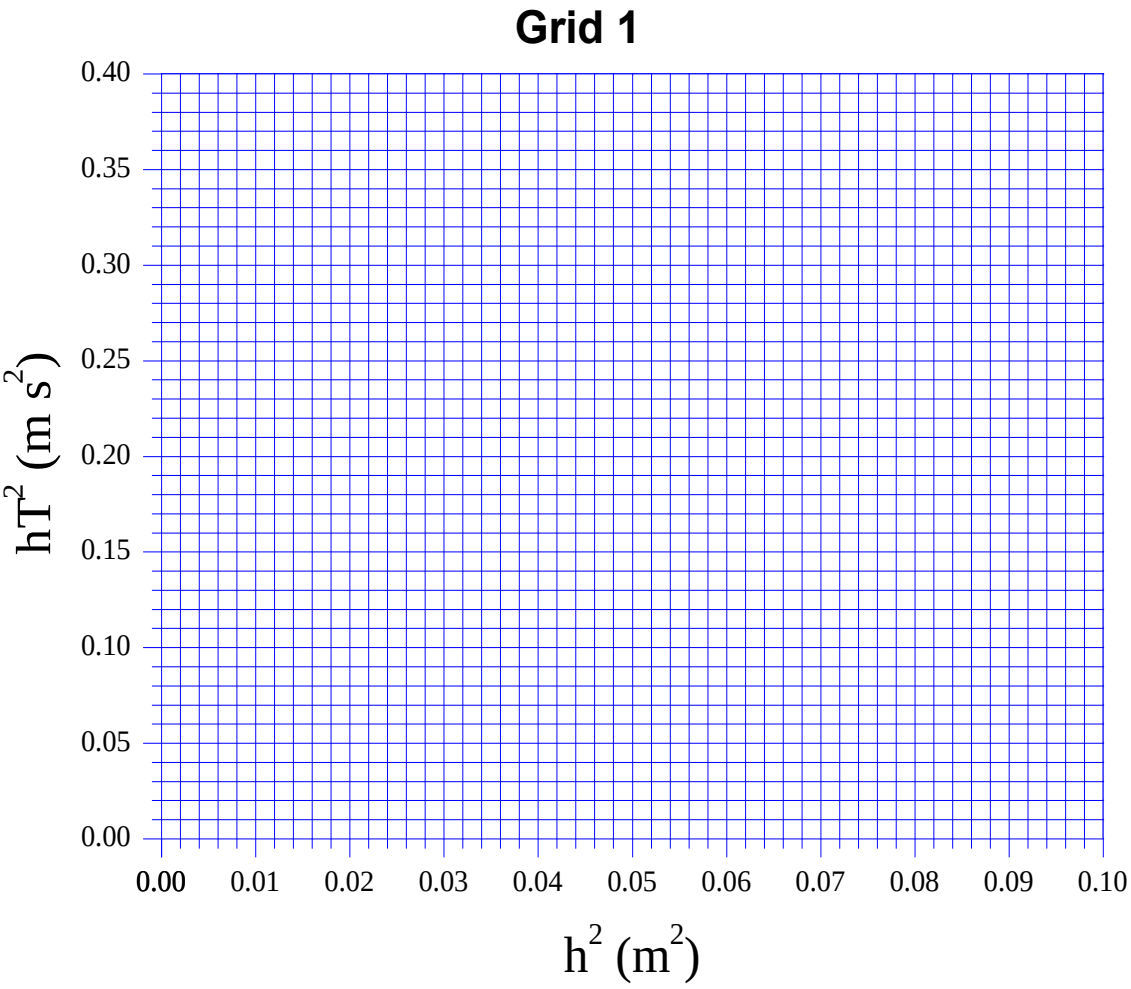
	h (m)	h^2 (m^2)	Time taken for 50 oscillations (s)				T = T1/50 (s)	T^2 (s^2)	hT^2 (ms^2)
			1st (t1)	2nd (t2)	3rd (t3)	Mean (T1) (t1+t2+t3)/3			
H1	0.243					53.65			
H2	0.155					47.77			
H3	0.179					49.08			
H4	0.098					45.48			

For each value of h within ±5 mm [0.25 x 4.0= 1.0]
For each value of T1 within ± 1 s [0.5 x 4.0= 2.0]
For each value of T1 within ± 2 s [0.25 x 4.0= 1.0]
For calculating h^2 and hT^2 [0.25 x 4.0= 1.0]

Experimental Tasks A + B + C

A.Q3 Results of the data analysis

(a) Grid1: hT^2 (y-axis) versus h^2 (x-axis) **[2.0 marks]**



Plotting 4 points correctly [0.25 x 4.0= 1.0]
For best fit straight line [1.0]

Experimental Tasks A + B + C

A.Q4Table A.2: Calculations from Grid 1 [3.0 marks]

Quantity	Numerical value	FULL CREDITS		HALF CREDITS
Slope of the graph (s)	4.06 ± 0.2	[0.5]	4.06 ± 0.4	[0.25]
y-intercept of the graph (c)	0.040 ± 0.005	[0.5]	0.040 ± 0.01	[0.25]
Acceleration due to gravity (g)	9.8 ± 0.5	[1.0]	9.8 ± 1.0	[0.5]
Radius of gyration (K)	0.10 ± 0.01	[1.0]	0.10 ± 0.02	[0.5]

Values outside the above mentioned range = Zero

A.Q5(a) Table A.3:

[3.0 marks]

Holes	h (m)	h' (m)
H1	**0.243**	**0.045**
H4	**0.098**	**0.11**

Each correct value of h' within ± 10 mm [0.5x 2 = 1.0]
Values outside the above mentioned range = Zero

(b) Sheet 1: Mark the positions of points of oscillation J1 and J4 on **Sheet 1**.Label them as J1 and J4 clearly.

