Indian National Physics Olympiad - 2009
HOMI BHABHA CENTRE FOR SCIENCE EDUCATION (TIFR), MUMBAI

INPhO-2009 Feb. 01, 2009
Duration: **3 Hours** Maximum Marks: **80**

Instructions:

1. This question paper has three (3) parts: Part A, B and C and consists of 22 pages.
2. Write your Name and Roll Number on every page of the answer booklet which is separately provided as well as on the first page of this question paper.
3. Part A and B is each a set of multiple choice questions. Only one of the given choices is the best choice. Select this most appropriate choice and fill in the corresponding space in the answer booklet which is separately provided.
4. In Part A, there are **38** questions. Each right answer carries 1.5 marks while a wrong choice **carries a negative marking** of 0.5 mark.
5. In Part B, there are **20** questions. Each right answer carries 0.5 marks. There is **no negative marking** for this part. You are encouraged to attempt all questions in this part.
6. In Part C, question should be answered in the space provided in the answer booklet.
7. Calculator, mobiles, pagers, smart watches etc. are **not** allowed.
8. This question paper may be retained by the candidate.
9. You can do the rough work in the space provided at the end of the question paper.
10. Useful information is provided in the answer booklet.

PART - A

1. A block of weight 200 N is at rest on a rough inclined plane of inclination angle $\theta = 30^0$. The inclined plane is at rest in the earth's inertial frame. Then the magnitude of the force the plane exerts on the block is

   (a) $100\sqrt{3}$ N.
   (b) 100 N
   (c) 200 N
   (d) zero.

2. A spatially uniform magnetic field $\vec{B}$ exists in the circular region S and this field is decreasing in magnitude with time at a constant rate (see Fig. (1)). The wooden ring C_1 and the conducting

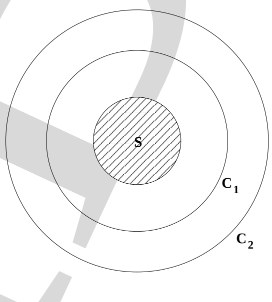

Figure 1:

ring C_2 are concentric with the magnetic field. The magnetic field is perpendicular to the plane of the figure. Then

   (a) there is no induced electric field in C_1.
   (b) there is an induced electric field in C_1 and its magnitude is greater than the magnitude of the induced electric field in C_2.
   (c) there is an induced electric field in C_2 and its magnitude is greater than the induced electric field in C_1.
   (d) there is no induced electric field in C_2.

3. During negative β decay, an anti-neutrino is also emitted along with the ejected electron. Then

   (a) only linear momentum will be conserved.

   (b) total linear momentum and total angular momentum but not total energy will be conserved.

   (c) total liner momentum and total energy but not total angular momentum will be conserved.

   (d) total linear momentum, total angular momentum and total energy will be conserved.

4. Five identical balls each of mass m and radius r are strung like beads at random and at rest along a smooth, rigid horizontal thin rod of length L, mounted between immovable supports (see Fig. (2)). Assume $10r < L$ and that the collision between balls or between balls and supports

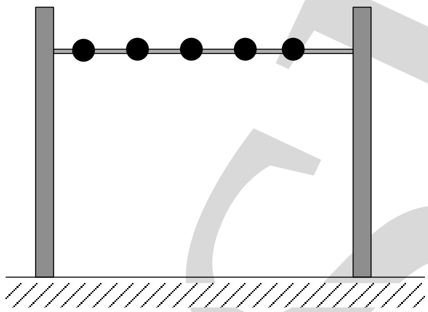

Figure 2:

are elastic. If one ball is struck horizontally so as to acquire a speed v, the average force felt by the support is

   (a) $\dfrac{5mv^2}{L-5r}$

   (b) $\dfrac{mv^2}{L-10r}$

   (c) $\dfrac{5mv^2}{L-10r}$

   (d) $\dfrac{mv^2}{L-5r}$

5. In Young's double slit experiment, one of the slits is wider than the other, so that the amplitude of the light from one slit is double that from the other slit. If I_m be the maximum intensity, the resultant intensity when they interfere at phase difference ϕ is given by

   (a) $\dfrac{I_m}{3}\left(1+2\cos^2\dfrac{\phi}{2}\right)$

   (b) $\dfrac{I_m}{5}\left(1+4\cos^2\dfrac{\phi}{2}\right)$

   (c) $\dfrac{I_m}{9}\left(1+8\cos^2\dfrac{\phi}{2}\right)$

   (d) $\dfrac{I_m}{9}\left(8+\cos^2\dfrac{\phi}{2}\right)$

6. A point luminous object (O) is at a distance h from front face of a glass slab of width d and of refractive index n. On the back face of slab is a reflecting plane mirror. An observer sees the image of object in mirror (see Fig. (3)). Distance of image from front face as seen by observer will be

   (a) $h+\dfrac{2d}{n}$

   (b) $2h+2d$

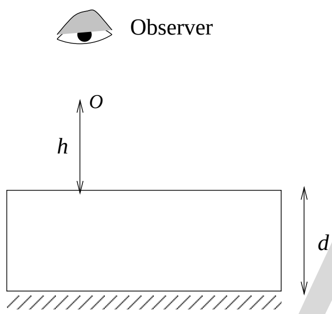

Figure 3:

(c) $h + d$

(d) $h + \frac{d}{n}$

7. A uniform wire of diameter 0.04 cm and length 60 cm made of steel (density 8000 kg-m^{-3}) is tied at both ends under a tension of 80 N. Transverse vibrations of frequency about 700 Hz will be predominant if the wire is plucked at

   (a) 15 cm and held at 30 cm.
   (b) 10 cm and held at 20 cm.
   (c) 30 cm.
   (d) 20 cm and held at 40 cm.

