National Experimental Skill Test: NEST 2014

National Anveshika Network of India (NANI)

Version 0.01, August 19, 2014

☞ ACKNOWLEDGMENT: Our sincere gratitude to,

(a) Dr H C Verma, Coordinator, National Anveshika Network of India (NANI). He is the driving force for NEST and other Anveshika activities.

(b) Anveshika Coordinators and their team members:

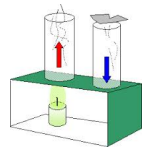
Kanpur	SGM	Amit Kumar Bajpayi
Agra	Raman	R K Awasthi
Siwan	Siwan	Mr. Rajeev Ranjan
Kolkata	TAXXILA	Dr. Amit Kumar Jana
Lucknow	Mitra	Dr. R. K Mitra
Patna	Patna	Dr Amarendra Narayan
Oraiya	Go&go	Brajesh Dixit
Munger	VSS	Dr. K N Rai
Kolhapur	GCG	Dr S A Masti
Bhilkwadi	SSB	Dr Gajanan Patil
Pilibhit	Samadhan	Dr Laxmi Kant Sharma
Pilani	BPS	Mr Manoranjan K Singh
Hissar	OPJS	Lalit Mohan Singh
Delhi	BVN	Pragya Nopani
Udhampur	Happy	Mineesh
Vizianagram	Focus	Chandrasekhar Joga
Chandigarh	SGGSC	Dr M S Marwaha
Dhanbad	Vidya	Arvind Kumar Pathak
Hyderabad	ViBha	Jitender Singh

Dedicated to those who appreciate
Physics and the work of
Dr. H. C. Verma

Contents

Screening Test

1. Lightning the Lamp: Why does smoke goes up in one of the chimney but goes down in another? Youtube.



The lighter air (low density) moves up. To fill the empty space (low pressure region) near flame, air from surrounding rushes towards it. Since box is closed, the air comes from other chimney. In essence, an invisible *convection current* is set up in the box. The smoke is used to see this convection current.

2. Interesting Bulbs: Youtube.

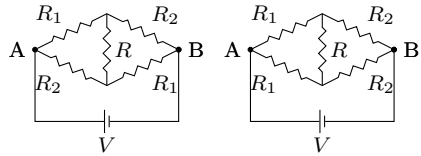
(a) Explain why intensity of two bulbs is reversed when connection is changed?

(b) Why bulb at centre stopped glowing when two bulbs are interchanged?

Initially, two bulbs of power rating $P_1 = 25$ W and $P_2 = 15$ W were connected in parallel to $V = 250$ V power supply. In this case, the brightness of two bulbs was as expected i.e., $P_1^{\text{parallel}} = 25$ W and $P_2^{\text{parallel}} = 15$ W. Then, these bulbs were connected in series to same supply. From power rating, the resistant of bulbs are $R_1 = \frac{V^2}{P_1} = \frac{250\times250}{25} = 2500\ \Omega$ and $R_2 = \frac{V^2}{P_2} = \frac{250\times250}{15} = 4167\ \Omega$ (note that bulb with lower power rating has more resistance). In

series, the current through both the bulbs is same and is equal to $I_1 = I_2 = \frac{V}{R_1+R_2} = \frac{250}{2500+4167} = 0.037$ A. The power output in series is $P_1^{\text{series}} = I_1^2 R_1 = 0.037 \times 0.037 \times 2500 = 3.4$ W and $P_2^{\text{series}} = I_2^2 R_2 = 0.037 \times 0.037 \times 4167 = 5.7$ W.

Second demonstration was of Wheatstone bridge. Let two types of peripheral bulbs have resistances R_1 and R_2 and central bulb is of resistance R_1. In first case, the bridge was not balanced giving non-zero current through R. In second case, the bridge was balanced giving zero current through R. Two cases are shown in figure.

