National Anveshika Experimental Skill Test (NAEST)-2015: Questions with Solutions

ViBha-IAPT Anveshika, Hyderabad

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Note on Videos: The NAEST-2015 videos are uploaded on YouTube. Search for "National Anveshika Experimental Skill Test" on YouTube and you will get it. You can also see these videos at `www.concepts-of-physics.com/anveshika-national-test-naest-2015`.

Disclaimer: We tried to give correct solutions but there may be better ways to explain the same thing. If you find any error then please send feedback at `www.concepts-of-physics.com/contact-us`.

Video 1: The students were asked to identify the four frequencies shown in the video.

Answer: The frequencies given in the video are,

(a) Sound 1 = 600 Hz

(b) Sound 2 = 300 Hz

(c) Sound 3 = 1500 Hz

(d) Sound 4 = 1000 Hz.

Video 2:
Question 1: In the beginning, water mass was rotating. Give a possible reason for it.

Answer: All logically correct answers are acceptable.

Question 2: In the central region of the bottom of the vessel there are no points of steam formation. Guess a reason for it.

Answer: Because in gas burners, the flame comes from the holes and spreads. In middle portion flame does not touch the vessel and is less heated.

Video 3:
Question 1: When water was poured on the hot plate it was distributed in separate drops. Why the drops dance on the hot plate so fast as if there is no friction between them?

Answer: The part in contact with the hot plate evaporates. The drop sits on the vapour and hence experiences much smaller friction.

Video 4:
Question 1: Why is it easier to take off the kurta in latter part of the video than in the former part?

Answer: In the first part, the Kurta rubs the inner cloth and there is good amount of friction. In the second part, no part of Kurta rubs the inner part and it comes like rolling.

Video 5:
Question 1: What is the time period of the pendulum shown in the video?

Answer: 1.37 s. The answer may vary slightly.

Video 6:
Question 1: Mark the correct options (More than one options may be correct)?

(a) $F_1 = W$, $F_2 > W$

(b) $F_1 = W$, $F_2 = W$

(c) $F_1 = W$, $F_2 < W$

(d) $F_1 \neq W$, $F_2 \neq W$

Answer: Option (b) is correct. The weight of the hanging mass is balanced by the upward force by hand.

Question 2: All torques are about the axis of the pipe in hand. Torque of F_1 is τ_1 and torque of F_2 is τ_2. Torque of W in case 1 is τ_3 and torque of W in case 2 is τ_4.

1. $\tau_1 = \tau_3$, $\tau_2 = \tau_4$
2. $\tau_2 > \tau_1$
3. $\tau_2 = \tau_1$
4. $\tau_2 < \tau_1$

Answer: Options (a) and (b) are correct. Net torque on the pipe is zero in both cases. Thus, torque of F_1 and W must be equal in magnitude but opposite in directions. Hence, $\tau_1 = \tau_3$. Similarly, $\tau_2 = \tau_4$. Now compare τ_3 and τ_4 i.e., torque of W in case 1 and in case 2. $\tau_4 > \tau_3$ because arm length is more in case 2 as compared to arm length in case 1. Using result of previous part, $\tau_2 > \tau_1$.

Video 7:
Question 1: (More than one options may be correct). The stream from the lower pipe covers the least distance. This is because,

(a) Pressure of water in the bottle at the lower pipe is least.

(b) Pipe diameter of the lower pipe is smaller than the others.

(c) Height of the lower pipe over the floor is smaller than for other pipes.

(d) Pressure of water in the bottle at the lower pipe is largest.

Answer: Option (c) is correct. Case (d) is true because pressure at a point increase with increase in height of water column above it. But this is not the answer. Higher pressure at the lower pipe leads to the high velocity of water stream. The horizontal distance covered by the water stream is product of its horizontal velocity and time taken to cover a vertical distance between ground and location of the pipe. The time is less for the lower pipe which makes it travel lesser distance. Hence, (c) is the correct explanation. You are encouraged to analyse the problem analytically.

Video 8:
Question 1: (More than one options may be correct) The upper flat face of the magnet is north pole. Consider the magnetic field due to this magnet at the tip of the loop. Its direction is close to,

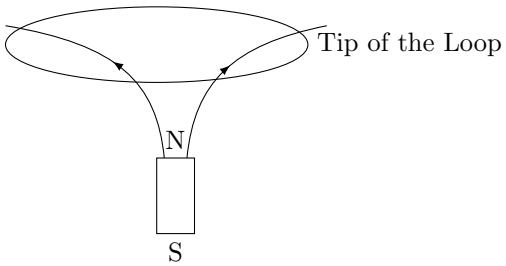
(a) Vertically upwards

(b) Vertically downwards

(c) Horizontal, towards or away from the battery

(d) Horizontal, towards or away from the experimenter.

