



# PhysicsByAaryan

## TIFR Physics 2016

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### Atomic and Molecular Physics

**Q1.** [TIFR\_2016\_A\_Q22]

*Year 2016 · Atomic and Molecular Physics · Molecular Physics · Both int. phd and phd · 3 marks*

TIFR GS	2016	Section A
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Two homonuclear diatomic molecules produce different rotational spectra, even though the atoms are known to have identical chemical properties. This leads to the conclusion that the atoms must be

- (a) isomers, i.e. with the same atomic number and weight.
- (b) isotones, i.e. with the same neutron number.
- (c) isobars, i.e. with the same atomic weight.
- (d) isotopes, i.e. with the same atomic number.

**Q2.** [TIFR\_2016\_C\_Q13]

Year 2016 · Atomic and Molecular Physics · Effects in atomic physics · Only PhD · 5 marks

TIFR GS	2016	Section C
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A continuous monochromatic ( $\lambda = 600 \text{ nm}$ ) laser beam is chopped into  $0.1 \text{ ns}$  pulses using some sort of shutter. Find the resultant linewidth  $\Delta\lambda$  of the beam in units of  $10^{-3} \text{ nm}$ .

**Q3.** [TIFR\_2016\_C\_Q2]

Year 2016 · Atomic and Molecular Physics · Bohr model · Only PhD · 5 marks

TIFR GS	2016	Section C
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In a Rutherford scattering experiment, the number  $N$  of particles scattered in a direction  $\theta$ , i.e.  $dN/d\theta$ , as a function of the scattering angle  $\theta$  (in the laboratory frame) varies as

- (a)  $\csc^4 \frac{\theta}{2}$
- (b)  $\csc^2 \frac{\theta}{2} \cot \frac{\theta}{2}$
- (c)  $\csc^2 \frac{\theta}{2} \tan^2 \frac{\theta}{2}$
- (d)  $\sec^4 \frac{\theta}{2}$

**Classical Mechanics**

**Q4. [TIFR\_2016\_A\_Q4]**

Year 2016 · Classical Mechanics · Basic Mechanics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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A ball is dropped vertically from a height  $H$  on to a plane surface and permitted to bounce repeatedly along a vertical line. After every bounce, its kinetic energy becomes a quarter of its kinetic energy before the bounce. The ball will come to rest after time

- (a) Infinity
- (b)  $(2H/g)^{1/2}$
- (c)  $2(2H/g)^{1/2}$
- (d)  $3(2H/g)^{1/2}$

**Q5. [TIFR\_2016\_A\_Q5]**

Year 2016 · Classical Mechanics · Basic Mechanics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In a moving car, the wheels will skid if the brakes are applied too suddenly. This is because

- (a) the impulsive retarding force exceeds the limiting force of static friction.
- (b) the kinetic friction will suddenly get converted to static friction.
- (c) the inertia of the car will carry it forward
- (d) the momentum of the car must be conserved.

**Q6. [TIFR\_2016\_A\_Q6]**

Year 2016 · Classical Mechanics · Basic Mechanics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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An aircraft, which weighs 12000 kg when unloaded, is on a relief mission, carrying 4000 food packets weighing 1 kg each. The plane is gliding horizontally with its engines off at a uniform speed of 540 kmph when the first food packet is dropped. Assume that the horizontal air drag can be neglected and the aircraft keeps moving horizontally. If one food packet is dropped every second, then the distance between the last two packet drops will be

- (a) 100 m
- (b) 150 m
- (c) 200 m
- (d) 1.5 Km

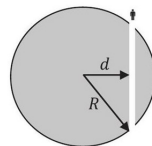
**Q7. [TIFR\_2016\_A\_Q7]**

Year 2016 · Classical Mechanics · Oscillations · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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Imagine that a narrow tunnel is excavated through the Earth as shown in the diagram on the left and that the mass excavated to create the tunnel is extremely small compared to Earth's mass  $M$ .

A person falls into the tunnel at one end. at time  $t = 0$ . Assuming that the tunnel is frictionless, the person will



- (a) fall straight through, escaping Earth's gravity at time  $2\pi\sqrt{R^3/GM}$
- (b) describe simple harmonic motion with period  $2\pi(d/R)\sqrt{R^3/GM}$
- (c) describe simple harmonic motion with period  $2\pi\sqrt{R^3/GM}$
- (d) describe simple harmonic motion with period  $2\pi\sqrt{(R-d)^3/GM}$

**Q8.** [TIFR\_2016\_B\_Q11]

Year 2016 · Classical Mechanics · Central Forces, Gravitation and Universe · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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On a planet having the same mass and diameter as the Earth, it is observed that objects become weightless at the equator. Find the time period of rotation of this planet in minutes (as defined on the Earth).