8. Consider a circle of radius R. A point charge lies at a distance a from its center and on its axis such that $R = a\sqrt{3}$. If electric flux passing through the circle is ϕ then the magnitude of the point charge is

   (a) $\sqrt{3}\epsilon_0\phi$
   (b) $2\epsilon_0\phi$
   (c) $4\epsilon_0\phi/\sqrt{3}$
   (d) $4\epsilon_0\phi$

9. A uniform tube 60 cm long, stands vertically with lower end dipping into water. When its length above water is 14.8 cm and again when it is 48 cm, the tube resonates to a vibrating tuning fork of frequency 512 Hz. The lowest frequency to which this tube can resonate when it is taken out of water is nearly

   (a) 275 Hz
   (b) 267 Hz
   (c) 283 Hz
   (d) 256 Hz

10. A binary star has a period (T) of 2 earth years while distance L between its components having masses M_1 and M_2 is four astronomical units. If $M_1 = M_S$ where M_S is the mass of Sun, the mass of other component M_2 is

    (a) $3M_S$
    (b) 7 M_S
    (c) 15 M_S
    (d) M_S

    Note: The earth - sun distance is one astronomical unit.

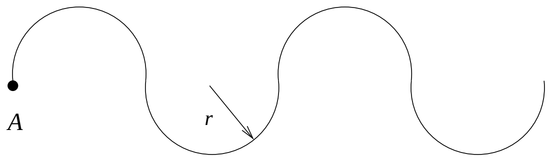

Figure 4:

11. A uniform rod of mass $2M$ is bent into four adjacent semicircles each of radius r all lying in the same plane (see Fig. (4)). The moment of inertia of the bent rod about an axis through one end A and perpendicular to plane of rod is

(a) $22Mr^2$
(b) $88Mr^2$
(c) $44Mr^2$
(d) $66Mr^2$

12. Two pulses on the same string are described by the following wave equations:

$$y_1 = \frac{5}{(3x-4t)^2+2} \quad \text{and} \quad y_2 = \frac{-5}{(3x+4t-6)^2+2}.$$

Choose the INCORRECT statement.

(a) Pulse y_1 and pulse y_2 travel along +ve and -ve x axis respectively.
(b) At $t = 0.75$ s, displacement at all points on the string is zero.
(c) At $x = 1$ m displacement is zero for all times.
(d) Energy of string is zero at $t = 0.75$ s.

13. A ray of light enters at grazing angle of incidence into an assembly of five isosceles right-angled prisms having refractive indices μ_1, μ_2, μ_3, μ_4 and μ_5 respectively (see Fig. (5)). The ray also

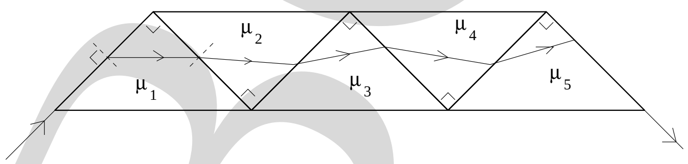

Figure 5:

emerges out at a grazing angle. Then

(a) $\mu_1^2 + \mu_3^2 + \mu_5^2 = 1 + \mu_2^2 + \mu_4^2$
(b) $\mu_1^2 + \mu_3^2 + \mu_5^2 = 2 + \mu_2^2 + \mu_4^2$
(c) $\mu_1^2 + \mu_3^2 + \mu_5^2 = \mu_2^2 + \mu_4^2$
(d) none of the above

14. The circuit shown in Fig. (6)) is allowed to reach steady state and then a soft iron core is inserted in the coil such that the coefficient of self inductance changes from L to nL. The current in the circuit at the time of complete insertion is

(a) E/R
(b) nE/R
(c) E/nR
(d) zero

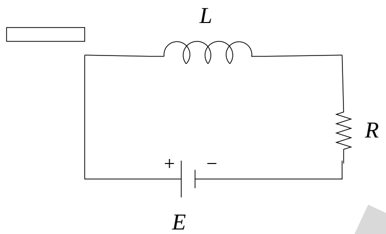

Figure 6:

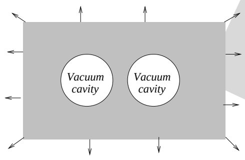

Figure 7:

15. Consider an infinitely extending gas cloud in space at temperature $T = 0$ K with two spherical vacuum cavities (see Fig. (7)). Consider only gravitational forces between gas molecules. Then

    (a) the cavities would come closer to each other.
    (b) the cavities would move away from each other.
    (c) the cavities would be static.
    (d) the motion of cavities would depend on the size of cavities.

Questions (16) and (17) are based on Fig. (8) and following information. A rod of mass m and

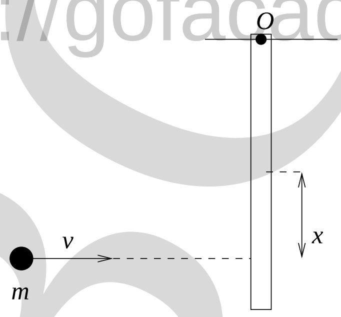

Figure 8:

length l is hinged at one end O. A particle of mass m travelling with speed v collides with the rod at a distance x from the center of mass of the rod such that the reaction force at the hinge is zero.

16. Then for the system

    (a) linear momentum is conserved.
    (b) angular momentum is not conserved about point O.
    (c) Linear momentum is not conserved and angular momentum about point O is conserved.
    (d) the mechanical energy is conserved.

17. Then

    (a) $x = l/6$.
    (b) $x = l/2$.
    (c) $x = l/3$.

(d) $x = l/4$.