[1 x 2 = 2.0]

A.Q6Table A.4: Lengths of equivalent simple pendulums [1.0 mark]

Holes	h (m)	L (m)
H1	**0.243**	**0.288**
H4	**0.098**	**0.209**

For each correct calculation within ± 0.015 m [0.5]

Task: B Milk (20 marks for this task)

Examination Rules:

1. You are not allowed to bring any tools **except** any personal medicine or any personal medical equipment.
2. You must sit at your designated table.
3. Before the examination starts, you must check the stationery and any tools (pen, ruler, calculator) provided by the organizers.
4. You must check the question paper and answer sheet. Raise your hand, if you find any missing sheets. You may start only when given the signal by the organizers.
5. During the examination, you are not allowed to leave the examination room except in an emergency and for that the examination supervisor/volunteer/invigilator will accompany you.
6. You are not to disturb any other competitor or disrupt the examination. In case any assistance is needed, you may raise your hand and the nearest supervisor will come to help.
7. You may not question or discuss the examination problems with anyone other than your team members. You must stay at your table until the time allocated for the examination is over, even if you have finished the examination or you do not want to continue working.
8. A signal will indicate the end of the allotted time for the examination. You are not allowed to write anything on the answer sheet after the allocated time is over. You must leave the room quietly after all the answer sheets have been collected.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

Read the following instructions carefully:

1. While you are in the examination hall, you should wear safety spectacles at all times. While doing your experimental task, always wear your lab coat, safety goggles, and hand gloves.
2. Handle each and every apparatus and chemicals with care.
3. Do not try to taste or smell any chemical substance.
4. Chemicals are very safe if handled and disposed of properly.
5. Ensure that you keep the answer sheet and question paper away from liquids.
6. Place all waste papers and used material in the waste basket provided.
7. Immediately report all accidents, injuries, however minor they may be, to the invigilator/supervisor/volunteer present.
8. Eating of any kind of food is strictly prohibited during the experimental task.
9. You are expected to work safely, to behave socially, and to keep the equipment and work environment clean. When carrying out discussions with your teammates, keep your voice low.
10. Do not leave the examination hall until you have permission to do so. Ask an invigilator/supervisor/volunteer if you need to use the bathroom.
11. You may start working only when the start signal is given.
12. You have 3 hours to complete the experimental tasks and to record your results on the answer sheets. You must stop your work immediately after the stop command is given.
13. Be sure that your team has a complete set of the question paper (3 copies) and 2 types of answer sheets (1 white copy for rough work and 1 yellow copy for final answers). **ONLY YELLOW ANSWER SHEETS WILL BE EVALUATED.**
14. Use only the pen and calculator provided.
15. ID code must be written on every page of the final (yellow) answer sheets. Each team member must sign on the front page of the final (yellow) answer sheets.

16. All results must be written in the designated boxes on the **yellow answer sheets**. **Data written elsewhere will not be graded.**

17. After completing the task, put all the equipment back to its original place. Make sure you clean your work place.

18. After the stop command is given, put all papers inside the envelope kept on the desk. Wait for the volunteer to check and collect it.

Task B: In this set of experiments we will investigate,

B1 The buffering capacity of milk.
B2 Enzymatic digestion of milk proteins.
B3 Estimating the calcium content of milk.

B1 The buffering capacity of milk

India is one of the largest milk producing countries in the world. A large part of the credit for this goes to the world's biggest agricultural development programme, Operation Flood, initiated and sustained by **Dr. Verghese Kurien**, known as the "Father of the White Revolution" for his billion-litre idea.

Milk is a source of many nutrients. It consists of 87% water and 13% solids suspended or dissolved in water, in the form of proteins (3.5%), carbohydrates (4.7%), fats (4.0%) and vitamins/minerals (0.8%). The major milk sugar is lactose, which is water soluble. Milk fat is in the form of globules emulsified in water. The most abundant protein in milk is casein, which exists as a suspension of particles called casein micelles. Each micelle consists of thousands of casein molecules; the micelles are, in turn, bound together by Ca^{2+}. The casein micelles and fat globules give milk its white colour and deflect light rays passing through it. Milk is slightly acidic with a pH between 6.4-6.8. Curdling of milk occurs when the pH of milk is reduced to 5.0. At this pH, the milk casein molecules clump together and precipitate. Milk is known to have a good buffering capacity.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

You are supplied with the following:

	Labeled as ….	Quantity Supplied
Milk	**Milk**	100 ml in red cap plastic jar
3% (v/v) acetic acid solution	**AA**	10 ml in sample container AA
3% (w/v) sodium carbonate solution	**SC**	10 ml in sample container SC
Water bottle	**Water**	1000 ml in bottle
100 ml glass beakers	**W, Exp**	2
20ml graduated syringe	**A**	1
1 ml graduated syringes	**B, C**	2
pH papers; range 2 to 10.5		2 booklets
Wash bottle		1
Glass rod		1
Tissue roll and Waste bucket		1 each

Procedure

1. Pour water from the water bottle into the beaker **W** until it is roughly full.
2. Transfer 40 ml of water into the beaker **Exp,** using syringe **A**.
3. Measure the pH of the water in beaker **Exp.** For this, dip the given pH paper strip in the water in the beaker for a few seconds. Take out the dipped pH paper and observe the colour change; match the colour with the pH range provided on the leaflet. Write the pH in the **box in the yellow answer sheet.**

   [B.Q1.A: 0.25 marks]

4. Measure the pH of sodium carbonate solution supplied in the sample container **SC**. Write the pH in the **box in the yellow answer sheet.**

   [B.Q1.B: 0.25 marks]

5. Add 0.1 ml of sodium carbonate solution to the water in beaker **Exp** using syringe **B**. Stir well with the glass rod and measure its pH with a pH paper. Write the new pH value observation **Table B.1 in the yellow answer sheet.**

6. Continue adding 0.1 ml of sodium carbonate solution and write the pH values in **Table B.1 in the yellow answer sheet**, till the pH of the solution reaches 10. Also write the total volume of sodium carbonate solution added.