**Q9.** [TIFR\_2016\_B\_Q2]

Year 2016 · Classical Mechanics · Rotational Motion · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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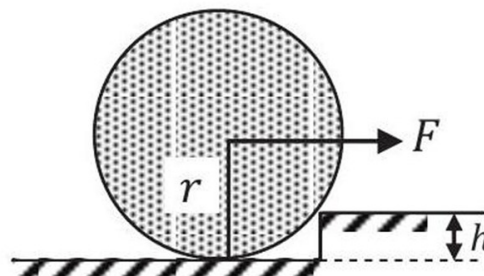
A uniform solid wheel of mass  $M$  and radius  $r$  is halted at a step of height  $h$  as shown in the figure. The minimum force  $F$ , applied horizontally at the centre of the wheel, necessary to raise the wheel over this step is

(a)  $Mg \frac{\sqrt{h(2r-h)}}{r+h}$

(b)  $Mg \frac{\sqrt{h(2r-h)}}{r-h}$

(c)  $Mg \frac{\sqrt{h(r+h)}}{r-h}$

(d)  $Mg \frac{\sqrt{h(2r+h)}}{r-h}$



**Q10.** [TIFR\_2016\_B\_Q3]

Year 2016 · Classical Mechanics · Special Theory of Relativity · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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In a futuristic scenario, two spaceships, A and B, are running a race, where they start from the same point (marked START) but fly in opposite directions at constant speeds close to the speed of light. An observer fixed at the starting point observes that they both cross the points marked END, which are equidistant from the starting point, at the same time. Afterwards this observer receives messages from both spaceships.



Which of the following could be true?

- (a) A and B both claim to have won the race.
- (b) Both A and B agree that A won the race.
- (c) Both A and B agree that they crossed the end point simultaneously.
- (d) A thinks B won the race while B thinks A won the race.

**Q11.** [TIFR\_2016\_B\_Q5]

Year 2016 · Classical Mechanics · Bulk Matter · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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The lattice constant of a material is of the order of a  $\mu\text{m}$ , and its bond energies are of the order of an eV. The bulk modulus of such a material, in Pascals, is of the order of

- (a)  $10^9$
- (b)  $10^{-1}$
- (c)  $10^{-3}$
- (d)  $10^{-6}$

**Q12.** [TIFR\_2016\_C\_Q3]

Year 2016 · Classical Mechanics · Central Forces, Gravitation and Universe · Only PhD · 5 marks

TIFR GS	2016	Section C
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In a simple stellar model, the density  $\rho$  of a spherical star of mass  $M$  varies according to the distance  $r$  from the centre according to

$$\rho(r) = \rho_0 \left( 1 - \frac{r^2}{R^2} \right)$$

where  $R$  is the radius of the star. The gravitational potential energy of this star (in terms of Newton's constant  $G_N$ ) will be

- (a)  $-5G_N M^2 / 7R$
- (b)  $-3G_N M^2 / 5R$
- (c)  $-G_N M^2 / 4\pi R$
- (d)  $-3G_N M^2 / 7R$

## Electromagnetism

**Q13.** [TIFR\_2016\_A\_Q10]

Year 2016 · Electromagnetism · Magnetostatics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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A circular loop of fine wire of radius  $R$  carrying a current  $I$  is placed in a uniform magnetic field  $B$  perpendicular to the plane of the loop. If the breaking tension of the wire is  $T_b$ , the wire will break when the magnetic field exceeds

- (a)  $\mu_0 T_b / 4\pi IR$
- (b)  $T_b / IR$
- (c)  $\mu_0 T_b / 2\pi IR$
- (d)  $T_b / 2\pi IR$

**Q14.** [TIFR\_2016\_A\_Q8]

Year 2016 · Electromagnetism · Image Problems · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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A grounded conducting sphere of radius  $a$  is placed with its centre at the origin. A point dipole of dipole moment  $\vec{p} = p\hat{k}$  is placed at a distance  $d$  along the  $x$ -axis, where  $\hat{i}, \hat{k}$  are the units vector along the  $x$  and  $z$ -axes respectively. This leads to the formation of an image dipole of strength  $\vec{p}'$  at a distance  $d'$  from the centre along the  $x$ -axis. If  $d' = a^2/d$ , then  $\vec{p}' =$

(a)  $-\frac{a^3 p}{d^3} \hat{k}$

(b)  $-\frac{a^2 p}{d^2} \hat{k}$

(c)  $-\frac{a^4 p}{d^4} \hat{k}$

(d)  $-\frac{ap}{d} \hat{k}$

**Q15.** [TIFR\_2016\_A\_Q9]

Year 2016 · Electromagnetism · Electric Field in matter · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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A long, solid dielectric cylinder of radius  $a$  is permanently polarized so that the polarization is everywhere radially outward, with a magnitude proportional to the distance from the axis of the cylinder, i.e.,  $\vec{P} = \frac{1}{2}P_0 r \hat{r}$ . The bound charge density in the cylinder is given by

(a)  $P_0/2$

(b)  $P_0$

(c)  $-P_0/2$

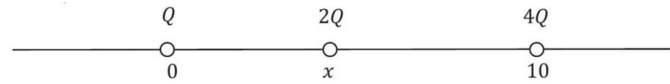
(d)  $-P_0$

**Q16. [TIFR\_2016\_B\_Q7]**

Year 2016 · Electromagnetism · Electrostatics · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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Three positively charged particles lie on a straight line at positions  $0, x$  and  $10$  as indicated in the figure below. Their charges are  $Q, 2Q$ , and  $4Q$  cm respectively.