18. Consider a huge charge reservoir at potential V. A spherical capacitor C_1 is brought in contact with the charge reservoir and then removed. Next another spherical capacitor C_2 is brought in contact with C_1 and removed. We repeat this process a large number of times. Assume that potential of reservoir does not change during this exercise. Then the charge on C_2 after a very long time is

(a) C_2V

(b) C_1V

(c) $C_2C_1V/(C_1 + C_2)$

(d) $(C_1 + C_2)V$

19. A particle of mass 1 kg is taken along the path $ABCDE$ from A to E (see Fig. (9)). The two "hills" are of heights 50 m and 100 m and the horizontal distance AE is 20 m while the path length is 400 m. The coefficient of friction of the surface is 0.1. Take $g = 10$ m-s^{-2} and $\sqrt{3} = 1.73$. The minimum work on the mass required to accomplish this is

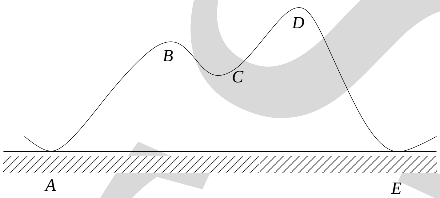

Figure 9:

(a) 20 J

(b) 173 J

(c) 400 J

(d) 0 J

20. Two positrons (e^+) and two protons (p) are kept on four corners of a square of side a as shown in Fig. (10). The mass of proton is much larger than the mass of positron. Let q denote the charge on the proton as well as the positron. Then the kinetic energies of one of the positrons and one of the protons respectively after a very long time will be

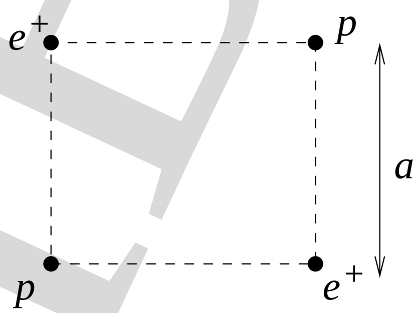

Figure 10:

(a) $\frac{q^2}{4\pi\epsilon_0 a}\left(1 + \frac{1}{2\sqrt{2}}\right)$, $\frac{q^2}{4\pi\epsilon_0 a}\left(1 + \frac{1}{2\sqrt{2}}\right)$

(b) $\frac{q^2}{2\pi\epsilon_0 a}$, $\frac{q^2}{4\sqrt{2}\pi\epsilon_0 a}$

(c) $\frac{q^2}{4\pi\epsilon_0 a}$, $\frac{q^2}{4\pi\epsilon_0 a}$

(d) $\dfrac{q^2}{2\pi\epsilon_0 a}\left(1+\dfrac{1}{4\sqrt{2}}\right)$, $\quad \dfrac{q^2}{8\sqrt{2}\pi\epsilon_0 a}$

21. An electrostatic field line leaves at angle α from point charge q_1, and connects with point charge $-q_2$ at angle β (see Fig. (11)). Then the relationship between α and β is

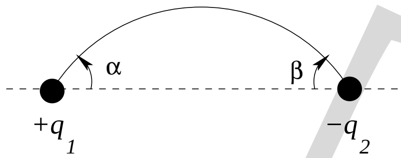

Figure 11:

(a) $q_1 \sin^2\alpha = q_2 \sin^2\beta$.

(b) $q_1 \tan\alpha = q_2 \tan\beta$.

(c) $q_1 \sin^2\dfrac{\alpha}{2} = q_2 \sin^2\dfrac{\beta}{2}$.

(d) $q_1 \cos\alpha = q_2 \cos\beta$.

22. A square metal frame in the vertical plane is hinged at O at its center (see Fig. (12)). A bug moves along the rod PN which is at a distance l from the hinge, such that the whole frame is always stationary, even though the frame is free to rotate in the vertical plane about the hinge. Then the motion of the bug will be simple harmonic, with time period,

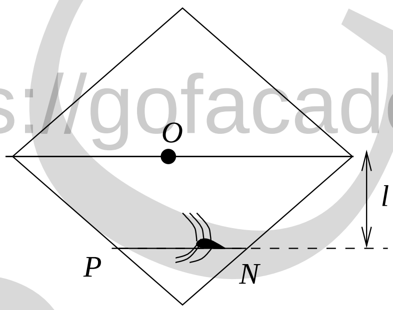

Figure 12:

(a) $2\pi\sqrt{l/g}$

(b) $2\pi\sqrt{2l/g}$

(c) $2\pi\sqrt{4l/g}$

(d) $2\pi\sqrt{l/2g}$

[**Hint:** There is a frictional force between the rod and the bug.]

23. A long flexible inextensible rope of uniform linear mass density λ is being pulled on a rough floor with horizontal force $\vec{F}$ in such a way that its lower part is at rest and upper part moves with constant speed v (see Fig. (13)). The magnitude of $\vec{F}$ will be

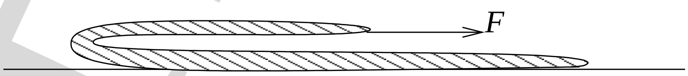

Figure 13:

(a) $2\lambda v^2$

(b) λv^2

(c) $\lambda v^2/2$

(d) some function of time and not constant.

24. A particle moving with initial velocity $\vec{v}_i = (3\hat{\imath} + 5\hat{\jmath})$ m-s^{-1}, collides with a smooth plane wall placed at some orientation to the particle's trajectory. The resulting velocity of the particle is $\vec{v}_f = (-2\hat{\imath} - \hat{\jmath})$ m-s^{-1}. The coefficient of restitution for this collision is

(a) 16/33

(b) 5/34

(c) 16/45

(d) 8/45

25. A long straight wire is carrying current I_1 in $+z$ direction. The $x - y$ plane contains a closed circular loop carrying current I_2 and not encircling the straight wire. The force on the loop will be

(a) $\mu_0 I_1 I_2/2\pi$.

(b) $\mu_0 I_1 I_2/4\pi$.

(c) zero.

(d) depends on the distance of the centre of the loop from the wire.

