# INDIAN ASSOCIATION OF PHYSICS TEACHERS

## National Graduate Physics Examination 2017

**Day and Date of Examination : Sunday, 22nd January 2017**

**Time : 10 AM to 1 PM**

***Instructions to Candidates***

1. In addition to this question paper, you are given **answer sheet for part A** and **answer paper for part B**.
2. On the answer sheet for part A, fill up all the entries carefully in the space provided, **Only in block capital. Do write the name and PIN of your city.**

   **Incomplete / incorrect / carelessly filled information may disqualify your candidature**
3. On part A answer sheet, use only BLUE or BLACK BALL PEN for making entries and marking answers.
4. In Part A each question has **FOUR** alternatives. Any number of these (4, 3, 2 or 1) may be correct. You have to mark **ALL** correct alternatives and mark a cross (⨯) for each, like

| Q.No. | a | b | c | d |
|---|---|---|---|---|
| 24 | | ⨯ | | ⨯ |

   Full marks are 6 for each question, you get them only when ALL correct answers are marked.
5. Part A answer sheet will be collected at the end of one hour.
6. Any rough work should be done only on the sheets provided with part B answer paper.
7. Use of non-programmable calculator is allowed.
8. No candidate should leave the examination hall before the completion of the examination. You will take away the question paper with you.
9. Symbols used in the paper have their usual meaning unless specified otherwise.

***PLEASE DO NOT MAKE ANY MARK OTHER THAN (⨯) IN THE SPACE PROVIDED ON THE ANSWER SHEET OF PART A***

Answer sheets for part A are likely to be evaluated with the help of a machine. Due to this, **CHANGE OF ENTRY IS NOT ALLOWED**

**Scratching or overwriting may result in wrong score**

**DO NOT WRITE ANYTHING ON BACK SIDE OF ANSWER SHEET FOR PART A**

# INDIAN ASSOCIATION OF PHYSICS TEACHERS

## National Graduate Physics Examination 2017

**Day & Date of Examination : Sunday, January 22, 2017**

**Time : 10 AM to 1 PM**

Part A- Maximum Marks: 150 — Time for Part A : 60 minutes

Part B- Maximum Marks: 150 — Time for Part B : 120 minutes

## Part A

25 x 6 = 150

**Mark the correct option/options (Any number of options may be correct).**
**Marks will be awarded only if all the correct options are marked. No negative marking.**

1. The correct statement(s) is/are
   (a) Gradient of a scalar field $\Phi(\vec{r})$ is a vector.
   (b) Gradient of a scalar field $\Phi(\vec{r})$ is its greatest rate of change with respect to space
   (c) $Grad\left(\frac{1}{r}\right) = -\frac{\vec{r}}{r^3}$
   (d) The electric field $\vec{E}$ in an electromagnetic wave is given by $\vec{E} = -\nabla\Phi$

2. For a rigid body oscillating as a compound / physical pendulum.
   (a) Time period $T = 2\pi\sqrt{\frac{l+\frac{K^2}{l}}{g}}$
   (b) There are four points collinear with CG about which T is the same.
   (c) The center of suspension and center of oscillation are interchangeable
   (d) Time period T has a lower limit.

3. An electromagnetic wave propagates in such a fashion that the
   (a) direction of ray is always the same as the direction of propagation vector $\vec{K}$.
   (b) direction of electric field $\vec{E}$ is always perpendicular to the direction of propagation vector $\vec{K}$.
   (c) direction of electric field $\vec{E}$ is always the same as that of displacement vector $\vec{D}$
   (d) direction of displacement vector $\vec{D}$ is always perpendicular to propagation vector $\vec{K}$.

4. In Newton's ring arrangement, the space between the plate and the plano-convex lens is filled with a homogenous liquid whose refractive index decreases uniformly at constant rate $\left(\frac{d\mu}{dT}\right)$ when the temperature of the liquid is raised. On raising the temperature the
   (a) radii of the rings increase
   (b) radii of the rings decrease
   (c) radii of the outer sings change more rapidly as compared to the inner ones.
   (d) rings do not remain circular.