[B.Q2: 1.0 mark]

7. Now wash the beaker **Exp** and glass rod so that no traces of the previous solution remain. Wipe it with tissue paper.
8. Add 40 ml of water in to the washed beaker **Exp** using syringe **A**.
9. Measure the pH of acetic acid in sample container **AA**. Write the pH in the **box in the yellow answer sheet.**

[B.Q1.C: 0.25 marks]

10. Add 0.1ml of given acetic acid solution to the water in beaker **Exp**, using syringe **C.** Stir well with the glass rod and measure the pH with a pH paper. Record the pH value in the **Table B.1 in the yellow answer sheet.**
11. Continue adding 0.1ml of acetic acid solution and write the pH values **in Table B.1 in the yellow answer sheet,** till the pH of the solution reaches 4. Also write the total volume of acetic acid solution added.

[B.Q2. 1.0 mark]

12. Now wash the beaker **Exp** and glass rod so that no traces of the previous solution remain. Wipe it with tissue paper.
13. Use syringe **A** to add 40 ml of milk to the washed beaker **Exp**.
14. Measure the pH of the milk using the pH paper. Write the pH in the **box in the yellow answer sheet.**

[B.Q1.D: 0.25 marks]

15. Using syringe **B**, add 0.5 ml of sodium carbonate solution to the milk in beaker **Exp**. Stir well with the glass rod and measure the pH. Write the pH value in **Table B.2 in the yellow answer sheet.**
16. Keep adding 0.5 ml of sodium carbonate solution till the pH value of the milk sample reaches 10.
17. Write the pH value for each addition in observation **Table B.2 in the yellow answer sheet.** Also write the total volume of sodium carbonate solution added.

[B.Q3: 1.0 mark]

18. Now wash the beaker **Exp** and glass rod so that no traces of the previous solution remain. Wipe it with tissue paper.

19. Use syringe **A** to again add 40 ml of milk in to the washed beaker **Exp**.
20. Using syringe **C**, add 0.5 ml of acetic acid solution to the milk in beaker **Exp**. Stir well with the glass rod and measure the pH. Keep adding 0.5 ml of acetic acid solution till the pH value of the milk sample reaches 4.
21. Write the pH value for each addition in **observation Table B.2 in the yellow answer sheet.** Also write the total volume of acetic acid solution added.

[B.Q3: 1.0 mark]

22. Wash the beaker **Exp** and glass rod, dry it with tissue, and keep it ready for the next task.

Questions

From your observations in **Tables B.1** and **B.2**, write on **the yellow answer sheet** whether the following two statements are true (T) or false (F).

a) You require more acetic acid solution to lower the pH of milk to 4 than to lower the pH of water to 4.
b) You require less sodium carbonate solution to raise the pH of milk to 10 than to raise the pH of water to 10.

[B.Q4: 1.0 mark]

As compared to water, milk resists change in pH of the resulting solution when acetic acid is added. This is because components of milk:

a) lead to increase in concentration of the OH^- ions in the resulting solution
b) prevent increase in concentration of the free H^+ ions in the resulting solution
c) lead to decrease in concentration of CH_3COO^- ions in the resulting solution

Write the correct option in the appropriate box in **the yellow answer sheet**.

[B.Q5: 1.0 mark]

B2 Enzymatic digestion of milk protein

To measure the change in opacity of milk due to digestion of milk proteins with trypsin (a protease)

Addition of trypsin to milk breaks down casein. This causes the milk to become translucent. The rate of reaction can be measured by determining the time it takes for the milk to turn translucent. You will use a photodiode in your measurements. A photodiode is a device that converts light into electrical current which you will measure using a digital multimeter. You will also use a light emitting diode (LED) as a light source.

You are supplied with the following:

	Labeled as...	**Quantity Supplied**
Power supply; 500 mA, 3 V		1
Acrylic set-up with photodiode (see photo on page 9)		1
White LED		1
Digital multimeter		1
Test tube	**ED**	1
Milk		As supplied for Task B1
Trypsin	**TE**	5 ml in a test tube
Water		As supplied for Task B1
Graduated syringe(1ml)	**TE**	1
Graduated syringe (12 ml)	**W**	1
Stop watch		1
Dropper		1
Sticky paper		

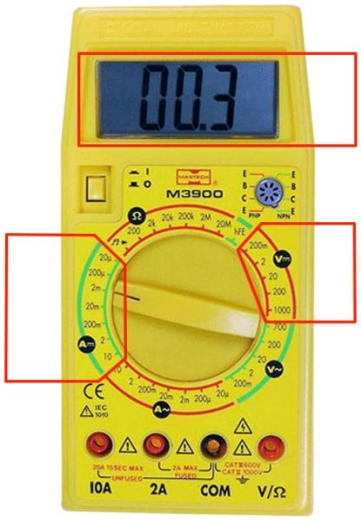
Note: The white LED has a white base. The blue LED has a coloured base.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

The photo below is that of a multimeter. Your multimeter may be either yellow or black.