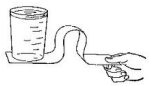


3. Tumbler and the Water: Explain why water does not fall when tumbler is inverted? Youtube.

The plastic cover does not fall because its weight mg is balanced by the pressure force acting on its two sides. Let P_0 be atmospheric pressure and P_1 be pressure in empty space above water (when glass is inverted). Downward pressure force on the cover is $(P_1 + h\rho g)A$ and upward pressure force is $P_0 A$. In balance condition, $P_0 A = mg + (P_1 + h\rho g)A$, which gives $P_1 = P_0 - \frac{mg}{A} - h\rho g$. Important question is, how come $P_1 < P_0$? Let us see the process more carefully. When glass was not inverted, pressure of air inside the glass is P_0. After inversion, this air moves to upper portion of the glass and its pressure remains P_0 (if cover is not moved relative to the glass). When hand is removed, the cover goes slightly down and there is a water slice between the glass and the cover. The surface tension does not allow the water to leak out inspite of physical

gap between cover and glass. As the cover goes slightly down, the volume of air in the upper portion increases. This decreases in pressure according to the Boyles law.

4. Tumbler and the Paper: Explain why tumbler does not move with paper in first case but starts moving with it in second case? Youtube.



The common explanation is that because of inertia, the glass remains at its place and the paper comes out. This explanation is not entirely correct. It is friction, acceleration and distance moved under this acceleration that have to be roped in for proper understanding.

5. Hacksaw Blade: Youtube.

(a) Why does nails start falling down?
(b) Why time interval between successive falling of nails increases as we go away from the candle?

(a) The candle is a source of heat. The heat is transferred from one end of the hacksaw blade to another end by conduction process. Due to this, temperature of various points on the blade start rising. Once temperature at the position of nail crosses melting point of wax, the nail falls down. In this demo, we can visualize how heat is being transferred.
(b) The temperature is a function of distance from heat source and time. The temperature rises slowly at far away point. The heat loss due to radiation etc further reduces rate of temperature rise. Thus, time interval between successive falling of nails increases as we go away from the candle.

6. Rotating Straw: Explain why straw starts rotating when we bring second straw near to it? Youtube.

Both straw gets charged due to friction. The nature of charge on both straw is same. By Coulomb's law, force acts on the straw

when another straw is brought near to it. This force gives a non-zero torque about centre of mass (same as point of suspension) of the straw. The torque is responsible for rotation of the straw.

7. Sticking Slides: Why a drop of water makes the slides stick together? Youtube.

The adhesive force between glass-water and cohesive force between water-water molecules is responsible for sticking of slides. This can be explained through the phenomenon of surface tension.

8. Two Pipes: Youtube.

(a) Guess the difference in the constructions of the pipes?
(b) With this difference why one floats vertically but the other falls on the surface?

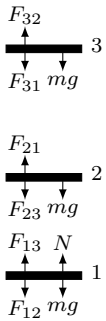
(a) The second pipe is made heavier at the bottom than the first.
(b) When floated vertically, *center of mass* of the second pipe is lower than that of the displaced water. Thus the couple made by buoyancy and weight makes the vertical state *stable equilibrium*. Opposite is true in the first pipe.

9. Three Magnets: Youtube.

(a) Which of the pairs of magnets repel each other and which attract each other?

(b) What is the resultant force on magnet 2? What is the resultant force on magnet 3?

(c) Why the separation between magnet 2 and 3 is more than the separation between magnet 1 and 2?



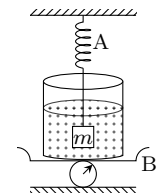
The free body diagram of three magnets is given in figure. The weight, mg, is same on all the three. The normal reaction from base on magnet 1 is N. Magnet 1 and 2 repel, also 2 and 3 repel, but 1 and 3 attract. Here, F_{12} is magnetic force (repulsive) on magnet 1 due to magnet 2 and F_{21} is magnetic force (repulsive) on magnet 2 due to magnet 1. By Newton's third law, $F_{12} = F_{21}$. Similarly, $F_{13} = F_{31}$ and $F_{23} = F_{32}$. Since magnets are stationary, Newton's second law gives resultant force on each magnet as zero. Thus, for magnet 1, $F_{13} + N - F_{12} - mg = 0$, for magnet 2, $F_{21} - F_{23} - mg = 0$ and for magnet 3, $F_{32} - F_{31} - mg = 0$. Substitute $F_{31} = F_{13}$, $F_{32} = F_{23}$ and $F_{21} = F_{12}$ to get $F_{13} + N - F_{12} - mg = 0$, $F_{12} - F_{23} - mg = 0$ and $F_{23} - F_{13} - mg = 0$. Solve to get, $N = 3mg$ and $F_{12} = F_{23} + mg$. If stand is kept on a pan balance then pan balance will measure $N = 3mg$. Also, repulsive force between 1 and 2 is greater than repulsive force between 2 and 3 ($F_{12} = F_{23} + mg$). This is possible when distance between 1 and 2 is less than distance between 2 and 3 (magnetic force increases as distance between magnets decreases).