26. A uniform electric field $\vec{E}$ in the y direction and uniform magnetic field $\vec{B}$ in the x direction exists in free space. A particle of mass m and carrying charge q is projected from the origin with speed v_0 along the y axis. The speed of particle as a function of its y co-ordinate will be

(a) $\sqrt{v_0^2 + \frac{2qEy}{m}}$

(b) $\sqrt{v_0^2 - \frac{4qEy}{m}}$

(c) $\sqrt{v_0^2 + \frac{qEy}{m}}$

(d) v_0.

27. The atmospheric pressure on the earth's surface is P in MKS units. A table of area 2 m^2 is tilted at 45^0 to the horizontal. The force on the table due to the atmosphere is (in newtons)

(a) $2P$

(b) $\sqrt{2}P$

(c) $2\sqrt{2}P$

(d) $P/\sqrt{2}$

28. The shear modulus of lead is 2×10^9 Pa. A cubic lead slab of side 50 cm is subjected to a shearing force of magnitude 9.0×10^4 N on its narrow face (see Fig. (14)). The displacement of

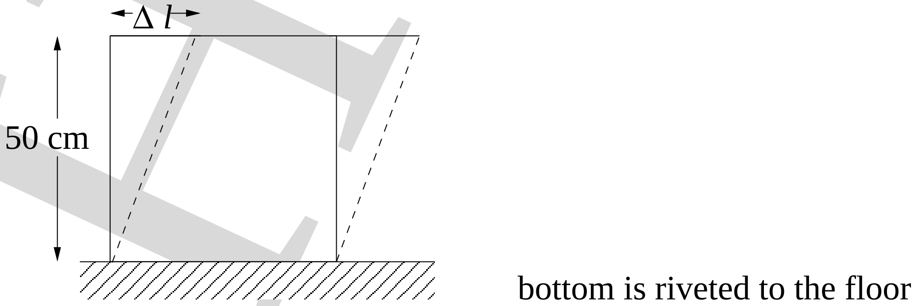

Figure 14:

the upper edge is δl, where δl is

(a) 2×10^{-3} m
(b) 5×10^{-4} m
(c) 4×10^{-4} m
(d) 9×10^{-5} m

29. In a moving coil galvanometer the number of turns $N = 24$, area of the coil $A = 2 \times 10^{-3}$ m^2, and the magnetic field strength $B = 0.2$ T. To increase its current sensitivity by 25% we

(a) Increase B to 0.30 T
(b) Decrease A to 1.5×10^{-3} m^2
(c) Increase N to 30
(d) None of the above.

30. Which of the following statement is TRUE ?

(a) Sound waves cannot interfere.
(b) Only light waves may interfere.
(c) The de Broglie waves associated with moving particles can interfere.
(d) The Bragg formula for crystal structure is an example of the corpuscular nature of electro-magnetic radiation.

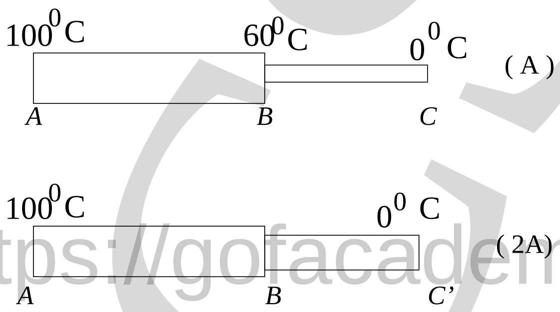

Figure 15:

31. Two metallic rods AB and BC of different materials are joined together at the junction B (see Fig.(15)). It is observed that if the ends A and C are kept at 100^0 C and 0^0 C respectively, the temperature of the junction B is 60^0 C. There is no loss of heat to the surroundings. The rod BC is replaced by another rod BC' of the same material and length ($BC = BC'$). If the area of cross-section of BC' is twice that of BC and the ends A and C' are maintained at 100^0 C and 0^0 C respectively, the temperature of the junction B will be nearly

(a) 29^0 C
(b) 33^0 C
(c) 60^0 C
(d) 43^0 C

32. Three closed vessels A, B and C are at the same temperature (T) and contain gases which obey the Maxwellian distribution of velocities. The vessel A contains only O_2, B only N_2 and C a mixture of equal quantities of O_2 and N_2. If the average speed of the N_2 molecules in vessel B is V_2 and that of oxygen molecules in A is V_1, the average speed of N_2 molecules in C is

(a) $(V_1 + V_2)/2$
(b) $(V_1 - V_2)/2$
(c) V_2
(d) $\sqrt{(V_1 V_2)}$

33. When a system is taken from state a to state b along the path $a - c - b$ (see Fig.(16)), 60 J of heat flows into the system and 30 J of work are done by the system. Along the path $a - d - b$, if the work done by the system is 10 J, heat flow into the system is

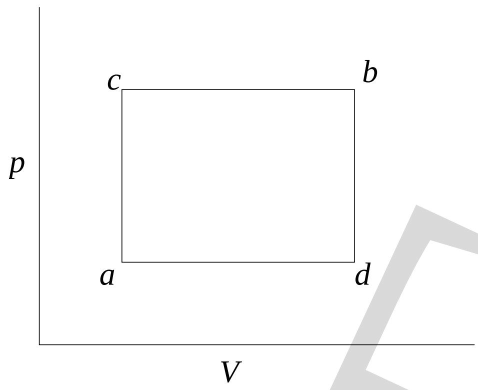

Figure 16:

(a) 100 J
(b) 20 J
(c) 80 J
(d) 40 J

34. Two identical piano strings, when stretched with the same tension T_0, have a fundamental frequency of 300 Hz. The tension in one of the strings is increased to $(T_0 + \Delta T)$ and 3 beats per second occur when both strings vibrate simultaneously. $(\Delta T/T_0) \times 100$ is

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

35. The half life of a certain radioactive material $({}_zX^{100})$ is 6.93×10^6 s. In order to have an activity of 6.0×10^8 disintegrations per second, the amount of material needed is nearly

(a) 10^{-9} kg
(b) 10^{-16} kg
(c) 10^{-6} kg
(d) 10^{-4} kg

36. Sound of frequency 1000 Hz from a stationary source is reflected from an object approaching the source at 30 m-s^{-1}, back to a stationary observer located at the source. The speed of sound in air is 330 m-s^{-1}. The frequency of the sound heard by the observer is

(a) 1200 Hz
(b) 1000 Hz
(c) 1090 Hz
(d) 1100 Hz

37. Current (I) - applied voltage (V) characteristics are shown in Fig. (17). Possible observed plot(s) for a photoelectric setup is(are):

(a) only II.
(b) I and II.
(c) II and III.
(d) II and IV.