Multimeter knob is to be positioned in this region for current measurement
2μA is the minimum range of current measurement
10A is the maximum range



If display read *-1*, it implies range is insufficient. Shift the knob to higher range. Working in higher range than required will result in loss of accuracy

For this experiment DO NOT keep the knob in A ~V ~Ω

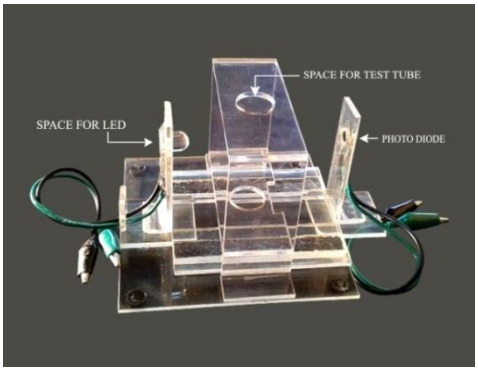
Multimeter knob is to be in this region for voltage measurement

To measure current

To Measure Voltage

1. Press MODE button, if the Stopwatch is on Time Mode, to bring it to Stop Watch Mode. 0:00 00
2. Press SPLIT/RESET button to reset the Stopwatch to Zero.
3. Press START/STOP button to start the Stopwatch.
4. Press START/STOP button to stop the Stopwatch.
5. In Stopwatch mode START/STOP button should be used to start and stop as many times as required.

Stopwatch



Acrylic set-up with photodiode

Procedure

1. Mount the White LED in the space provided on the fixed part of the acrylic stand, as shown in the photograph above. You may have to use sticky paper provided to you to ensure that the LED is mounted tightly.
2. Connect the White LED to the Power supply such that shorter leg of the LED connects to black wire. Then switch the power supply on. The LED should glow brightly.
3. Set the multimeter in the current mode and 2 mA current range.
4. Connect the photodiode mounted on the movable part of the acrylic stand to the multimeter.
5. Add 10 ml of water to test tube **ED** using syringe **W*;*** use tissue paper to wipe the outer surface of **ED** so that it is completely dry. Then place the test tube in the space provided for it on the acrylic stand.
6. Ensure that the light from the LED passes through the water in the test tube and falls on the photodiode. Orient the test tube such that the light is not blocked by the label.
7. Adjust the positions of the photodiode and test tube by carefully sliding either the mounted photodiode or the test tube holder such that the current reading on the multimeter maximizes. Record the maximum current I_W **in the yellow answer sheet.**

[B.Q6.A: 0.5 mark]

Note that for subsequent readings these positions of the photodiode and test tube holder must remain the same.

8. Remove the test tube from the acrylic stand and pour out the water.
9. Add 5 ml of water in test tube **ED** and then add 5 ml of milk to it with the help of syringe **W.** Mix well by gently tapping the test tube. Wipe the outside of the test tube with tissue paper to ensure that it is dry. Carefully place the test tube in the space provided on the acrylic stand and record the current I_0 **in the yellow answer sheet**.

[B.Q6.B: 0.5 mark]

10. Keep the stopwatch ready to start.
11. Use syringe **TE** to add 1 ml of trypsin to this milk sample in the test tube. Mix thoroughly using the plastic dropper. Ensure that test tube holder stand is at its original place (where previous readings were taken).
12. Immediately start the stopwatch.
13. Read the current on the multimeter at 15 seconds intervals and record the values in **Table B.3 in the yellow answer sheet.**

14. Continue recording the values of current up to **7** minutes.

[B.Q7: 2.0 marks]

15. Discard the solution and wash the test tube.

Graph plotting

Plot a graph of current versus time in the grid provided in the answer sheet.

[B.Q8: 3.5 marks]

Questions

Mark a point K on the graph where the casein concentration is maximum, a point L where the casein concentration is minimum, and a point M where the casein concentration is half-way between maximum and minimum values.

[B.Q9: 1.0 mark]

If the increase in current is proportional to the amount of digested casein and maximum current represents complete digestion of casein, deduce from the graph the time taken for digestion of 50% casein.

[B.Q10: 1.0 mark]

B3 Estimation of calcium content in milk

Calcium content in milk can be estimated by a special form of titration using a reagent called **Na_2EDTA**. Na_2EDTA reacts with metal ions in 1:1 proportion irrespective of the charge on the metal ion. Indicators used in such titrations are called metal-ion indicators. The indicator used in the present experiment is Eriochrome black T **(EBT)**.

You are supplied with the following:

	Labeled as ...	**Quantity Supplied**
Trypsin-treated milk	**CM**	100 ml in a volumetric flask
Water		As supplied in task B1
100 ml glass beaker	**HM**	1
10 ml graduated syringe	**CM**	1
100 ml conical flask	**HM**	1
Buffer solution pH 10	**BF**	Three 5 ml test tubes with screw caps
Dropper		1
Eriochrome Black T indicator	**EBT**	Dropping bottle
Burette 25 ml (on a stand)		1
Na_2EDTA solution (0.0027 M)	**EDTA**	80 ml in plastic bottle
Funnel		1

Procedure:

1. Add the Na_2EDTA solution to the burette using the funnel.
2. Write the initial burette reading in **Table B.4 in the yellow answer sheet**
3. Dilute the given trypsin-treated milk in the volumetric flask **CM** with water up to the mark. Insert the stopper and shake the solution well to homogenize it.
4. Now pour out the homogenized solution into beaker **HM**.
5. Add 10 ml of homogenized solution, using syringe **CM,** to the conical flask **HM**.
6. Add 10 ml of water to it, using syringe **W**.
7. Now add all the supplied buffer amount from *one* of the test tubes **BF**.
8. Add 5 drops of **EBT** indicator from the dropping bottle. The colour of the solution will change to red (pinkish red).

9. Titrate this solution in the conical flask **HM** with Na_2EDTA from the burette. Continue till the colour of the solution changes initially to purple and then to the first appearance of blue (which is the end point).
10. Write the final burette reading in **Table B.4 in the yellow answer sheet**
11. Repeat the titrations twice.
12. Enter your readings in the observation **Table B.4 in the yellow answer sheet.**
13. Calculate the volume of the solution needed for titration I, II and III. Write the values in **Table B.4 in the yellow answer sheet.**
14. Calculate the average volume.