If the charges at  $x = 0$  and  $x = 10$  are fixed and the charge at  $x$  is movable, the system will be in equilibrium when  $x =$

- (a) 8
- (b) 2
- (c)  $20/3$
- (d)  $10/3$

**Q17. [TIFR\_2016\_B\_Q8]**

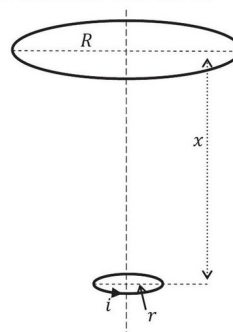
Year 2016 · Electromagnetism · Electrodynamics · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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Consider the following system. Two circular loops of wire are placed horizontally, having a common axis passing vertically through the centre of each coil (see figure). The lower loop has radius  $r$  and carries a current  $i$  as shown in the figure. The upper loop has a radius  $R$  ( $R \gg r$ ) and is at a distance  $x$  ( $x \gg R$ ) above it.

If the lower loop is held fixed and the upper loop moves upwards with a uniform velocity  $v = dx/dt$ , then the induced e.m.f. and the direction of the induced current in this loop will be

- (a)  $2i\mu_0\pi^2r^2R^2v/2x^4$ ; clockwise
- (b)  $3i\mu_0\pi^2r^2R^2v/2x^4$ ; anti-clockwise
- (c)  $3i\mu_0\pi^2r^2R^2v/2x^3$ ; anti-clockwise
- (d)  $2i\mu_0\pi^2r^2R^2v/3x^3$ ; clockwise



**Q18.** [TIFR\_2016\_C\_Q6]

Year 2016 · Electromagnetism · Electric Field in matter · Only PhD · 5 marks

TIFR GS	2016	Section C
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Two semi-infinite slabs A and B of dielectric constant  $\epsilon_A$  and  $\epsilon_B$  meet in a plane interface, as shown in the figure below.

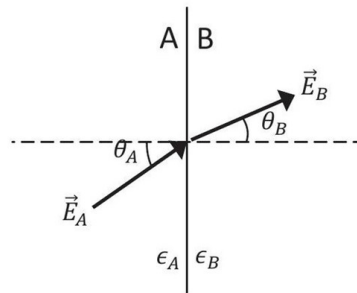
If the electric field in slab A makes an angle  $\theta_A$  with the normal to the boundary and the electric field in slab B makes an angle  $\theta_B$  with the same normal (see figure), then

(a)  $\tan \theta_A = \frac{\epsilon_A}{\epsilon_B} \tan \theta_B$

(b)  $\sin \theta_A = \frac{\epsilon_A}{\epsilon_B} \sin \theta_B$

(c)  $\cos \theta_A = \frac{\epsilon_A}{\epsilon_B} \cos \theta_B$

(d)  $\sin \theta_A = \frac{\epsilon_B}{\epsilon_A} \sin \theta_B$



**Electronics**

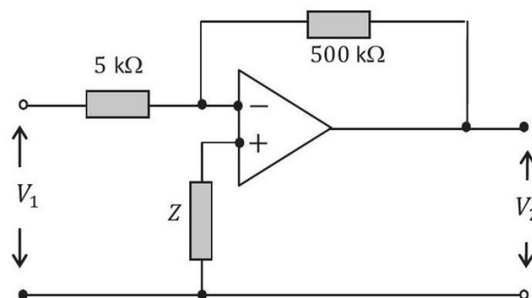
**Q19.** [TIFR\_2016\_A\_Q23]

Year 2016 · Electronics · OPAMP · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In the generalized operational amplifier circuit shown on the right, the op. amp. has a very high input impedance ( $Z > 50M\Omega$ ) and an open gain of 1000 for the frequency range under consideration. Assuming that the op. amp. draws negligible current, the voltage ratio  $V_2/V_1$  is approximately

- (a) -190
- (b) -190
- (c) -90
- (d) 80



**Q20.** [TIFR\_2016\_A\_Q24]

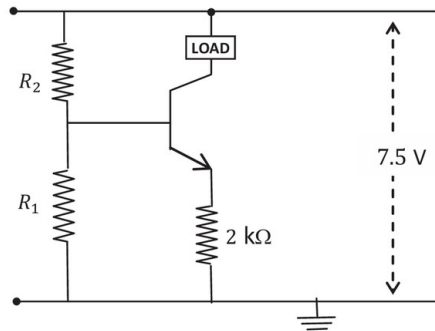
Year 2016 · Electronics · Transistors · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In the transistor circuit shown on the right, assume that the voltage drop between the base and the emitter is 0.5 V .

What will be the ratio of the resistances  $R_2/R_1$ , in order to make this circuit function as a source of constant current,  $I = 1mA$  ?

- (a) 4.5
- (b) 3.0
- (c) 2.5
- (d) 2.0

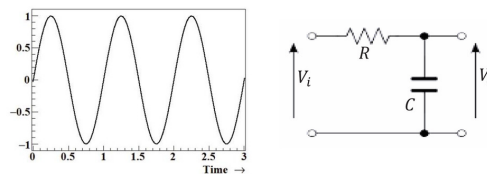


**Q21.** [TIFR\_2016\_A\_Q25]

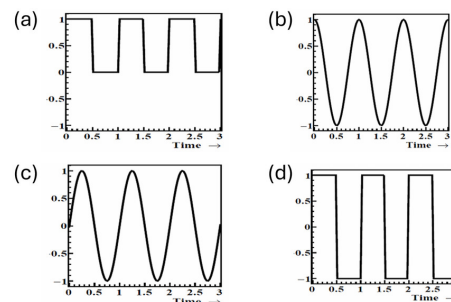
Year 2016 · Electronics · Filters · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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For the circuit depicted on the right, the input voltage  $V_i$  is a simple sinusoid as shown below, where the time period is much smaller compared to the time constant of this circuit.