[Please note: This question is dropped]

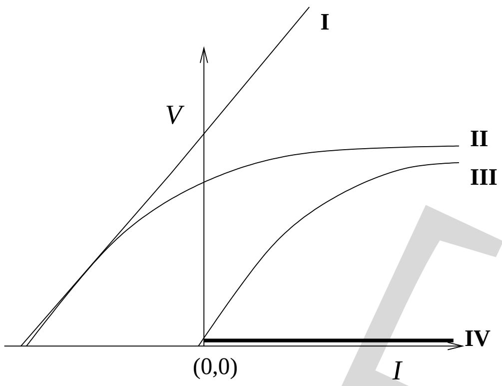

Figure 17:

38. A triply ionized beryllium (Be^{+++}) has the some orbital radius as the ground state of hydrogen. Then the quantum state n of Be^{+++} is

(a) $n = 1$
(b) $n = 2$
(c) $n = 3$
(d) $n = 4$

****** END OF "PART A" OF THE QUESTION PAPER ******

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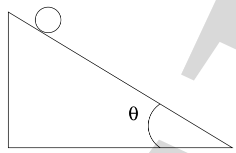
Part - B

Setup for the next three questions

You are to conduct a series of trials. For each trial the inclination of the plane is set to an angle θ, ranging from 0^0 to 90^0, and an object is released from rest at the top of the stationary inclined plane. The coefficient of static friction between the object and the inclined plane is μ_s. In each case below, predict the observed outcome for the trial.

In the following questions 'tumble' means 'tip over and rotate' and 'sliding' means NO tumbling.

1. Case 1: The object is a sphere and $\mu_s = 0$:



(a) The sphere will roll without slipping for small θ and slide down only for θ greater than a certain non-zero value.

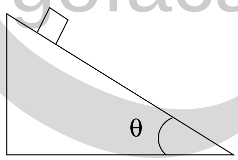
(b) The sphere will remain at rest for small θ and roll without slipping only for θ greater than a certain non-zero value.

(c) The sphere will slide down for all $\theta > 0^0$.

(d) The sphere will roll without slipping for all $\theta > 0^0$.

(e) None of the above.

2. Case 2: The object is a cube and $\mu_s = 0$. In this experiment, the angle θ is varied only between 0^0 and 45^0:



(a) The cube will slide down for all $45^0 > \theta > 0^0$.

(b) The cube will remain at rest for small θ and slide down only for θ greater than a certain non-zero value.

(c) The cube will roll without slipping for all $45^0 > \theta > 0^0$.

(d) The cube will tumble down for all $45^0 > \theta > 0^0$.

(e) None of the above.

3. Case 3: The object is a cube and μ_s is very large ($\mu_s >> 1$):

(a) The cube will remain at rest for small θ and slide down only for θ greater than a certain non-zero value.

(b) The cube will stay on the incline as if it were glued to it, for all θ.

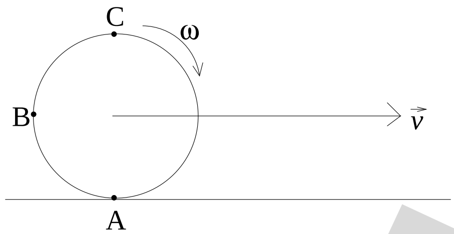
(c) The cube will move relative to the inclined plane only for $\theta = 90^0$.

(d) The cube will tumble down only for $\theta > 45^0$.

(e) None of the above.

Setup for next two questions

A rigid wheel of radius R rolls without slipping on a horizontal road. The linear velocity of the center of the wheel with respect to the road is $\vec{v}$ and the angular speed is ω.



4. The direction of instantaneous velocity of point B (see the figure above) with respect to the road is roughly:

   (a) 

   (b) 

   (c)

   (d)

   (e) There is no direction since the instantaneous speed of point B is zero with respect to the road.

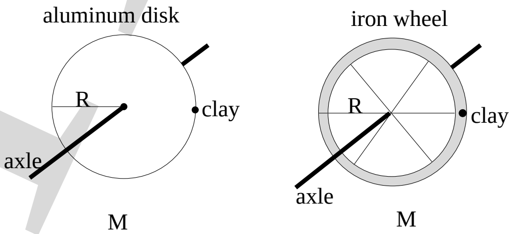
5. Rank order the speeds of points A, B, C at the rim of the wheel with respect to the *road*, largest first (see the figure above).

   (a) $v_A = v_B = v_C$.
   (b) $v_A > v_B > v_C$.
   (c) $v_B > v_C > v_A$.
   (d) $v_C > v_A > v_B$.
   (e) $v_C > v_B > v_A$.

6. Whenever a constant non-zero net torque acts on a rigid object, it produces a

   (a) rotational equilibrium.
   (b) constant angular velocity.
   (c) constant angular momentum.
   (d) change in angular acceleration.
   (e) change in angular velocity.

Setup for next two questions
An aluminum disk and an iron wheel (with spokes of negligible mass) have the same radius R and mass M as shown below. Each is free to rotate about its own fixed horizontal frictionless axle. Both objects are initially at rest. Identical small lumps of clay are attached to their rims as shown in the figure.