[B.Q11: 3.5 marks]

Question:

Deduce the amount in milligrams of Ca^{2+} per 10 ml of the diluted solution (the atomic weight of Ca is 40).

[B.Q12: 1.0 mark]

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

Space for rough work

Country | Team

ID Code: 1) | 2) | 3)

2013 india 10th

International Junior Science Olympiad,
Pune, India

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

Task B

In this set of experiments we will investigate, **Total Marks: 20**

A1: The buffering capacity of milk
A2: Enzymatic digestion of milk proteins
A3: Determining the calcium content of milk

B1 The buffering capacity of milk

B.Q1.A pH of water = [ ] **[0.25 Mark]**
[6.0 – 7.0: 0.25, Other values = Zero]

B.Q1.B pH of sodium carbonate = [ ] **[0.25 Mark]**
[>10: 0.25, Other values = Zero]

B.Q1.C pH of acetic acid = [ ] **[0.25 Mark]**
[2 – 4: 0.25, Other values = Zero]

B.Q1.D pH of milk = [ ] **[0.25 Mark]**
[6.0 – 8.0: 0.25, Other values = Zero]

Country | Team

ID Code: 1) | 2) | 3)

2013 india 10th ijso

International Junior Science Olympiad,
Pune, India

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

B.Q2 Observation Table B.1 **[2.0 Marks]**

	Stepwise addition to 40 ml water			
	Sodium carbonate solution		Acetic acid solution	
	Stepwise volume added in ml	**pH** value	Stepwise volume added in ml	**pH** value
1	0		0	
2	0.1		0.1	
3	0.1		0.1	
4	0.1		0.1	
5	0.1		0.1	
6	0.1		0.1	
7	0.1		0.1	
Total	……	Volume of Na_2CO_3 solution added to reach pH 10.0	……	Volume of CH_3COOH solution added to reach pH 4.0

Marks will be given based on the volume of the solution required to get the desired pH in each case.

Range of volume: 0.3 - 0.5 ml for each solutions [1 x 2 = 2.0]

0.2 - 0.3 ml or 0.5-0.6 ml for each solutions [0.5 x 2 = 1.0]

Other values = zero.

Country | Team

ID Code: 1) | 2) | 3)

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

B.Q3 Observation Table B.2 **[2.0 Marks]**

	Stepwise addition to 40 ml Milk			
	Sodium carbonate solution		Acetic acid solution	
	Stepwise volume added in ml	**pH** value	Stepwise volume added in ml	**pH** value
1	0		0	
2	0.5		0.5	
3	0.5		0.5	
4	0.5		0.5	
5	0.5		0.5	
6	0.5		0.5	
7	0.5		0.5	
Total	……	Volume of Na_2CO_3 solution added to reach pH 10.0	……	Volume of CH_3COOH solution added to reach pH 4.0

Marks will be given based on the volume of the solution required to get the desired pH in each case.

Range of volume: 1.5 - 2.5 ml for each solutions [1 x 2 = 2.0]

1.0 - 1.5 ml or 2.5-3.0 ml for each solutions [0.5 x 2 = 1.0]

Other values = zero

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

Questions:

B.Q4 **[1.0 Mark]**

Comparing the observations in Table B.1 and B.2 which of the following statements describe the role played by milk?

a) You require more acetic acid solution to lower the pH of milk to 4 than to lower the pH of water to 4.

True (T) [X] False (F) [ ]

b) Less sodium carbonate solution is required to raise the pH of milk to 10 than to raise the ph of water to 10

True (T) [ ] False (F) [X]

B.Q5 **[1.0 Mark]**

As compared to water, milk resists change in pH of the resulting solution when acetic acid is added. This is because components of milk:

a) lead to increase in concentration of the OH^- ions in the resulting solution
b) prevent increase in concentration of the free H^+ ions in the resulting solution
c) lead to decrease in concentration of CH_3COO^- ions in the resulting solution

Write the correct option in the appropriate box [b)]

Country | Team

ID Code: 1) | 2) | 3)

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

B2 Enzymatic digestion of Milk protein

B.Q6.A I_w = [ ] **[0.5 Mark]**

I_w > 0.6 mA [0.5]
I_w = 0.2-0.6 mA [0.25]

B.Q6.B I_O = [ ] **[0.5 Mark]**

Anything below 0.2mA or the value based on the curve [0.5]

Country | Team

ID Code: 1) | 2) | 3)

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

B.Q7 Observation Table B.3 **[2.0 Marks]**

	Time (in s)	Current (in mA)		Time (in s)	Current (in mA)
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.		