5. A cantilever of weight w is uniformly loaded with weight W (W >> w) along its length. The depression produced within elastic limit, at its free end is $\delta_1$. Another cantilever of same dimension and same material is loaded at its free end with same weight W. The depression produced in this case is $\delta_2$. Then
   (a) $\delta_2 = 4\delta_1$
   (b) $2\delta_2 = 5\delta_1$
   (c) $3\delta_2 = 4\delta_1$
   (d) $3\delta_2 = 8\delta_1$

6. For an isolated thermodynamical system, P, V, T, U, S and F are the pressure, volume, temperature, internal energy, entropy and free energy, respectively, the correct relation (s) among them is/are.
   (a) $\left(\frac{\partial F}{\partial T}\right)_v = -S$
   (b) $\left(\frac{\partial F}{\partial T}\right)_p = -S$
   (c) $\left(\frac{\partial U}{\partial S}\right)_p = -T$
   (d) $\left(\frac{\partial F}{\partial V}\right)_T = -P$

7. The velocity of a point particle on the equator of a rotating planet is v. The effect of the rotation of the planet is to make g, at the equator, a half of that at the poles. Under the conditions, if the escape velocity of the particle at the poles is $v_P$ and that at the equator is $v_E$, then the correct relation(s) is/are
   (a) $v_P = \sqrt{3}v$
   (b) $v_P = 2v$
   (c) $v_E = 2v$
   (d) $v_E = \sqrt{3}v$

8. The crystal structure of diamond is
   (a) simple cubic with two atoms basis at (0,0,0) and $\frac{a}{2}\left(\hat{i}+\hat{j}+\hat{k}\right)$
   (b) b.c.c. with two atoms basis at (0,0,0) and $\frac{a}{2}\left(\hat{i}+\hat{j}+\hat{k}\right)$
   (c) f.c.c. with two atoms basis at (0,0,0) and $\frac{a}{2}\left(\hat{i}+\hat{j}+\hat{k}\right)$
   (d) f.c.c. with two-atoms basis at (0,0,0) and $\frac{a}{4}\left(\hat{i}+\hat{j}+\hat{k}\right)$

9. A conservative force $\vec{F}$ satisfies
   (a) $\frac{d\vec{F}}{dt}=0$
   (b) $\vec{\nabla}.\vec{F}=0$
   (c) $\vec{\nabla}\times\vec{F}=0$
   (d) $\oint\vec{F}.\vec{dr}=0$

10. For the $^2P_{3/2}$ to $^2S_{1/2}$ transition in the presence of a external magnetic field,
   (a) the original spectral line splits into 3 components.
   (b) the original spectral line splits into 6 components.
   (c) the transition corresponds to sodium $D_1$ line.
   (d) the transition corresponds to sodium $D_2$ line.

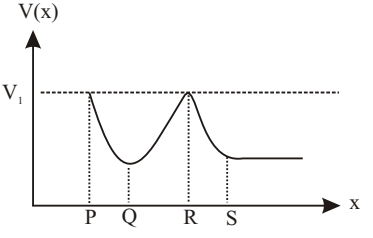
11. A pulsed LASER of 660 nm wavelength has average power of 30 mW, pulse duration of 30 nS and pulse repetition rate of 20 Hz. The number of photons per pulse is
   (a) $3\times10^9$
   (b) $5\times10^{15}$
   (c) $2\times10^{18}$
   (d) $1\times10^{20}$

12. Excess pressure is 2T/R across the surface of a
   (a) spherical drop
   (b) spherical meniscus
   (c) cylindrical bubble in air
   (d) spherical bubble in water

13. The overall efficiency of a transformer is 90%. The transformer is rated for an output of 9 KW. The primary voltage is 1000 volt and the resistance of the primary coil is $R_P = 1k\Omega$. The ratio of turns in the primary to the secondary coil is 5:1. The iron losses at full load are 700 watt.
   (a) The current in the Secondary is $I_s = 4.5A$
   (b) The resistance of the secondary coil is approximately 4.5 Ω
   (c) The copper loss in the primary is 1000 watt.
   (d) The copper loss in the secondary is 700 watt