7. Consider the net torque acting on the disc+clay and wheel+clay systems, about a point on its own axle. Which one of the following statements is true?
   (a) The net torque is greater for the disc+clay system.
   (b) The net torque is greater for the wheel+clay system.
   (c) Which system has a greater net torque depends on actual numerical values of R and M.
   (d) There is no net torque on either system.
   (e) The net torque on both systems are equal and non-zero.

8. Which one of the following statements about their angular acceleration is true?
   (a) The angular acceleration is greater for the disk+clay system.
   (b) The angular acceleration is greater for the wheel+clay system.
   (c) Which system has greater angular acceleration depends in the actual numerical values of R and M.
   (d) There is no angular acceleration for either system.
   (e) The angular acceleration of both the systems are equal and non-zero.

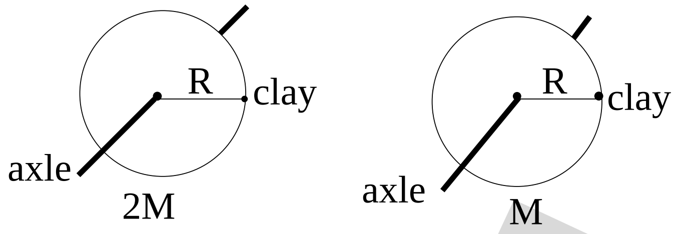
9. Which one of the following statements about their maximum angular velocities is true?
   (a) The maximum angular velocity is greater for the disk+clay system.
   (b) The maximum angular velocity is greater for the wheel+clay system.
   (c) Which object has a greater maximum angular velocity is determined by the actual numerical values of R and M.
   (d) The maximum angular velocities of both systems are equal and non-zero.
   (e) There is no angular velocity for either system so the question of a maximum value does not arise.

10. Two identical rigid marbles roll without slipping across rigid horizontal floors. One rolls on a stone floor with coefficient of static friction $\mu_s = 0.080$, and the other rolls on a glass floor with $\mu_s = 0.040$. Which marble is slowed down more by friction, and why? Ignore air-resistance.
   (a) Both marbles are slowed equally because the marbles themselves are identical.
   (b) Neither marble is slowed down by friction because both roll without slipping.
   (c) The marble rolling on stone is slowed more, because the greater μ_s makes the force of friction on it greater.
   (d) The marble rolling on glass is slowed more, because the slippery nature of the glass impedes rolling.
   (e) It is impossible to answer without knowing the coefficient of kinetic friction μ_k because the marbles are moving.

Setup for the next two questions

Two copper disks of different thicknesses have the same radius but different masses as shown below. Each disk is free to rotate about its own fixed horizontal frictionless axle. Both disks are initially at rest. Identical small lumps of clay are attached to their rims as shown in the figure.

11. Consider the net torque acting on each disk+clay system, about a point on its own axle. Which one of the following statements is true?
   (a) The net torque is greater for the system in which the disk has larger mass.
   (b) The net torque is greater for the system in which the disk has smaller mass.



(c) Which system has a greater net torque depends on the actual numerical values of their masses.

(d) There is no torque on either system.

(e) The net torque on both systems are equal and non-zero.

12. Which one of the following statements about their angular acceleration is <u>true</u>?

(a) The angular acceleration is greater for the system in which the disc has a larger mass.

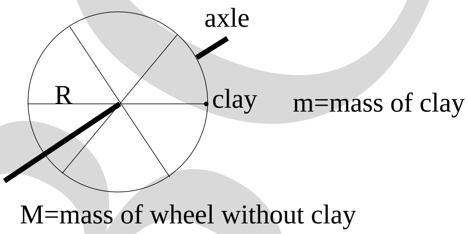
(b) The angular acceleration is greater for the system in which the disc has a smaller mass.

(c) Which system has a greater angular acceleration depends on the actual numerical values of their masses.

(d) There is no angular acceleration for either system.

(e) The angular acceleration of both systems are equal and non-zero

13. A wheel of mass M and radius R is free to rotate about a fixed horizontal axle. A small lump of clay of mass m is attached to its rim as shown in the figure. Consider the magnitude of the net torque τ acting on the wheel+clay system about a point on the axle shown in the figure given below, and let g be the magnitude of the acceleration due to gravity. Which one of the following statements is <u>true</u>?



(a) $\tau = mgR$

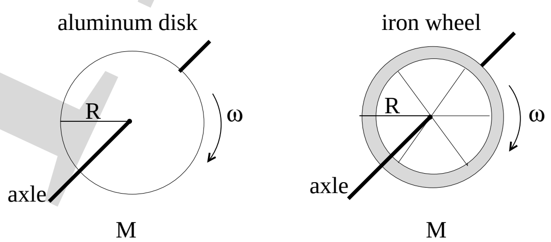
(b) $\tau = (m + M)gR$

(c) $\tau = (m + M/2)gR$

(d) $\tau = (m + M)g/R$

(e) None of the above.

14. An aluminum disk and an iron wheel (with spokes of negligible mass) have the same mass M and radius R. They are spinning around their frictionless axles with the <u>same</u> angular speed as shown. Which of them has more rotational kinetic energy?



(a) The aluminum disk.

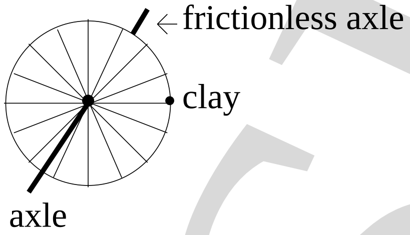
(b) The iron wheel.

(c) Both have the same rotational kinetic energy.

(d) It depends on the actual numerical value of the mass M.

(e) None of the above.

15. A bicycle wheel is free to rotate about a horizontal frictionless axle. A small lump of clay is attached to the rim as shown in the figure, and the wheel is released from rest. Which one of the following statements about the motion of the wheel is true?