10. Eureka!Youtube.

(a) Find the mass of the beaker + water?

(b) Find the mass of the hanging object in gram?

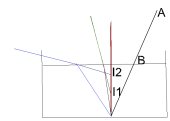
(c) What is the reading on the dial of the pan balance at this time?



The reading pan balance with beaker and water is 600 g. Thus, mass of the beaker and water together is $m_{bw} = 600$ g. The reading of the spring balance with hanging cylindrical mass is 1.4 N. Thus, $mg = 1.4$, gives $m = 1.4/g = 1.4/10 = 0.14$ kg $=$ 140 g. When cylindrical mass is placed in beaker, reading of the spring balance is 0.2 N. Thus, an upward force, $F = 0.2$ N, acts on the hanging mass by the spring balance. Consider cylindrical mass, beaker and water together as a system. The forces acting on this system are weight $(m_{bw} + m)g$, force F due to spring balance, and normal reaction N by the pan balance. Since system is stationary, Newton's second law gives resultant force on the system as zero i.e., $N + F - (m_{bw} + m)g = 0$ which gives $N = (m_{bw} + m)g - F = (0.600 + 0.140)10 - 0.2 = 7.2$ N. By Newton's third law, reaction force acting on the pan is also 7.2 N and mass corresponding to this force is $m = 7.2/10 = 0.72$ kg $=$ 720 g. The readers are encouraged to draw free body diagram of cylindrical mass and find the buoyant force acting on it.

11. Bending of Pencil: Youtube.

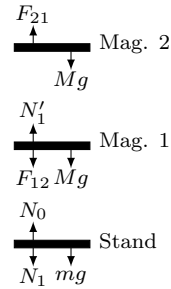
(a) Why does the pencil look bend?
(b) Drawing rays, explain why the pencil appears more sharply bent when viewed at an angle?



Because of refraction parts of the pencil in water appear to rise up. When viewed from a side, apparent rise of the bottom of the pencil is more and hence the pencil looks more bent.

12. Action-Reaction: Youtube.

(a) What is the mass of stand?
(b) What is the mass of magnet 1? Of magnet 2?
(c) What reading do you expect at the end?



The mass of the stand is $m = 20$ g. Two magnets are identical with mass of each magnet $M = 70$ g. Figure shows free body diagram of the stand and two magnets. The forces on the stand are its weight mg, reaction N_1 from magnet 1 and reaction N_0 from the pan balance. The forces on magnet 1 are its weight Mg, reaction from the stand N_1', and magnetic force on magnet 1 due to magnet 2, F_{12}. The forces on magnet 2 are its weight Mg and magnetic force on magnet 2 due to magnet 1, F_{21}. By Newton's third law, $N_1' = N_1$ and $F_{21} = F_{12}$. Since each object is stationary, by Newton's second law, resultant force on each of them is zero. Thus, $N_0 = N_1 + mg$, $N_1' = F_{12} + Mg$ and $F_{21} = Mg$. Substitute $F_{21} = F_{12}$ and $N_1' = N_1$ and then solve to get $N_0 = mg + 2Mg$. Again, by Newtons third law, reaction on the pan balance by the stand is $N_0 = mg + 2Mg = (m + 2M)g$. The mass measured by the pan balance is $N_0/g = m + 2M = 20 + 2 \times 70 = 160$ g.

13. Laser in Air and Water: Youtube

(a) Why was smoke put in the vessel to begin with?
(b) Why does laser look red when its wavelength in water is 475 nm?

The smoke is added to create scattering centers so that a part of laser light comes to our eyes. We see the laser when its comes out of water and hence we see laser of red light.

14. Magnet Sliding on Inclined Plane: Youtube.

(a) How much time the magnet has taken to slip down the plane 1? Of plane 2?

(b) What are the materials used in inclined plane 1 and plane 2?
(c) Explain why magnet moves differently on two planes?