The voltage  $V_o$  across  $C$  is best represented by



**Q22.** [TIFR\_2016\_B\_Q10]

Year 2016 · Electronics · Logic Gates · Only int. Phd · 5 marks

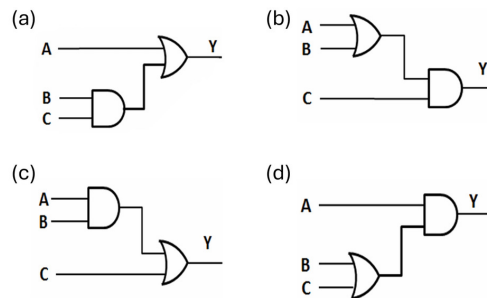
TIFR GS	2016	Section B
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In a digital circuit for three input signals ( A , B and C ) the final output ( Y ) should be such that for inputs

A	B	C
0	0	0
0	0	1
0	1	0

the output (Y) should be low and for all other cases it should be high.

Which of the following digital circuits will give such output?



**Q23.** [TIFR\_2016\_B\_Q15]

Year 2016 · Electronics · Basic Electronics · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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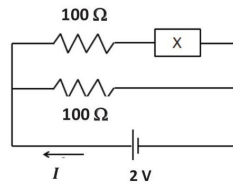
Consider a sawtooth waveform which rises linearly from 0 Volt to 1 Volt in 10 ns and then decays linearly to 0 V over a period of 100 ns . Find the r.m.s. voltage in units of milliVolt?

**Q24. [TIFR\_2016\_C\_Q15]**

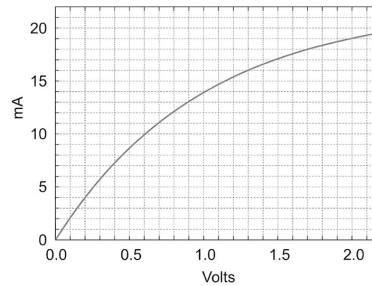
Year 2016 · Electronics · AC and DC Circuits · Only PhD · 5 marks

TIFR GS	2016	Section C
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The circuit shown below contains an unknown device  $X$ .



The current-voltage characteristics of the device  $X$  were determined and are shown in the plot given below.



Determine the current  $I$  (in mA) flowing through the device  $X$ .

**Experimental Physics****Q25. [TIFR\_2016\_A\_Q19]**

Year 2016 · Experimental Physics · Experimental design · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In an ionization experiment conducted in the laboratory, different singly-charged positive ions are produced and accelerated simultaneously using a uniform electric field along the  $x$ -axis. If we need to determine the masses of various ions produced, which of the following methods will NOT work

- Apply a uniform magnetic field along  $y$ -axis and measure the deviation.
- Apply a uniform electric field along  $y$ -axis and measure the deviation.
- Detect them at a fixed distance from the interaction point along  $x$ -axis and measure their time of arrival.
- Apply a uniform electric field along  $y$ -axis and a (variable) uniform magnetic field along  $z$ -axis simultaneously and note the zero deviation.

**Q26.** [TIFR\_2016\_B\_Q9]

Year 2016 · Experimental Physics · Instruments · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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A student in the laboratory is provided with a bunch of standard resistors as well as the following instruments

- Voltmeter accurate to 0.1 V
- Thermometer accurate to 0.1 C
- Ammeter accurate to 0.01 A
- Stop watch accurate to 0.05 s
- Constant current source (ideal)
- Constant voltage source (ideal)

Using this equipment (and nothing else), the student is expected to measure the resistance  $R$  of one of the given resistors. The least accurate result would be obtained by

- (a) measuring the current on application of a constant voltage across it.
- (b) passing a constant current and measuring the voltage across it.
- (c) measuring the Joule heating.
- (d) the Wheatstone bridge method.

## Mathematical Physics

**Q27.** [TIFR\_2016\_A\_Q1]

Year 2016 · Mathematical Physics · Probability · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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If  $x$  is a continuous variable which is uniformly distributed over the real line from  $x = 0$  to  $x \rightarrow \infty$  according to the distribution

$$f(x) = \exp(-4x)$$

then the expectation value of  $\cos 4x$  is

- (a) 1/16
- (b) 1/4
- (c) 1/2
- (d) zero

**Q28.** [TIFR\_2016\_A\_Q2]

Year 2016 · Mathematical Physics · Matrices · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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If the eigenvalues of a symmetric  $3 \times 3$  matrix  $\mathbf{A}$  are 0,1,3 and the corresponding eigenvectors can be written as

$$\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix}, \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}$$

respectively, then the matrix  $\mathbf{A}^4$  is

(a)  $\begin{pmatrix} 14 & -27 & 13 \\ -27 & 54 & -27 \\ 13 & -27 & 14 \end{pmatrix}$

(b)  $\begin{pmatrix} -82 & -81 & 79 \\ -81 & 81 & -81 \\ 79 & -81 & 83 \end{pmatrix}$

(c)  $\begin{pmatrix} 41 & -81 & 40 \\ -81 & 0 & -81 \\ 40 & -81 & 41 \end{pmatrix}$

(d)  $\begin{pmatrix} 14 & -13 & 27 \\ -13 & 54 & -13 \\ 27 & -13 & 14 \end{pmatrix}$