(a) The wheel will remain at rest if the mass of the lump of clay is smaller than a certain critical value.

(b) The wheel will oscillate.

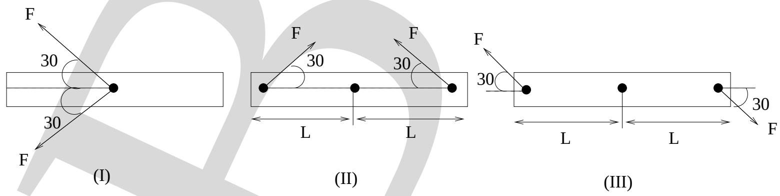
(c) The wheel will rotate and come to rest when lump of clay is at the lowest possible point.

(d) The number of full revolutions (angle 2π) the wheel makes before coming to rest depends on the mass of the lump of clay.

(e) None of the above.

Setup for the next two questions
The figures in the next two questions show three cases in which a rigid rod of length $2L$ is acted upon by some forces. All forces labelled F have the same magnitude.

16. Which cases have a non-zero net torque acting on the rod about its center?



(a) (I) only.

(b) (II) only.

(c) (III) only.

(d) (I) and (II) only.

(e) The net torque is zero in all cases.

17. Which cases have a non-zero net torque acting on the rod about its center?

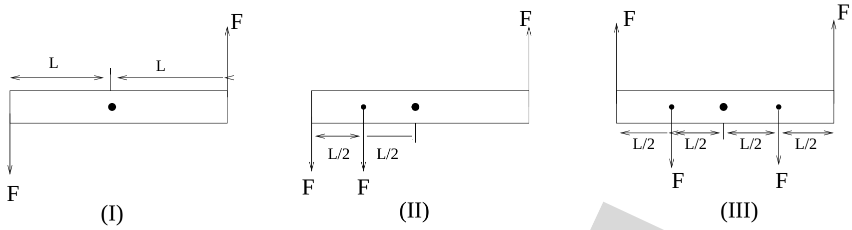
(a) (I) only.

(b) (II) only.

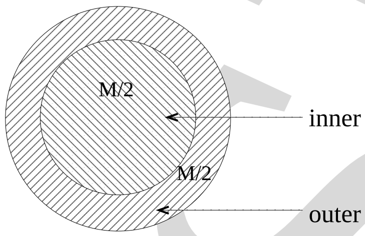
(c) (III) only.

(d) (I) and (II) only.

(e) The net torque is zero in all cases.



18. Consider the moment of inertia, I, of the rigid homogeneous disk of mass M shown below, about an axis through its center (different shadings only differentiate the two parts of the disk, each with equal mass $M/2$). Which one of the following statements concerning I is correct?



(a) The inner and outer parts of the disk, each with mass $M/2$ (see figure), contribute equal amounts to I.

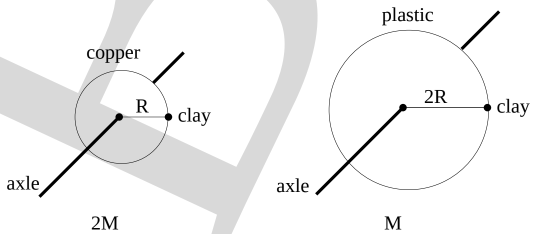
(b) The inner part of the disk contributes more to I than the outer part.

(c) The inner part of the disk contributes less to I than the outer part.

(d) The inner part of the disk may contribute more or less to I than the outer part depending on the actual numerical value of the mass M of the disk.

(e) None of the above.

19. A copper disc and a plastic disc have different radii and masses as shown below. Each disk is free to rotate about its own fixed horizontal frictionless axle. Both disks are initially at rest. Identical small lumps of clay are attached to their rims as shown in the figure. Consider the net torque acting on each disc+clay system, about a point on its own axle. Which one of the following statements is true?



(a) The net torque is greater for the system with the plastic disk.

(b) The net torque is greater for the system with the copper disk.

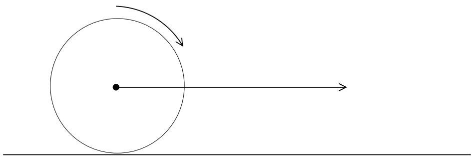
(c) Which system has a greater net torque depends on the actual numerical values of the masses and the radii of the disks.

(d) There is no net torque on either system.

(e) The net torques on both systems are equal and non-zero.

20. A bicycle wheel rolls without slipping on a horizontal floor. Which one of the following is true about the motion of points on the rim of the wheel, relative to the axis at the wheel's center?

(a) Points near the top move faster than points near the bottom.



(b) Points near the bottom move faster than points near the top.

(c) All points on the rim move with the same speed.

(d) All points have the velocity vectors that are pointing in the radial direction towards the center of the wheel.

(e) All points have acceleration vectors that are tangent to the wheel.

****** END OF "PART B" OF THE QUESTION PAPER ******

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PART - C

One mole of gas undergoes a linear process as shown in Fig. (18).

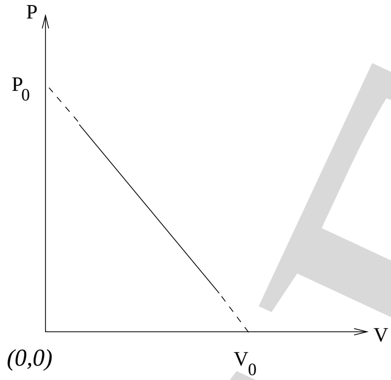

Figure 18:

1. Express P in terms of $\{V,\ V_0,\ P_0\}$.
2. Assuming that the gas is ideal, obtain the expression for T in terms of gas constant R and $\{V,\ V_0,\ P_0\}$.
3. Obtain the expression for volume change with temperature (dV/dT) in terms of $\{R,\ V,\ V_0, P_0\}$.
4. Let T_{max} be the maximum temperature in the process. Express T_{max} in terms of $\{V_0,\ P_0,\ \mathrm{R}\}$.
5. Sketch the $T-V$ diagram. (T on y-axis and V on x-axis.)
6. Let $C_p/C_v = \gamma$, where C_p (C_v) is specific heat at constant pressure (volume). Express heat capacity C_v in terms of R and γ.
7. Using the first law of thermodynamics, obtain the expression for specific heat C for the above linear process in terms of $\{R,\ \gamma,\ V_0,\ V\}$.
8. Suppose mixture consists of half mole of mono atomic and half mole of diatomic gas. Obtain γ for this mixture.
9. For the mixture described in Part (8), obtain C in terms of $\{R,\ V,\ V_0\}$.
10. Plot C/R (on y-axis) vs V/V_0 (x-axis).