14. A particle travels a distance of 2 light - year between two stars A and B with velocity v = 0.8c as measured by an observer on the star A. The time of the trip estimated by an observer sitting on the particle itself will be
   (a) 2.5 yr
   (b) 2.0 yr
   (c) 1.5 yr
   (d) 1.0 yr

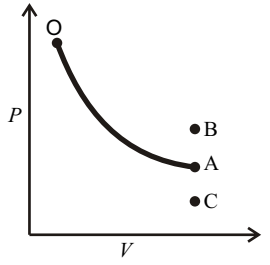
15. Consider the motion of a particle in potential V(x) shown in the figure. If the particle has total energy $E = V_1$




   (a) the speed of the particle is zero at point P.
   (b) the speed of the particle is zero at point Q.
   (c) the particle experiences no force at points Q and R.
   (d) The particle is in stable equilibrium at point Q

16. The short range strong nuclear force is
   (a) charge dependent
   (b) velocity dependent
   (c) spin dependent
   (d) isospin dependent

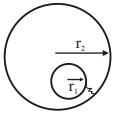
17. The curve OA in the P-V diagram represents a reversible adiabatic expansion of an ideal gas. The same sample of gas starting from same state O now undergoes an adiabatic free expansion to same final volume. Which point on the diagram represents the final state of the gas?




(a) Same point A as for the reversible expansion
(b) Point B
(c) Point C
(d) Any of the points A, B or C.

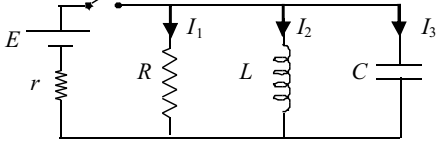
18. The ground state spin and parity of $^{16}N$ (Z=7) nucleus is
(a) $1^+$
(b) $2^-$
(c) $2^+$
(d) $4^+$

19. A metal sphere of radius, $r_1$ charged to an electric potential $\phi_1$ is enveloped by a thin walled conducting spherical shell of radius $r_2$ as shown. The metal sphere is made to touch the shell through a conducting wire. Then the




(a) charge on the shell after contact is $4\pi\varepsilon_0 r_1\phi_1$
(b) charge on outer shell now is $4\pi\varepsilon_0 r_2\phi_1$
(c) potential acquired by spherical shell after contact is $\phi_2 = \phi_1 r_1/r_2$
(d) potential acquired by sherical shell after contact $\phi_2 = \phi_1 r_2/r_1$

20. A resistance R, an ideal inductance L and an ideal capacitance C all are connected in parallel to a source of emf E and internal resistance r as shown in the figure below

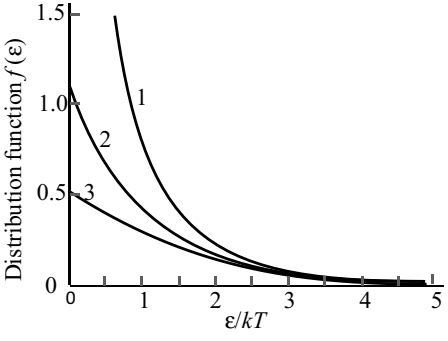



After switching on, currents $I_1$, $I_2$ and $I_3$ flow through R, L and C, respectively. The value of the current

(a) $I_1 = \frac{E}{R+r}$ at all times
(b) $I_2 = \frac{E}{r}$ at t = 0 just at the time of switching on
(c) $I_2 = \frac{E}{r}$ long time after switching on
(d) $I_3 = \frac{E}{r}$ at t = 0 just at the time of switching on

21. According to Sommerfeld atom model the electron orbits are elliptical consistent with the fact that
(a) $\oint \vec{p}_r.\vec{dr} = n_r h$ and $\oint \vec{p}_\theta.\vec{d\theta} = kh$
(b) $\frac{\text{semi minor axis}}{\text{semi major axis}} = \frac{b}{a} = \frac{k}{n_r}$
(c) azimuthal quantum number k is never zero
(d) out of the s, p, d and f electron orbitals, the d orbit with n=3, has two elliptical orbitals.