20 Readings [0.1 x 20 = 2.0]

Country | Team

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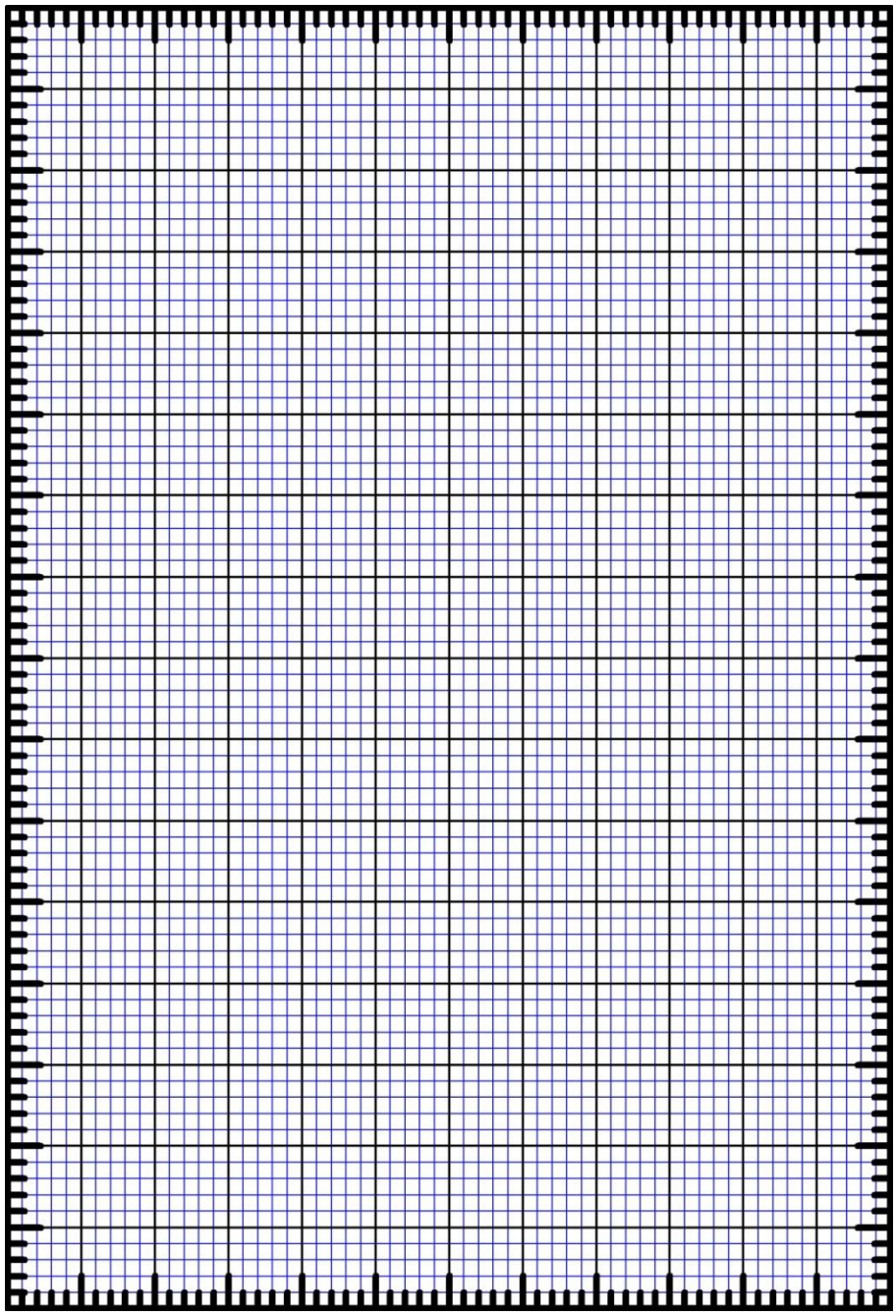
2013 india 10th

International Junior Science Olympiad,
Pune, India

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

B.Q8 Graph plotting: [3.5 Marks]



Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

Plot a graph of current versus time.
Labels on each axis [0.25]
Scale on each axis [0.25]
Marks for occupying more than 60 % of graph paper [0.25]
Drawing smooth curve [0.25]
Based on the plot, within I_w and I_0 ranges and the nature of the curve [0.1 x 20 = 2.0]

B.Q9 **[1.0 Mark]**

Mark a point K on the graph paper where the casein concentration is maximum, a point L where casein concentration is minimum and a point M where the casein concentration is half-way between the maximum and minimum values.

Based on the plot, all 3 correct [1.0]
2 correct [0.5]
1 correct [0.25]

B.Q10 **[1.0 Mark]**

If the increase in current is proportional to the amount of digested casein and maximum current represents complete digestion of casein, deduce from the graph the time taken for digestion of 50% casein.

Time taken based on the value of M in the above question [1.0]
Other values = Zero

Experimental Tasks A + B + C

Time : 3 hrs
Marks : 40

B3 Estimation of calcium content in milk

B.Q11 Observation Table B.4 **[3.5 Marks]**

Sr. No.		Titration I	Titration II	Titration III
1	Initial burette reading ml			
2	Final burette reading ml			
3	Difference in burette reading ml			

Average burette reading: (A)……ml of 0.001 M Na_2EDTA

Average difference in burette reading (m1) = (6.8 – 7.2) [2.0 marks]
Average difference in burette reading (m1) = (6.6 – 7.4) [1.5 marks]
Average difference in burette reading (m1) = (6.2 – 7.8) [1.0 marks]
Average difference in burette reading (m1) = (6.0 – 8.0) [0.5 marks]
Any other Average difference in burette reading: [0.0 marks]

An average value deduced using anomalous reading will result in deduction of 0.25 mark.

B.Q12 **[1.0 Mark]**

Deduce the amount in milligrams of Ca^{2+} per 10 ml of the diluted solution (the atomic weight of Ca is 40).

0.756 mg based on 7.0 ml in the previous question or for correctly calculated value based on the previous question [1.0]
Wrong calculations [0.5]

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

Task: C Tomato (6 marks for this task)

Examination Rules:

1. You are not allowed to bring any tools **except** any personal medicine or any personal medical equipment.
2. You must sit at your designated table.
3. Before the examination starts, you must check the stationery and any tools (pen, ruler, calculator) provided by the organizers.
4. You must check the question paper and answer sheet. Raise your hand, if you find any missing sheets. You may start only when given the signal by the organizers.
5. During the examination, you are not allowed to leave the examination room except in an emergency and for that the examination supervisor/volunteer/invigilator will accompany you.
6. You are not to disturb any other competitor or disrupt the examination. In case any assistance is needed, you may raise your hand and the nearest supervisor will come to help.
7. You may not question or discuss the examination problems with anyone other than your team members. You must stay at your table until the time allocated for the examination is over, even if you have finished the examination or you do not want to continue working.
8. A signal will indicate the end of the allotted time for the examination. You are not allowed to write anything on the answer sheet after the allocated time is over. You must leave the room quietly after all the answer sheets have been collected.