**Q29.** [TIFR\_2016\_B\_Q1]

Year 2016 · Mathematical Physics · Delta, Gamma, Beta and Integrals · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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The integral

$$\int_0^{\infty} \frac{dx}{x} \left[ \exp\left(-\frac{x}{\sqrt{3}}\right) - \exp\left(-\frac{x}{\sqrt{2}}\right) \right]$$

evaluates to

(a) Zero

(b) 2.03

(c)  $2.03 \times 10^{-2}$

(d)  $2.03 \times 10^{-1}$

**Q30.** [TIFR\_2016\_B\_Q12]

Year 2016 · Mathematical Physics · Differential Equations · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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The function  $y(x)$  satisfies the differential equation

$$x \frac{dy}{dx} = y(\ln y - \ln x + 1)$$

with the initial condition  $y(1) = 3$ . What will be the value of  $y(3)$  ?

**Q31.** [TIFR\_2016\_C\_Q1]

Year 2016 · Mathematical Physics · Complex Analysis · Only PhD · 5 marks

TIFR GS	2016	Section C
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The value of the integral

$$\oint_C \frac{\sin z}{z^6} dz$$

where  $C$  is the circle of centre  $z = 0$  and radius = 1

- (a)  $i\pi/60$
- (b)  $i\pi/120$
- (c)  $-i\pi/6$
- (d)  $i\pi$

**Q32.** [TIFR\_2016\_C\_Q11]

Year 2016 · Mathematical Physics · Limits, Continuity and Differentiation · Only PhD · 5 marks

TIFR GS	2016	Section C
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Given the infinite series

$$y(x) = 1 + 3x + 6x^2 + 10x^3 + \dots + \frac{(n+1)(n+2)}{2}x^n + \dots$$

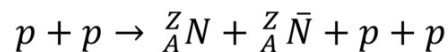
find the value of  $y(x)$  for  $x = 6/7$ .

**Nuclear and Particle Physics****Q33.** [TIFR\_2016\_A\_Q16]

Year 2016 · Nuclear and Particle Physics · Radioactivity · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In a fixed target experiment, a proton of total energy 200 GeV is bombarded on a proton at rest and produces a nucleus  ${}^Z_A N$  and its anti-nucleus  ${}^Z_A \bar{N}$



The heaviest nucleus  ${}^Z_A N$  that can be created has atomic mass number  $A =$

- (a) 15
- (b) 4
- (c) 5
- (d) 9

**Q34.** [TIFR\_2016\_A\_Q21]

Year 2016 · Nuclear and Particle Physics · Radioactivity · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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Consider a process in which atoms of Actinium-226 ( ${}_{89}^{226}\text{Ac}$ ) get converted to atoms of Radium-226 ( ${}_{88}^{226}\text{Ra}$ ) and the yield of energy is 0.64 MeV per atom. This occurs through

- (a) Both  $p \rightarrow n + e^+ + \nu_e$  and  $p + e^- \rightarrow n + \nu_e$   
 (b) Both  $p \rightarrow n + e^+ + \nu_e$  and  $n \rightarrow p + e^- + \bar{\nu}_e$   
 (c) Only  $p + e^- \rightarrow n + \nu_e$   
 (d) Only  $p \rightarrow n + e^+ + \nu_e$

**Q35.** [TIFR\_2016\_C\_Q10]

Year 2016 · Nuclear and Particle Physics · Particle Physics · Only PhD · 5 marks

TIFR GS	2016	Section C
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Consider the hyperon decay (1)  $\Lambda \rightarrow n + \pi^0$  followed by (2)  $\pi^0 \rightarrow \gamma\gamma$ . If the isospin component, baryon number and strangeness quantum numbers are denoted by  $I_z, B$  and  $S$  respectively, then which of the following statements is completely correct?

- (a) In (1)  $I_z$  is not conserved,  $B$  is conserved,  $S$  is conserved;  
 In (2)  $I_z$  is conserved,  $B$  is conserved,  $S$  is conserved.  
 (b) In (1)  $I_z$  is conserved,  $B$  is not conserved,  $S$  is not conserved;  
 In (2)  $I_z$  is conserved,  $B$  is conserved,  $S$  is conserved.  
 (c) In (1)  $I_z$  is not conserved,  $B$  is conserved,  $S$  is not conserved;  
 In (2)  $I_z$  is not conserved,  $B$  is conserved,  $S$  is conserved.  
 (d) In (1)  $I_z$  is not conserved,  $B$  is conserved,  $S$  is not conserved;  
 In (2)  $I_z$  is conserved,  $B$  is conserved,  $S$  is conserved.

**Q36. [TIFR\_2016\_C\_Q7]**

Year 2016 · Nuclear and Particle Physics · Liquid Drop Model · Only PhD · 5 marks

TIFR GS	2016	Section C
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The Weizsäcker semi-empirical mass formula for an odd nucleus with  $Z$  protons and  $A$  nucleons may be written as

$$M(Z, A) = \alpha_1 A + \alpha_2 A^{2/3} + \alpha_3 Z + \alpha_4 Z^2$$

where the  $\alpha_i$  are constants independent of  $Z, A$ . For a given  $A$ , if  $Z_A$  is the number of protons of the most stable isobar, the total energy released when an unstable nuclide undergoes a single  $\beta^-$  decay to  $(Z_A, A)$  is

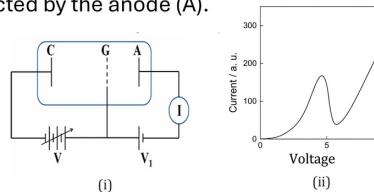
- (a)  $\alpha_1 + \alpha_2$
- (b)  $\alpha_4 - \alpha_3$
- (c)  $\alpha_3$
- (d)  $\alpha_4$

**Q37. [TIFR\_2016\_C\_Q8]**

Year 2016 · Nuclear and Particle Physics · Accelerator and Detectors · Only PhD · 5 marks

TIFR GS	2016	Section C
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In the experiment shown in figure (i) below, the emitted electrons from the cathode (C) are made to pass through the mercury vapor filled in the tube by accelerating them using a grid (G) at potential  $V$ , positive w.r.t. the cathode. The electrons are collected by the anode (A).