By visual observation, we can say magnet takes something around 0.1 s to 0.5 s on plane 1. On plane 2, it moves much slowly and takes approximately 2 s to 5 s. Since both planes are covered with similar white paper (material), we can assume frictional force to be equal in both cases. Possible material behind the paper can be non conducting material like wood, plastic, etc in plane 1 and and a *non magnetic* conducting plate like Al, Cu, Steel etc in plane 2. The material in plane 2 is non-magnetic since magnet is not sticking to it. Why magnet slows down when moving on an aluminium sheet? Paramagnetic nature of aluminium is not the answer because these forces are too small. What is happening here is very interesting! The strong magnet (Neodymium magnet here) produces is magnetic field and magnetic flux passes through aluminium sheet. As magnet start moving (due to gravity), the magnetic flux in a region close to magnet changes. This changing magnetic flux produces an *emf* (Faraday's Law). This induced *emf* sets current loops in the aluminium sheet (Eddy Current). The direction of current in these loops is such that they opposes movement of the magnet (Lenz's law). That is why magnet slows down! Readers are encouraged to draw the eddy current loops as magnet moves. What is the effect of aluminium sheet thickness? What will be effect of using copper instead of aluminium?

15. Two Bottles: Youtube.

(a) Pressure of air in bottle 1 is (i) less than P_0 (ii) more than P_0 (iii) equal to P_0?
(b) Pressure of air in bottle 2 is (i) less than P_0 (ii) more than P_0 (iii) equal to P_0?
(c) If the cap of the bottle 1 is opened, what kind of water flow do you expect?
    (i) No water will flow
    (ii) Some water will flow from bottle 1 to bottle 2

(iii) Water will be equally divided in both bottles

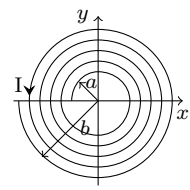
(a) Bottle 1 is open. So pressure in it is P_0. At the tube level pressure in bottle is also the same. As you go up in bottle 1 pressure decreases by $h\rho g$. So pressure of air in bottle 1 is less than P_0.
(b) P_0 as it is open to atmosphere.
(c) Water will be equally divided in the two bottles.

16. Electrolysis of Salt Solution: Youtube

(a) Why salt (table salt) was added in water?
(b) Why gases produced at one of the electrode is more?

(a) Pure water is poor conductor of electricity. Table salt (NaCl) ionizes into Na^+ and Cl^- increasing conductivity of water.
(b) At anode, hydrogen ions get electron releasing H_2 gas. At cathode, there is a possibility of getting O_2 or Cl_2 depending on concentration of NaCl. The rate of gas production at cathode suggest that it is O_2 because 2 molecules of H_2O gives 2 molecules of H_2 and 1 molecule of O_2.

17. Magnetic Line of Forces: Draw the magnetic line of forces of the spiral coil? Youtube

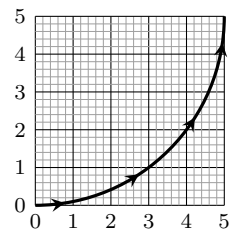


Let I be current, N be number of turns, and spiral has inner radius a and outer radius b. To find magnetic field at the centre of spiral, consider a small circular element of thickness $\mathrm{d}r$ at a distance r from the centre of spiral. The number of turns in this element is $\frac{N}{b-a}\mathrm{d}r$ and thus current $i = \frac{N}{b-a}\mathrm{d}rI$ flows through it. The magnetic field due to this element at the centre is $\mathrm{d}B = \frac{\mu_0 i}{2r} = \frac{\mu_0 NI}{2(b-a)}\frac{\mathrm{d}r}{r}$. Integrating from $r = a$ to $r = b$ gives $B = \frac{\mu_0 NI}{2(b-a)}\ln\left(\frac{b}{a}\right)$.

18. Jumping of the Aluminum Ring: Explain why the aluminium ring jumps when switch is pressed?Youtube.

The coil is connected to an AC source. The coil produce a magnetic field that passes through the Aluminium ring. The magnitude of magnetic field (and hence magnetic flux through ring) varies with time. By Faraday's law, an *emf* is produced in ring which sets eddy current to flow along the ring. Thus, ring becomes a current carrying conductor in magnetic field. The magnetic force on this current carrying conductor produces a force in upward direction and ring jumps up. The readers are encouraged to draw magnetic line of forces of the coil and find which component of magnetic field (horizontal or vertical) is responsible for jumping of the ring.