Experimental Tasks A + B + C

Time : 3 hrs
Marks :40

Read the following instructions carefully:

1. While you are in the examination hall, you should wear safety spectacles at all times. While doing your experimental task, always wear your lab coat, safety goggles, and hand gloves.
2. Handle each and every apparatus and chemicals with care.
3. Do not try to taste or smell any chemical substance.
4. Chemicals are very safe if handled and disposed of properly.
5. Ensure that you keep the answer sheet and question paper away from liquids.
6. Place all waste papers and used material in the waste basket provided.
7. Immediately report all accidents, injuries, however minor they may be, to the invigilator/supervisor/volunteer present.
8. Eating of any kind of food is strictly prohibited during the experimental task.
9. You are expected to work safely, to behave socially, and to keep the equipment and work environment clean. When carrying out discussions with your teammates, keep your voice low.
10. Do not leave the examination hall until you have permission to do so. Ask an invigilator/supervisor/volunteer if you need to use the bathroom.
11. You may start working only when the start signal is given.
12. You have 3 hours to complete the experimental tasks and to record your results on the answer sheets. You must stop your work immediately after the stop command is given.
13. Be sure that your team has a complete set of the question paper (3 copies) and 2 types of answer sheets (1 white copy for rough work and 1 yellow copy for final answers). **ONLY YELLOW ANSWER SHEETS WILL BE EVALUATED.**
14. Use only the pen and calculator provided.
15. ID code must be written on every page of the final (yellow) answer sheets. Each team member must sign on the front page of the final (yellow) answer sheets.

16. All results must be written in the designated boxes on the **yellow answer sheets**. **Data written elsewhere will not be graded.**

17. After completing the task, put all the equipment back to its original place. Make sure you clean your work place.

18. After the stop command is given, put all papers inside the envelope kept on the desk. Wait for the volunteer to check and collect it.

Experimental Tasks

A + B + C

Time : 3 hrs
Marks :40

Task C: In this experiment we will extract lycopene from tomato and study its absorbance

Tomatoes are one of the main ingredients of pizzas. Tomatoes have two ingredients, lycopene and β-carotene, which are antioxidants and very good for health. They are soluble in oil but not water and, hence, in many parts of the world tomatoes are cooked in oil. Red tomatoes can contain as much as 50 mg of lycopene per kilogram of tomato.

In order to test the presence of lycopene in tomatoes, we shall dissolve tomato concentrate in an extracting solvent made up of petroleum ether and ethanol; we shall allow the solution to settle. The lycopene-rich solution separates out, resulting in two immiscible liquids. The top solution will be carefully separated out; its moisture content will be removed by using magnesium salts (which are hygroscopic in nature).

Experimental Tasks

A + B + C

Time : 3 hrs
Marks :40

You are supplied with the following:

	Labelled as…	Quantity Supplied
Tomato Concentrate	**TP**	In 50 ml beaker
Extracting Solvent	**ES**	(20ml) in 50 ml tube
Anhydrous Magnesium sulphate	**$MgSO_4$**	(1.5g) in a plastic container
Sodium chloride	**NaCl**	In plastic container
Test tube with stopper	**FL**	1
Test tubes	**Ab, UL**	2
Funnel		1
Glass rod		1
Filter paper		3
12 ml syringe	**SS**	1
Wash Bottle		1
White LED and Photodiode acrylic set-up		1
50 ml beaker	**SS**	1
Test tube stand		1
Blue LED		1
Bag containing acrylic collar for test tubes	**Collar**	
Dropper		
Multimeter		as in task B

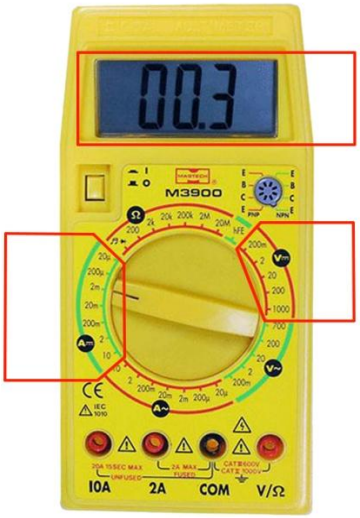
Experimental Tasks

A + B + C

Time : 3 hrs
Marks :40

The photo below is that of a multimeter. Your multimeter may be either yellow or black.

Multimeter knob is to be positioned in this region for current measurement
2μA is the minimum range of current measurement
10A is the maximum range



If display read *-1*, it implies range is insufficient. Shift the knob to higher range. Working in higher range than required will result in loss of accuracy

For this experiment DO NOT keep the knob in A ~V ~Ω

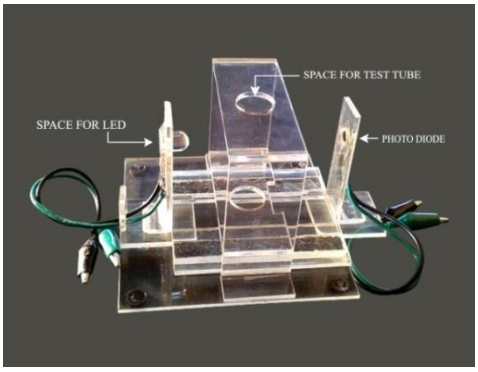
Multimeter knob is to be in this region for voltage measurement

To measure current

To Measure Voltage

1. Press MODE button, if the Stopwatch is on Time Mode, to bring it to Stop Watch Mode. 0:00 00
2. Press SPLIT/RESET button to reset the Stopwatch to Zero.
3. Press START/STOP button to start the Stopwatch.
4. Press START/STOP button to stop the Stopwatch.
5. In Stopwatch mode START/STOP button should be used to start and stop as many times as required.