22. Choose the correct distribution curve (1, 2 or 3) and respective function for Bose Einstein (BE), Fermi Dirac (FD) and Maxwell Boltzmann (MB) statistics.



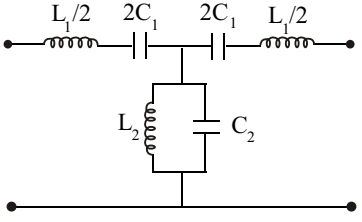

(a) 1. BE 2. MB 3. FD
(b) 1. MB 2. BE 3. FD
(c) 1. $\frac{1}{e^{(\varepsilon-\mu)/KT}-1}$, 2. $\frac{1}{e^{\varepsilon/KT}}$ *and* 3. $\frac{1}{e^{(\varepsilon-\mu)/KT}+1}$
(d) 1. $\frac{1}{e^{\varepsilon/KT}}$, 2. $\frac{1}{e^{(\varepsilon-\mu)/KT}+1}$ *and* 3. $\frac{1}{e^{(\varepsilon-\mu)/KT}-1}$

23. Two metals having Fermi energy $E_{F1}$ & $E_{F2}$ are brought in contact the
    (a) two Fermi levels equalize.
    (b) contact potential developed between metals is $(E_{F1} \sim E_{F2})/e$
    (c) electrons flow from the metal of higher $E_F$ to that of lower $E_F$.
    (d) electrons flow from metal of higher carrier concentration to that of lower carrier concentration.

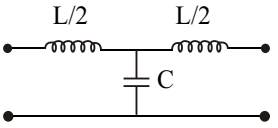
24. A particle is moving in a two-dimensional potential well $V(x, y) = 0$, for $0 \le x \le L, 0 \le y \le 2L$
    $= \infty$ elsewhere
    Identify the ground state energy $E_1$ and ground state eigen function $\Psi_1$ of the particle
    (a) $E_1 = \frac{\pi^2 \hbar^2}{2mL^2}$
    (b) $E_1 = \frac{5\pi^2 \hbar^2}{8mL^2}$
    (c) $\Psi_1 = \frac{\sqrt{2}}{L} \sin \frac{\pi x}{L} \sin \frac{\pi y}{2L}$
    (d) $\Psi_1 = \frac{\sqrt{2}}{L} \cos \frac{\pi x}{L} \cos \frac{\pi y}{2L}$

25. Parts of electronic circuits have been drawn below in certain specific arrangements.

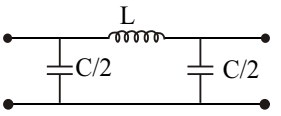
(p)



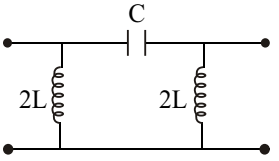

(q)



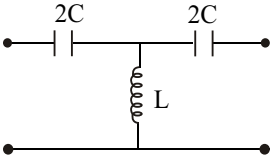

(r)



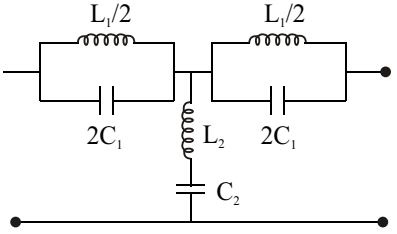

(s)




(u)




(v)




Identify that the
(a) figure (p) represents a band pass filter
(b) figures (q) and (r) are low pass filters
(c) figures (s) and (u) are high pass filters
(d) figure (v) represents a band attenuate filter

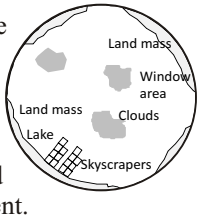
## Part $B_1$ — 10x5 = 50

**Answer all the following in brief (not more than 10 lines)with appropriate reasoning**

$B_1$ The argument of an exponential is always dimensionless. Defend or refute.