19. Moving Ant:



An ant starts from (0,0) and arrives at (5,5) as shown in figure. The marked distances are in centimetre. Total time taken by the ant is 3 second. Find (a) average speed and (b) average velocity, of the ant.

The distance travelled is $\frac{1}{2}\pi r = 0.5 \times 3.14 \times 5 = 7.85$ cm. The magnitude of displacement is $5\sqrt{2} = 5 \times 1.41 = 7.05$ cm. The average speed is $7.85/3 = 2.62$ cm/s. Magnitude of average velocity is $7.05/3 = 2.35$ cm/s. The direction of average velocity a unit vector from (0,0) to (5,5).

School Level

Expt 1: Salt Solution

Objective: Make concentrated salt solution with 10 gram of salt, and calculate the concentration in g/ml of the solution at the existing temperature of the solution.

Apparatus: Packet of 10g salt, 500ml of water, Beaker of glass, Stirrer, Measuring Cylinder, Thermometer, Syringe

Instructions: The amount of salt is fixed and you have to put minimum needed water to dissolved it. In case you fail at certain stage you may ask for another packet of 10g salt only once. Make as accurate measurements as you can. Write the approximations, you have taken, errors that could have gone, your efforts to reduce the error. Write the final value obtained for concentration in gram/milliliter of solution. Estimate the uncertainty /error in the measurement. Write the temperature of the solution. Presentation is yours. You have to plan for tables, headings, etc.

Expt 2: Calibrating Spring

Objective: To calibrate a spring and get the mass of a given object.

Apparatus: A spring, A hanger of 100g and 4 separate weights of 100g each, Meter Scale fixed with a nail for hanging the spring , clamp, Object of unknown mass, Graph paper, 6" plastic scale

Instructions: You have to clamp the given meter scale vertically with the nail /rod on the upper side. It is a nonlinear spring and hence you cannot have a unique spring constant. To measure the mass of the given object you must first calibrate the spring with the given standard masses, that is to know the extension of the spring for each of these masses. You should draw a calibration graph with the standard masses and then obtain the mass of the given object from the extension corresponding to it. Actual extension is not needed for this calibration. Do your experiments as accurately on you can and mentions the possible errors and your efforts to reduce it.

Expt 3: Centre of Mass

Objective: To find the Center of Mass (C.M.) of the given rectangular plate.

Apparatus: Clamp with nail fixed, Plumb Line, 30 cm Plastic Scale, Rectangular Plate

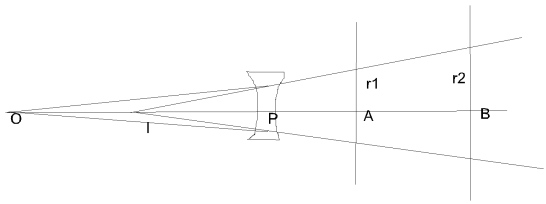
Instructions: You are given a rectangular cardboard plate and are supposed to find out its Center of Mass. You can think of your method with the given apparatus, but one way is to hang the board from the fixed nail and with the help of the plumb line you can locate vertical lines through the holes. If you decide for that, mark two or three points on the surface, along the plumb line for each hole. Dont draw lines till you finish with all the holes.Only at the end, put the plate on the table and draw all the lines using scale and pencil. Write your name and roll number on the sheet before submitting to the evaluators.

Expt 4: Focal Length

Objective: To measure the focal length of a concave lens.

Apparatus: Arrangement to fix the lens, Arrangement to fix the laser, 30 cm plastic scale, 5 ft tape.

Instructions: You are given a Laser and you can assure that it sends a parallel beam of light.



If this light goes through the concave lens it will diverge, if you place the screen at two different distances from the lens and measure a linear dimension such as height or diameter or something else, you can get similar triangle properties.

$$\frac{r_2}{r_1} = \frac{IB}{IA} = \frac{\text{IP} + \text{PB}}{\text{IP} + \text{PA}}$$

r_2, r_1, PA and PB should be measured in the experiment. From this youcan calculate IP which is the focal length. Do it as accurately as you can.