Stopwatch



Procedure

Acrylic set-up with photodiode

1. **<u>Use the same acrylic apparatus that you used in Task:B2</u>**. Insert a white LED and photo-diode in their respective slots.
2. Half-fill test tube **Ab** with solvent from tube **ES**, using a dropper.
3. Using the acrylic collar provided, place test tube **Ab** in the acrylic apparatus, such that it is located between the LED and the photodiode (*as shown in the photograph).*
4. Adjust the position of the photodiode and the test tube so as to maximize the current in the photodiode which is connected to the multimeter, as described in **TASK: B2.** Please ensure that the label on the test tube does not obstruct the light.
5. Measure the maximum current, I_s, and record your observation in **Table C.1 in the yellow answer sheet.**
6. Replace the WHITE LED with the BLUE LED **without changing the position of either the test tube holder or the photodiode.** Measure the maximum current and record the value in **Table C.1 in the yellow answer sheet.**
7. Pour all the solvent back in test tube **ES**.

Note: Do not disturb the position of the photodiode and the acrylic test tube holder, it is crucial for subsequent readings.

We shall now extract lycopene from tomato concentrate, as follows.

8. Transfer all the solvent from test tube **ES** into the tomato concentrate in beaker **TP**. Stir the mixture well with the glass rod and allow it to settle for 2-3 minutes. Wash the glass rod for further use.
9. Now, filter the solution carefully by using funnel, and filter paper, in test tube **FL**. The red clear solution in test tube **FL** is your lycopene-containing extract (impure).
10. Preparation of saturated solution of NaCl: Take approximately 20 ml water in beaker **SS** using syringe SS; then add all the solid NaCl from container **NaCl,** stir well using the glass rod. Some part of the salt may remain undissolved.
11. Use syringe **SS** to add 10 ml of saturated NaCl solution in test tube **FL** containing lycopene extract. Put the stopper on the test tube and shake gently.
12. Keep the test tube on the test tube stand. Let the liquid in the test tube separate into two distinct layers. This should take about a minute.
13. Using the plastic dropper provided**,** carefully remove most of the upper layer (coloured) into test tube **UL**.

14. Add all the anhydrous $MgSO_4$ from the container labeled **$MgSO_4$** into test tube **UL** and swirl gently to allow water to be absorbed by the salt.
15. The yellow-red coloured solution in test tube **UL** is your lycopene extract (pure).

    We shall now carry out a comparative study of absorbance between solvent and the lycopene extract.

16. Place test tube **UL** in the acrylic apparatus.
17. Using the blue LED, measure the current I_l on the multimeter and record the value in **Table C.1 in the yellow answer sheet.**
18. Replace the blue LED with a white LED.
19. Measure the maximum current and record your respective observations in **Table C.1 in the yellow answer sheet.**
20. Deduce the percentage of light transmitted in each case.

[C.Q1: 3.5 Marks]

Questions

If the test tube **Ab** (containing the solvent) was removed from between the photodiode and the white LED,

a) The current measured would be less than I_s
b) The current measured would be more than I_s
c) The current measured would be equal to I_s

Write the correct option in the appropriate box in the yellow answer sheet.

[C.Q2: 1.0 Mark]

Which of the following can you *deduce from your observations in the experiments* on transmitted light. Indicate your answers as YES (Y) or NO (N) on **the yellow answer sheet**.

a) Lycopene absorbs more blue light relative to other parts of the visible spectrum.
b) Lycopene preferentially absorbs light in the red and yellow parts of the spectrum.
c) Lycopene is an antioxidant.
d) Red and yellow parts of the spectrum are absorbed relatively less compared to blue parts of the spectrum.
e) Blue light passes through the solution better compared to red light.
f) Lycopene absorbs light equally across the spectrum.

[C.Q3: 1.5 Marks]

Space for rough work

Country | Team

ID Code: 1) | 2) | 3)

2013 india ijso 10th

International Junior Science Olympiad,
Pune, India

Time : 3 hrs
Marks : 40

Experimental Tasks A + B + C

Task C : Extraction of lycopene from tomato — Total Marks: 6.0

Absorbance of extract:

C.Q1 Observation Table C.1 **[3.5 Marks]**

	Current in mA	Blue LED	White LED
1	I_s	0.8 – 1.0 mA	0.6 mA and above
2	I_l	0.0 – 0.08 mA	~ 0.4 mA
Percentage of light transmitted		0 to 8% [0.25]	30 – 70% [0.25]

Is (Blue LED) 0.8 – 1.0 mA [1.5]
Is (Blue LED) 0.6 – 0.8 mA and 1.0 – 1.2 mA [0.75]

Is (White LED) 0.6 mA and above [1.5]
Is (White LED) 0.3-0.6 mA [0.75]

Percentage transmitted in each case [2 x 0.25 = 0.5]

Questions

C.Q2 **[1.0 Mark]**

If the test tube **Ab** (containing the solvent) was removed from between the photodiode and the white LED,

a) The current measured would be less than I_s
b) The current measured would be more than I_s
c) The current measured would be equal to I_s

Write the correct option in the box below. **a)**

Experimental Tasks A + B + C

C.Q3 **[1.5 Marks]**

Which of the following can you *deduce from your observations in the experiments* on transmitted light. Indicate your answers as YES (Y) or NO (N) in the table below.

a) Lycopene absorbs more blue light relative to other parts of the visible spectrum.
b) Lycopene preferentially absorbs light in the red and yellow parts of the spectrum.
c) Lycopene is an antioxidant.
d) Red and yellow parts of the spectrum are absorbed relatively less compared to blue parts of the spectrum.
e) Blue light passes through the solution better compared to red light.
f) Lycopene absorbs light equally across the spectrum.

a)	**Y**
b)	**N**
c)	**N**
d)	**Y**
e)	**N**
f)	**N**

Each correct option [0.25]