$B_2$ Of the two identical strings on a particular key of a piano, only one is tuned correctly to 100 Hz. When the key is pressed, the two strings sound together producing beats with frequency 1 Hz. By what percent must a piano tuner change the tension of the untuned string to make it match perfectly? Assume that the beating is between the fundamental tones.

$B_3$ The figure shows a possible design for a space colony of the future. It consists of a 25 km diameter cylinder of height 60 km floating in space. Its interior is provided with an earthlike environment.




What can be done to simulate gravity in this colony ensuring that a person standing on the land mass will experience the same weight as on the earth? Take $g = 10\ m/s^2$.

$B_4$ A thermo-dynamical identity relates the variables (P,V,T and S) for an ideal gas as $Tds = C_V\, dT + T\left(\frac{\partial p}{\partial T}\right) dV$. Defend or refute.

$B_5$ A point charge +q is placed at a distance d from the center of an earthed conducting (initially neutral) sphere of radius R (R < d). The earthing is now removed first and after that the point charge +q is moved to a for-off location (say infinity). Determine the net charge remained on the sphere. Explain your answer.

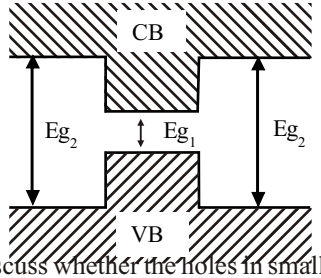
$B_6$ Term symbols $^4S_1$, $^2D_{7/2}$, and $^0P_1$ are erroneous. Explain why?

$B_7$ Consider two particles 1 & 2 and the two states $|A\rangle$ and $|B\rangle$, where either particle can be in either state. Determine the number of independent states possible if the two particles are
(a) identical fermions
(b) identical bosons
(c) classical but distinguishable

$B_8$ A linearly polarized light after passing through a quarter wave plate remains linearly polarized. Defend or refute.

$B_9$ The information is stored on a compact disc in a coded pattern of tiny pits. The pits are arranged in a track that spirals outward towards the rim of the disc. How must the rotation speed of the disc change as the writer's scanning head moves over the track?

$B_{10}$ The conduction-band valence-band profile, when a small bandgap semiconductor is sandwiched between two large bandgap semiconductors, is as shown below.



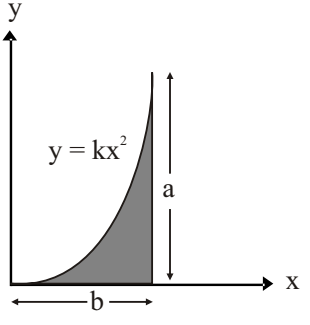

(a) Discuss whether the holes in small bandgap material experience a potential well or a potential barrier. Justify your answer.
(b) Name the physical quantities plotted on the x-axis and y-axis of the given diagram?

## Part $B_2$ 10x10 = 100

**Solve all the 10 problems. Each carries 10 marks.**

$P_1$ (a) Consider a fixed rod AB whose one end A is at the origin and B is at (20, 40, 40) mm. A force $F = -500\,\hat{k}$ N acts at the center of the rod. Determine the component of F parallel and perpendicular to AB.

(b) Determine the moment of inertia, of the shaded plane lamina of mass m bounded by the curves $y = Kx^2$ and x = b in x-y plane above x-axis, about z - axis.




$P_2$ A spherical shell of radius R, centered at the origin of coordinates, has a charge Q spread uniformly on its entire spherical surface. The spherical shell is now rotated, about its diameter along the z- axis, with an angular velocity ω. Determine
(a) The magnetic moment of the spherical shell.
(b) Magnetic field ($\vec{B}$) produced by rotating charges on the shell surface both for $z \geq R$ and for $z \leq R$.