Answer: (c) option is correct.



Question 2: The direction of current at the tip of the loop is,

(a) Horizontal, towards the battery.

(b) Horizontal, away from the battery.

(c) Horizontal, towards the experimenter.

(d) Horizontal, away from the experimenter.

Answer: (d) option is correct. When current is passed through the loop, it will act like a magnet. The direction of field produced by the loop depends on the direction of current in the loop. We observed that the loop is repelled when current is passed through the loop. This can happen only when current in the loop is clockwise when looking from the top. Thus, current at the tip of the loop is towards the experimenter. (In simple language, the north pole of the loop is below the loop and south pole is above the loop).

Video 9:
Question 1: The balance shown in video measure mass in grams. Calculate the tension in the string when the hanging mass is stationary and rotating mass (eraser) rotates at constant speed?
Answer: The tension in the string is $0.284\,\text{N} \approx 0.29\,\text{N}$ (upwards). The mass of the bob (as shown in video) is 29 g. When hanging mass (bob) is stationary, its weight is balanced by the tension in the string. Hence, tension $T = mg = 0.029 \times 9.8 \approx 0.29$ N.

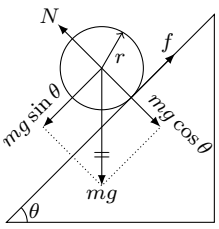
Question 2: The hanging mass starts rising up when the eraser is rotated faster. Explain?
Answer: Centripetal or Centrifugal force. Let us analyse the motion of eraser (rotating mass). It rotates in almost a horizontal circle. The tension in the string provides centripetal force ($m\omega^2 r$) for the rotational motion, where m is mass of the eraser, ω is angular speed, and r is distance from the axis of rotation. The centripetal force (string tension) increases when ω is increased. Thus, tension is greater than the weight of hanging mass and hence it starts rising upward.

Question 3: When hanging mass is pulled down by hand, the eraser starts rotating faster. Why?
Answer: Conservation of angular momentum. Consider motion of the rotating mass (eraser). Its angular momentum about the axis of rotation is $m\omega r^2$. The angular momentum should not change when string is pulled down (the torque due to change in tension is zero because tension force passes through the axis of rotation.). Thus, when r is reduced from r_1 to r_2, the angular velocity increases from ω_1 to ω_2, because $m\omega_1 r_1^2 = m\omega_2 r_2^2$ (by conservation of angular momentum).

Video 10: The cylinders and inclined plane are made up of non-magnetic material. The surface properties of the two cylinders are also same.
Question 1: The time taken by the two cylinders to reach the ground changes with change in inclination angle. The time taken is more for larger inclination angle or smaller inclination angle? Why?
Answer: Due to change in acceleration along the inclined plane.

Question 2: The Yellow Color Cylinder takes lesser time in comparison to Blue Color Cylinder. Explain in detail?
Answer: Due to different moment of Inertia about the axis of rotation. The answers based on different values of friction coefficient or magnetic properties are in-correct.

This question was asked in IIT JEE 2012. The yellow cylinder P has most of its mass concentrated near its surface (it was intentionally designed so), its moment of inertia (about the cylinder axis) is more than the moment of inertia of the blue cylinder Q i.e., $I_P > I_Q$. The forces acting on the cylinder are weight mg, normal reaction N, and frictional force f (see figure). In case of rolling without slipping, $v = \omega r$ and $a = \alpha r$. The torque about centre of mass is related to α by,



$$\tau = rf = I\alpha, \tag{1}$$

and the force along the plane is related to a by,

$$mg\sin\theta - f = ma. \tag{2}$$

Solve equations (1) and (2) to get,

$$a = \frac{g \sin\theta}{1 + I/(mr^2)}. \tag{3}$$

The equation (3) gives $a_P < a_Q$ (since $I_P > I_Q$). Hence, P reaches the ground latter, it will have lesser velocity, lesser angular velocity ($\omega = v/r$) and lesser translational kinetic energy. The readers are encouraged to show same results by using conservation of energy. *Hint:* $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ gives $\frac{1}{2}mv_P^2 < \frac{1}{2}mv_Q^2$ and thus $v_P < v_Q$, $\omega_P < \omega_Q$, $a_P < a_Q$ and $t_P > t_Q$.