College Level

Expt 1: Torsional Oscillations

*Objective:*To study the torsional oscillation of a rectangular body suspended by two non parallel threads.

Apparatus: Clamp, Suspension plate with nails fixed, Oscillating plate with hooks and threads fixed, Meter Scale, Stop Watch, Graph Paper

Instructions: Suspend the oscillating plate using the threads and the inner pair of nails on the suspension plate. The upper edges of the plate should be horizontal.

Rotate the plate about the vertical bisector through a small angle and release. The plate should start oscillating.

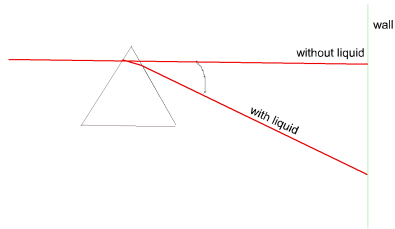
Let the height of the nails over the upper edge of the plate be H and time period of oscillation be T. You are suppose to find the relation between T and H. So measure T and H at appropriate length and draw a graph between T and H. From this, guess whether $T \propto H^2$, $T \propto H$ or $T \propto \sqrt{H}$.

Expt 2: Refrective Index

*Objective:*To find the refractive index of water and saturated salt solution.

Apparatus: The hollow prism, A glass tumbler, Chalk piece, Laser torch, Clamp in which laser can be fixed horizontally, Measuring steel tape, Salt, spoon and beaker, sin and tan table

Instructions: Glass tumbler is to be used as a stand for placing the prism and the wall as the screen. Clamp the laser at an appropriate height so that the beam can go through the prism placed on inverted glass tumbler. Make arrangement so that the laser, without the prism, falls perpendicularly on the wall. Prism may be placed about 1.5 m away from the wall.



With the laser switch pressed, and putting the hollow prism on the tumbler, mark the spot on the wall. Put water in the prism so that the laser beam goes through water. The spot will shift. Rotate the tumbler about its axis to get the position of minimum deviation. Measure different distances and calculate the angle of minimum deviation. From this calculate the refractive index of water.

Make saturated salt solution and find its refractive index.

Write all the approximations that you have made and the estimate the errors that could result from the approximations.

Expt 3: Magnetic Field Lines

*Objective:*To draw magnetic field lines for a given magnet.

Apparatus: A drawing board , A compass, Two A4 size paper sheets or an A3 paper sheet, Pencil, Eraser, Sharpner

Instructions: You have to draw magnetic field lines for the given magnet. Place the paper sheet on the board and fix the corners using the tape. Draw 8 field lines starting from one end of the magnet, 4 on each side of it.

Expt 4: R-L Circuit

*Objective:*To atudy the effect of core on the R-L circuit voltages.

Apparatus: A solenoid, Bicycle spokes, a known resistor, A 12 volt transformer with center tapping, Connecting wires with clips, Graph paper, 5-A power socket with a switch

Instructions: In L-R AC circuit, the current is given by $i = \frac{V}{\sqrt{R^2+\omega^2 L^2}}$. This assumes an AC source giving voltage of fixed rms voltage V. However transformer has more complex working and the voltage supplied depends on resistance and inductance in the circuit.

Make a series L-R AC circuit joining solenoid and the known resistance with the transformer. Using multimeter you can measure the solenoid resistor and also the AC RMS voltage on different parts of this series circuit. The value of ω can be calculated from line frequency 50 Hz. You can also measure the current i using the multimeter. Your multimeter may not have AC current measuring option. But you can measure the AC voltage across the given resistance and divide by the resistance get the current in the circuit.

Connect the circuit and put the power on. Measure voltages across the solenoid, resistor and the transformer secondary. Do it without any core and then after putting some cycle spokes in the solenoid. Do it with different number of spokes and give your data on how the three voltages and the current in the circuit varies with number of spokes put in.

Make a graph to show the variation of transformer output voltage as a function of number of spokes.

With no spoke in the solenoid, calculate the inductance of the solenoid using the current equation given above. (This may not be the true inductance as you are using an ideal AC source equation.) The multimeter often has display up to one decimal place. If it reads 2.2, the actual value may be anywhere between 2.15 to 2.25. Calculate the range of uncertainty in L value calculated.

IMPORTANT: Make sure you do not touch 220 V power points. Keep the switch off when not making the measurements.