The variation of electron current ( $I$ ) as a function of  $V$  is given in figure (ii). The shape of this curve must be interpreted as due to

- (a) ionization of mercury atoms.
- (b) an emission line from mercury atoms.
- (c) attachment of electrons to mercury atoms.
- (d) resonant backscattering of electrons to cathode from grid.

**Optics**

**Q38.** [TIFR\_2016\_A\_Q18]

Year 2016 · Optics · Ray Optics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
---------	------	-----------

In a glass fibre, light propagates by total internal reflection from the inner surface. A very short pulse of light enters a perfectly uniform glass fibre at  $t = 0$  and emerges from the other end of the fibre with negligible losses. If the refractive index of the glass used in the fibre is 1.5 and its length is exactly 1.0 km, the time  $t$  at which the output pulse will have completely exited the fibre will be

- (a)  $750ns$
- (b)  $25ns$
- (c)  $7.5\mu s$
- (d)  $5.0\mu s$

**Q39.** [TIFR\_2016\_A\_Q20]

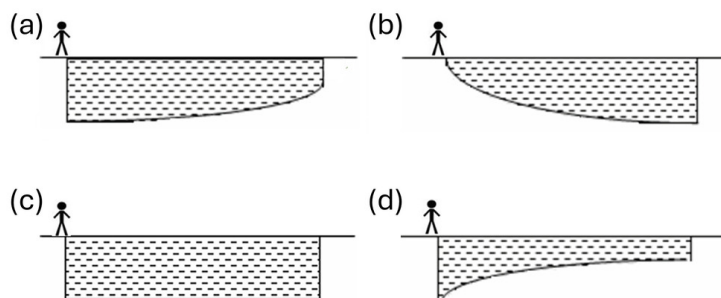
Year 2016 · Optics · Ray Optics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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An observer stands at the edge of a swimming pool, as sketched in the figure below.



This observer will perceive the pool as



**Quantum Mechanics**

**Q40.** [TIFR\_2016\_A\_Q11]

Year 2016 · Quantum Mechanics · Basic Quantum Mechanics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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A gas of non-interacting particles, each of rest mass 1 MeV, is at a temperature  $T = 2.0 \times 10^7$  K and has an average particle density  $n = 2.7 \times 10^{34} \text{cm}^{-3}$ . We can obtain a reasonably correct treatment of this system

- (a) by neglecting quantum mechanics but not special theory of relativity.
- (b) by neglecting special relativity but not quantum mechanics.
- (c) only by using special relativity as well as quantum mechanics.
- (d) by neglecting both special relativity and quantum mechanics.

**Q41.** [TIFR\_2016\_A\_Q12]

Year 2016 · Quantum Mechanics · Basic Quantum Mechanics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
---------	------	-----------

A one-dimensional harmonic oscillator of mass  $m$  and natural frequency  $\omega$  is in the quantum state

$$|\psi\rangle = \frac{1}{\sqrt{3}}|0\rangle + \frac{i}{\sqrt{3}}|1\rangle + \frac{i}{\sqrt{3}}|2\rangle$$

at time  $t = 0$ , where  $|n\rangle$  denotes the eigenstate with eigenvalue  $(n + \frac{1}{2})\hbar\omega$ . It follows that the expectation value  $\langle x \rangle$  of the position operator  $\hat{x}$  is

- (a)  $x(0) \left[ \cos \omega t + \frac{1}{\sqrt{3}} \sin \omega t \right]$
- (b)  $x(0) [\cos \omega t - \sin \omega t]$
- (c)  $x(0) \left[ \cos \omega t + \frac{1}{\sqrt{2}} \sin \omega t \right]$
- (d)  $x(0) \left[ \cos \omega t - \frac{1}{2} \sin \omega t \right]$

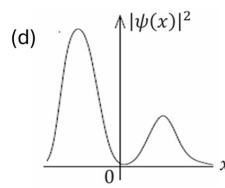
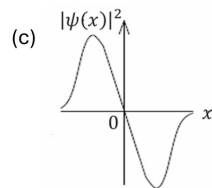
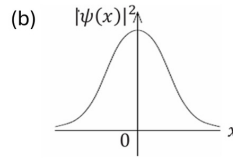
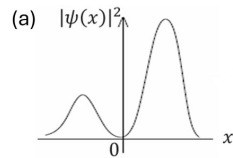
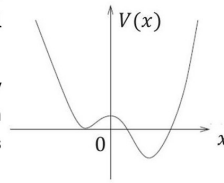
**Q42.** [TIFR\_2016\_A\_Q13]

Year 2016 · Quantum Mechanics · Basic Quantum Mechanics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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A particle is confined inside a one-dimensional potential well  $V(x)$ , as shown on the right.