[1 + 1 + 1 + 1 + 1.5 + 0.5 + 3 + 0.5 + 1 + 2.5 = 13]

****** END OF THE QUESTION PAPER ******

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Space for Rough Work

Space for Rough Work

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Answer sheet INPhO -2009

Name: ________________________________ Roll No.**P09**________

PART-A

No.	(a)	(b)	(c)	(d)	Mark	No.	(a)	(b)	(c)	(d)	Mark
1.	a	b	●	d		20.	a	b	c	●	
2.	a	●	c	d		21.	a	b	●	d	
3.	a	b	c	●		22.	●	b	c	d	
4.	a	●	c	d		23.	a	b	●	d	
5.	a	b	●	d		24.	a	b	●	d	
6.	●	b	c	d		25.	a	b	●	d	
7.	a	●	c	d		26.	●	b	c	d	
8.	a	b	c	●		27.	●	b	c	d	
9.	a	●	c	d		28.	a	b	c	●	
10.	a	b	●	d		29.	a	b	●	d	
11.	a	b	●	d		30.	a	b	●	d	
12.	a	b	c	●		31.	a	b	c	●	
13.	a	●	c	d		32.	a	b	●	d	
14.	a	b	●	d		33.	a	b	c	●	
15.	a	●	c	d		34.	●	b	c	d	
16.	●	b	c	d		35.	●	b	c	d	
17.	●	b	c	d		36.	●	b	c	d	
18.	●	b	c	d		37.					dropped
19.	a	b	c	●		38.	a	●	c	d	

Subtotal : **Subtotal :**

Total :

Answer sheet INPhO -2009

Name: ______________________________ Roll No.**P09**__________

PART - B

No.	(a)	(b)	(c)	(d)	(e)	Mark	No.	(a)	(b)	(c)	(d)	(e)	Mark
1.	ⓐ	ⓑ	●	ⓓ	ⓔ		11.	ⓐ	ⓑ	ⓒ	ⓓ	●	
2.	●	ⓑ	ⓒ	ⓓ	ⓔ		12.	ⓐ	●	ⓒ	ⓓ	ⓔ	
3.	ⓐ	ⓑ	ⓒ	●	ⓔ		13.	●	ⓑ	ⓒ	ⓓ	ⓔ	
4.	ⓐ	●	ⓒ	ⓓ	ⓔ		14.	ⓐ	●	ⓒ	ⓓ	ⓔ	
5.	ⓐ	ⓑ	ⓒ	ⓓ	●		15.	ⓐ	●	ⓒ	ⓓ	ⓔ	
6.	ⓐ	ⓑ	ⓒ	ⓓ	●		16.	ⓐ	ⓑ	●	ⓓ	ⓔ	
7.	ⓐ	ⓑ	ⓒ	ⓓ	●		17.	ⓐ	ⓑ	ⓒ	●	ⓔ	
8.	●	ⓑ	ⓒ	ⓓ	ⓔ		18.	ⓐ	ⓑ	●	ⓓ	ⓔ	
9.	●	ⓑ	ⓒ	ⓓ	ⓔ		19.	●	ⓑ	ⓒ	ⓓ	ⓔ	
10.	ⓐ	●	ⓒ	ⓓ	ⓔ		20.	ⓐ	ⓑ	●	ⓓ	ⓔ	

Subtotal : **Subtotal :**

Total :

Name: ________________________________ Roll No.**P09**__________

PART - C

Equivalent solutions may exist.

1.

$$\frac{P}{P_0} + \frac{V}{V_0} = 1 \text{ (valid for } V < V_0,\ P < P_0)$$

2.

$$T = \frac{P_0 V}{R}\left(1 - \frac{V}{V_0}\right)$$

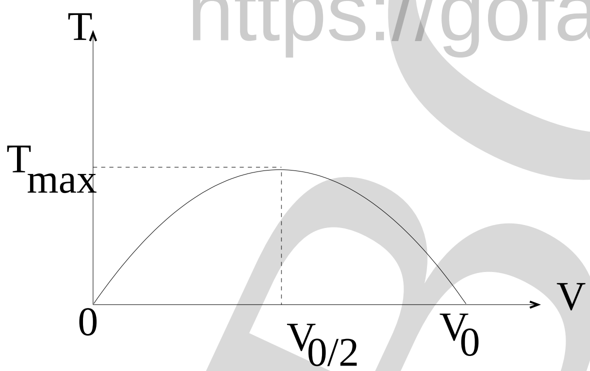
3.

$$\frac{dV}{dT} = \frac{R\,V_0}{P_0\,(V_0 - 2V)}$$

4.

$$T_{max} = \frac{P_0 V_0}{4R}$$

5.



6.

$$C_V = \frac{R}{\gamma - 1}$$

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7.

$$C = \frac{R}{\gamma - 1} + \frac{(V_0 - V)R}{(V_0 - 2V)}$$

8.

$$\gamma = \frac{3}{2}$$

9.

$$C = R\frac{\left(3 - \frac{5V}{V_0}\right)}{\left(1 - \frac{2V}{V_0}\right)}$$

10.