Video 11:
Question 1: In first case (when the book and the paper are dropped separately from the same height) the book reaches the ground earlier than the paper. In second case (when paper is placed over the book) they reach the ground together. Why?
Answer: Due to air drag. The forces acting on the paper are its weight $m_{\rm p}g$ and air drag $D_{\rm p}$. Similarly, the forces acting on the book are its weight $m_{\rm b}g$ and air drag $D_{\rm b}$. The downward accelerations of the paper and the book are $a_{\rm p} = (g - D_{\rm p}/m_{\rm p})$ and $a_{\rm b} = (g - D_{\rm b}/m_{\rm b})$. Generally, $D_p \approx D_b$. Since $m_p \ll m_b$, we get $a_p \ll a_b$. Hence, paper reach late in first case. In second case, $D_p \approx 0$. Thus, $a_p = a_b$, and both reaches together. Readers are encouraged to find why $a_p \not> a_b$.

Video 12:
Question 1: The flexible corrugated pipe is hollow and open at both ends. When the pipe is rotated, the bits of paper are being sucked by the pipe at one end and thrown out from the other end. Why?
Answer: Difference in air pressure at two ends of the pipe. The air near the rotating end moves along with the pipe. Thus, pressure drops at this end of the pipe (by Bernoulli principle, pressure decreases when air speed is increased). Due to pressure difference at two ends, air enters from the stationary end and exits from the rotating end. To verify that air really passes through the rotating tube, hold tiny paper bits near the end in your hand. These papers bits are sucked up and comes out through the rotating end.

Question 2: When the corrugated pipe is rotated faster, it produces a roaring sound. Explain the physics behind this sound?
Answer: The corrugations in the pipe cause the passing air to vibrate. These vibrations strike your eardrums and you hear the sound. Whirl the tube faster, the sound is of higher frequency. Slow whirling lowers the frequency.

Video 13:
Question 1: The oscillations of the pendulum stops very fast when Aluminium sheet is placed below the oscillating magnet. Why?
Answer: Faraday's Law/ Eddy Currents. The aluminium sheet (conductor) is placed in a varying magnetic field of the magnet (bob). Thus, by Faraday's law, *emf* is induced in the aluminium sheet which leads to *Eddy currents* in the sheet. By Lenz's law, the direction of eddy current is such that it opposes the change in magnetic field (caused by oscillations of the magnet). Thus, oscillations stops very fast. This experiment is one nice way to demonstrate eddy currents.

Video 14:
Question 1: What is the least count of the plastic scale given to you?
Answer: 1 mm.
Question 2: Measure the length and breadth of this paper? Calculate the area of the sheet and the percentage error in the area?
Answer: Length $l = 297$ mm, Breadth $b = 210$ mm, Area $= A = lb = 297 \times 210 = 62370$ mm^2 (the paper given to students is standard A4 paper). The error in measurement of length and breadth is equal to the least count of the scale i.e., $\Delta l = \Delta b = 1$ mm. Differentiate $A = lb$ to get error in area,

$$\Delta A = l\Delta b + b\Delta l$$

Divide by $A = lb$ to get percentage error in area,

$$\frac{\Delta A}{A} = \frac{\Delta b}{b} + \frac{\Delta l}{l} = \left(\frac{1}{297} + \frac{1}{210}\right) 100 = 0.81\%.$$

Video 15:
Question 1: Why the water is not coming out of the hole when the cap is closed? What will happen if we increase the hole size?
Answer: The gravitational force is balanced by the pressure force and surface tension force. When cap is closed, the pressure of the air above the water column become less than atmospheric pressure because the height of water column is slightly reduced (when water occupies the space of the hole, apply Boyles Law). The surface tension force on the water just above the hole acts upward and this force plays a key role. If you increase the hole size, the water will start coming out of the hole.
Question 2: Why the water starts coming out when the cap is removed?
Answer: When cap is removed, the pressure above the water column is increased (becomes equal to the atmospheric pressure). The downward force is more than the upward force and water starts coming out of the hole.

Video 16:
Question 1: It is not possible to drink water with punctured straw. Why?
Answer: There is air in the straw between the top of water and the top of straw. When sucked, a partial vacuum is created in the space above the water in the straw. The difference between the pressure on the surface of water in the glass and the reduced pressure inside the straw causes the water to rise in the straw. In the straw with a hole, partial vacuum cannot be created by sucking as the inside of the straw is always connected with the outside atmosphere. Hence there is no pressure difference to force the water up.

Video 17: The bulb shown in the video is a normal household bulb of 100 Watt power rating.
Question 1: Calculate the resistance of the bulb filament?
Answer: The power rating is generally given at hose hold power supply of 220 V. Thus, resistance of the $P = 100$ W bulb is $R = V^2/P = (220 \times 220)/100 = 484\ \Omega$ (any value between $484\ \Omega$ to $676\ \Omega$ is acceptable provided supply voltage (220 V to 260 V) is mentioned in the answer).