One of the possible probability distributions  $|\psi(x)|^2$  for an energy eigenstate for this particle is



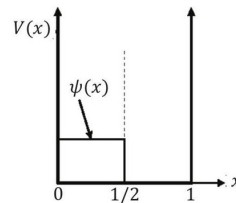
**Q43.** [TIFR\_2016\_B\_Q14]

Year 2016 · Quantum Mechanics · Basic Quantum Mechanics · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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A particle is confined in a one-dimensional box of unit length, i.e.  $L = 1$ , i.e. in a potential

$$V(x) = \begin{cases} 0 & \text{if } 0 < x < 1 \\ \infty & \text{otherwise} \end{cases}$$



The energy eigenvalues of this particle are denoted  $E_0, E_1, E_2, E_3, \dots$

In a particular experiment, the wavefunction of this particle, at  $t = 0$ , is given by

$$\psi(x) = \begin{cases} \sqrt{2} & \text{if } 0 < x < 1/2 \\ 0 & \text{otherwise} \end{cases}$$

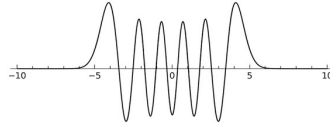
If, simultaneously, i.e. at  $t = 0$ , a measurement of the energy of the particle is made, find  $100p_3$ , where  $p_3$  is the probability that the measurement will yield the energy  $E_3$ .

**Q44.** [TIFR\_2016\_B\_Q6]

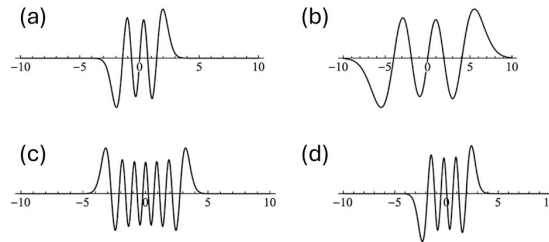
Year 2016 · Quantum Mechanics · quantum Harmonic Oscillator · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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Two harmonic oscillators  $A$  and  $B$  are in excited eigenstates with the same excitation energy  $E$ , as measured from their respective ground state energies. The natural frequency of  $A$  is twice that of  $B$ .



If the wavefunction of  $B$  is as sketched in the above picture, which of the following would best represent the wavefunction of  $A$  ?



**Q45.** [TIFR\_2016\_C\_Q12]

Year 2016 · Quantum Mechanics · Angular Momentum and Hydrogen atom · Only PhD · 5 marks

TIFR GS	2016	Section C
---------	------	-----------

A quantum mechanical plane rotator consists of two rigidly connected particles of mass  $m$  and connected by a massless rod of length  $d$  is rotating in the  $x - y$  plane about their centre of mass. Suppose that the initial state of the rotor is given by

$$\psi(\varphi, t = 0) = A \cos^2 \varphi,$$

where  $\varphi$  is the angle between one mass and the  $x$  axis, while  $A$  is a normalization constant. Find the expectation value of  $3\hat{L}_z^2$  in this state, in units of  $\hbar^2$ .

**Q46. [TIFR\_2016\_C\_Q4]**

Year 2016 · Quantum Mechanics · Basic Quantum Mechanics · Only PhD · 5 marks

TIFR GS	2016	Section C
---------	------	-----------

A particle moving in one dimension is confined inside a rigid box located between  $x = -a/2$  and  $x = a/2$ . If the particle is in its ground state

$$\psi_0(x) = \sqrt{2/a} \cos \frac{\pi x}{a}$$

the quantum mechanical probability of its having a momentum  $p$  is given by

- (a)  $\frac{16\hbar^4}{(\pi^2\hbar^2 - p^2a^2)^2}$
- (b)  $\frac{\pi^2\hbar^4}{(\pi^2\hbar^2 - p^2a^2)^2} \sin^2 \frac{pa}{2\hbar}$
- (c)  $\frac{2\hbar^4}{(\pi^2\hbar^2 + p^2a^2)^2} \cos^2 \frac{pa}{2\hbar}$
- (d)  $\frac{8\hbar^4}{(\pi^2\hbar^2 - p^2a^2)^2} \cos^2 \frac{pa}{2\hbar}$

**Q47. [TIFR\_2016\_C\_Q5]**

Year 2016 · Quantum Mechanics · Angular Momentum and Hydrogen atom · Only PhD · 5 marks

TIFR GS	2016	Section C
---------	------	-----------

Consider two spin- 1/2 identical particles A and B , separated by a distance  $r$ , interacting through a potential

$$V(r) = \frac{V_0}{r} \vec{S}_A \cdot \vec{S}_B$$

where  $V_0$  is a positive constant and the spins are  $\vec{S}_{A,B} = \vec{\sigma} = (\sigma_x, \sigma_y, \sigma_z)$  in terms of the Pauli spin matrices. The expectation values of this potential in the spin-singlet and triplet states are

- (a) Singlet :  $-\frac{V_0}{3r}$ , Triplet :  $\frac{V_0}{r}$
- (b) Singlet :  $-\frac{3V_0}{r}$ , Triplet :  $\frac{V_0}{r}$
- (c) Singlet :  $\frac{3V_0}{r}$ , Triplet :  $-\frac{V_0}{r}$
- (d) Singlet :  $-\frac{V_0}{r}$ , Triplet :  $\frac{3V_0}{r}$