$P_3$ One mole of $H_2$ gas (molecular weight = 2.02) is heated from 0°C to 50°C at constant pressure (P = 1 atm) and is further heated at constant volume from 50°C to 100°C. The specific heats of $H_2$ gas are $C_P$ = 28.74 J/(mole-K) and $C_V$ = 20.42 J/(mole-K). The gas may be treated as an ideal gas with gas constant R = 8.32 J/(mole-K). Determine
(a) the final state (P, V, T) of the gas
(b) the net change in the entropy of the gas.

$P_4$ (a) Estimate the temperature ($T_E$) of Earth assuming that it is in radiative equilibrium with the Sun ($T_S$ = 5800K).
Use $R_S = 7\times10^8\ m$ *and* $r_{S-E} = 1.5\times10^{11}\ m$

(b) Using Gauss's law in gravitational field and Gauss's divergence theorem of vector algebra, show that the gravitational field $\vec{g}$ due to a spherical mass of uniform density ($\rho$) such as Earth located with its center at the origin satisfy $\nabla\cdot\vec{g}=4\pi G\rho$

$P_5$ (a) Consider a 20 μm diameter p-n junction device with donor density = $10^{16}$ $cm^{-3}$. The charge developed on the n-side is $1.6x10^{-13}$C. Estimate the width of the depletion region.

(b) Metallic iron changes from bcc to fcc structure at 910°C. At this temperature, the atomic radii of the iron atom in the two structures are 1.258 Å and 1.292 Å, respectively. Calculate the change in volume available per atom.

$P_6$ A point electric dipole with dipole moment $\vec{p}$ is placed in an external uniform electric field E such that $\vec{P}||\vec{E}$. One of the equipotential surfaces enclosing the dipole is spherical. Obtain its radius R.

$P_7$ A point performs damped harmonic oscillations according to the law $x = Ae^{-bt}\sin\beta t$. Find

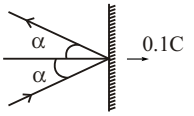
(a) The oscillation amplitude and the velocity of the point at the moment t = 0;

(b) The instances of time at which the point reaches the extreme positions and the practically observed first amplitude.

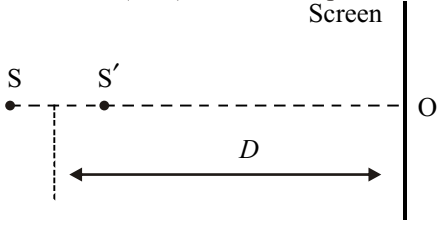
$P_8$ (a) Calculate the uncertainty Δx for a particle in an infinite potential well in the $n^{th}$ state. Also calculate the same classically. Compare and discuss the two results .

(b) The trajectory of a one dimensional harmonic oscillator of mass m, force constant $K = m\omega^2$ and angular frequency ω is a straight line. Determine the nunber of cells of extent h (Planck constant) in the phase space that are enclosed inside the ellipse belonging to the Harmonic oscillator of energy E in position and momentum space. Justify your answer.

$P_9$ (a) A plane mirror whose face is parallel to the y-z plane is moving in positive x direction with a velocity of 0.1c in the laboratory frame. If the angle of incidence equals the angle of reflection each being equal to α in the mirror frame, find the two angles in the laboratory frame.




(b) Two point monochromatic coherent sources of light (wavelength λ), S and S′ are separated by a small distance d set to be $d = m_0\lambda$ where $m_0$ is an integer. Interference fringes are obtained on a plane screen placed transverse to the line SS′ at a large distance D (>>λ ) from the mid point of SS'.




(i) Explore the shape of the fringes on the screen centered around O. Write a general equation. Argue whether the order of fringe at O is the lowest or the highest.

(ii) Obtain the radius of $n^{th}$ bright fringe (counted from O) in terms of D, n, λ and d if fringes happen to be circular.

$P_{10}$ Determine the operating point ($V_{GSQ}$, $I_{DQ}$), $V_{DS}$, $V_S$, $V_G$ and $V_D$ for the following FET circuit.