Question 2: How much is the difference between calculated value and measurement shown by the multi-meter? Why these two values are different?
Answer: The measured value of the resistance is $41.6\ \Omega$. Difference between the calculated value and the measured value is $484 - 41.6 = 442.4\ \Omega$. (answer should be compatible with part 1). The difference is due to temperature dependence of the resistance ($R_T = R_0(1+\alpha\Delta T)$). When we measure the resistance of the bulb with the multimeter, the filament is at the room temperature (about 30 °C). But using the formula, the obtained resistance is the resistance of the bulb in full glow i.e., when it is connected to a 220 V and has attained a temperature at which it starts giving light. This temperature is around 3000 °C. So the calculated resistance is much higher than the measured resistance.

Video 18:
Question 1: Which bottle was emptied first? Give explanation?
Answer: The bottle with longer straw get emptied first. If a hole is made in a water bottle with its cap open, water goes out through the hole. The speed at which water goes out depend on the height of the open water surface above the hole. You must carefully think of the height between the point of release of water and the free surface. It is more in case of bottle with longer straw as compared to the bottle with shorter straw. Thus, speed at which water goes out is more in case of bottle with longer straw and hence this bottle get emptied first.

Evaluation Scheme:

Dear teacher/evaluator, we believes that you would serve as an excellent evaluater of NAEST-2015 Screening Test. The objective is to select best students for next round of NAEST. While evaluating, if you find a student performing exceptionally well then mention the same in the final mark sheet. Please adhere to the marking scheme scheme given below and be objective (unbiased). While evaluating, pay attention to students understanding of physics concepts and not on his/her writing style, language etc.

Vid	QN	**Key Evaluation Points**	Marks
1	Q1	Sound 1 = 600 Hz, Sound 2 = 300 Hz, Sound 3 = 1500 Hz , Sound 4 = 1000 Hz	10
		Sound 1 and 2 = 300/600 , Sound 3 and 4 = 1500/1000	5
2	Q1	Logical answer	10
	Q2	Burner properties	10
		Other logically correct observations/explanations	5
3	Q1	Evaporation. Water sits on vapour. Less friction.	10
4	Q1	Frictional force.	10
5	Q1	1.375 s (8 Oscillations in 11 sec)	10
		1.125 s to 1.625 s (8 Oscillations in 9-13 sec)	5
6	Q1	(b) with explanation	10
	Q2	(a) and (b) with explanation	10
		Only (a) with explanation	5
7	Q1	(c) with explanation	10
8	Q1	(c) with explanation	10
	Q2	(d) with explanation	10
9	Q1	0.28 N to 0.29 N	10
	Q2	Angular speed, centripetal/centrifugal force, tension greater than weight	10
	Q3	Angular Momentum Conservation	10
10	Q1	Complete Derivation	10
		Acceleration $g \sin\theta$ with logical reasoning	5
	Q2	Moment of Inertia of Yellow is More than that of Blue	10
11	Q1	Air Drag and $m_{\text{paper}} \ll m_{\text{book}}$ in Case 1 and No Drag on Paper in Case 2	10
		Air Drag Only	5
12	Q1	Pressure difference along with its cause (low pressure at rotating end due to Bernoulli's Principle)	10
		Pressure Difference	5
	Q2	Corrugations in Pipe Cause Air to Vibrate	10
13	Q1	Faraday's Law (Eddy Current) and Lenz's Law	10
		Eddy Current	5
14	Q1	1 mm	10
	Q2	$l = 297 \pm 2$ mm, $b = 210 \pm 2$ mm, $A = 62370 \pm 2000$ mm^2, 0.81%	20
		$l = 297 \pm 2$ mm, $b = 210 \pm 2$ mm, $A = 62370 \pm 2000$ mm^2, -	10
		$l = 297 \pm 2$ mm, $b = 210 \pm 2$ mm, -, -	5
		$l = 297 \pm 5$ mm, $b = 210 \pm 5$ mm, $A = 62370 \pm 5000$ mm^2, -	5
15	Q1	Surface Tension, Low pressure at top (Boyles Law), Water will if hole size increased	10
		Pressure Difference	5
	Q2	Pressure increase at top (Boyles Law), Pressure Difference, Water Column Pressure	10
		Pressure Difference	5
16	Q1	Able to drink because of pressure difference (partial vacuum), Unable to have partial vacuum if hole in straw.	10
		Pressure Difference	5
17	Q1	484 Ω to 676 Ω with calculations	10
		Value without calculations	zero
	Q2	Difference 442.4 Ω to 634.4 Ω, Temperature Dependence of Resistance	10
		Difference 442.4 Ω to 634.4 Ω without reason	5
18	Q1	Bottle with longer straw gets emptied first. More speed because height of water column is more.	10

Total maximum marks is 290 (27 questions of 10 marks each and 1 question of 20 marks).