**Solid State Physics**

**Q48.** [TIFR\_2016\_A\_Q17]

Year 2016 · Solid State Physics · Crystallography · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In a simple cubic lattice of lattice constant 0.287 nm, the number of atoms per  $\text{mm}^2$  along the 111 plane is

- (a)  $2.11 \times 10^{13}$
- (b)  $1.73 \times 10^{13}$
- (c)  $1.29 \times 10^{13}$
- (d)  $1.21 \times 10^{13}$

**Q49.** [TIFR\_2016\_C\_Q9]

Year 2016 · Solid State Physics · Lattice Vibrations and Thermal Properties · Only PhD · 5 marks

TIFR GS	2016	Section C
---------	------	-----------

The dispersion relation for electrons in the conduction band of a  $n$ -type semiconductor has the form  $E(k) = ak^2 + b$  where  $a$  and  $b$  are constants. It was observed that the cyclotron resonance frequency of such electrons is  $\omega_0 = 1.8 \times 10^{11} \text{rads}^{-1}$ , when placed in a magnetic field  $B = 0.1 \text{W m}^{-2}$ . It follows that the constant  $a$  must be about

- (a)  $10^{-36}$
- (b)  $10^{-28}$
- (c)  $10^{-38}$
- (d)  $10^{-32}$

**Statistical Mechanics**

**Q50.** [TIFR\_2016\_A\_Q14]

Year 2016 · Statistical Mechanics · Microstates · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
---------	------	-----------

The energy per oscillator of an isolated system of a large number of identical non-interacting fermions in a one-dimensional harmonic oscillator potential is  $5\hbar\omega/4$ , where  $\omega$  is the angular frequency of the harmonic oscillator. The entropy of the system per oscillator is given by

- (a) 0.75
- (b) 0.63
- (c) 0.56
- (d) 0.25

**Q51.** [TIFR\_2016\_A\_Q3]

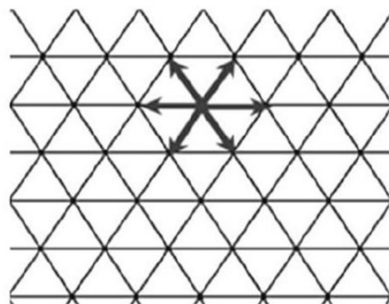
Year 2016 · Statistical Mechanics · Random Walk · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
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In a triangular lattice a particle moves from a lattice point to any of its 6 neighbouring points with equal probability, as shown in the figure on the right.

The probability that the particle is back at its starting point after 3 moves is

- (a) 5/18
- (b) 1/6
- (c) 1/18
- (d) 1/36



**Q52.** [TIFR\_2016\_C\_Q14]

Year 2016 · Statistical Mechanics · Canonical Ensemble · Only PhD · 5 marks

TIFR GS	2016	Section C
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$N$  distinguishable particles are distributed among three states having energies  $E = 0, k_B T$  and  $2k_B T$  respectively. If the total equilibrium energy of the system is  $138.06k_B T$ , find the number  $N$  of particles.

**Thermodynamics****Q53.** [TIFR\_2016\_A\_Q15]

Year 2016 · Thermodynamics · Laws of thermodynamics · Both int. phd and phd · 3 marks

TIFR GS	2016	Section A
---------	------	-----------

In the temperature range  $100 - 1000\text{C}$ , the molar specific heat of a metal varies with temperature  $T$  (measured in degrees Celsius) according to the formula  $C_p = (1 + T/5)\text{J-deg C}^{-1} - \text{mol}^{-1}$ . If  $0.2\text{ kg}$  of the metal at  $600\text{ C}$  is brought in thermal contact with  $0.1\text{ kg}$  of the same metal at  $300\text{ C}$ , the final equilibrium temperature, in deg C, will be [Assume that no heat is lost due to radiation and/or other effects.]

- (a) 466
- (b) 519
- (c) 383
- (d) 567

**Q54.** [TIFR\_2016\_B\_Q13]

Year 2016 · Thermodynamics · Kinetic Theory of Gases · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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Two containers are maintained at the same temperature and are filled with ideal gases whose molecules have mass  $m_1$  and  $m_2$  respectively. The mean speed of molecules of the second gas is 10 times the r.m.s. speed of the molecules of the first gas. Find the ratio of  $m_1/m_2$ , to the nearest integer.

**Q55.** [TIFR\_2016\_B\_Q4]

Year 2016 · Thermodynamics · Phase transition · Only int. Phd · 5 marks

TIFR GS	2016	Section B
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The equation of state for a gas is given by

$$\left[ p + \left( \frac{\alpha N}{V} \right)^2 \right] (V - \beta N) = N k_B T$$

where  $P, V, T, N$ , and  $k_B$  represent pressure, volume, temperature, number of atoms and the Boltzmann constant, respectively, while  $\alpha$  and  $\beta$  are constants specific to the gas.

If the critical point C corresponds to a point of inflexion of the  $p - V$  curve, then the critical volume  $V_c$  and critical pressure  $p_c$  for this gas are given by

- (a)  $V_c = 3\beta N, p_c = \alpha^2/3\beta^2$
- (b)  $V_c = 3\beta N, p_c = \alpha/27\beta^2$
- (c)  $V_c = 3\beta N, p_c = 8\alpha^2/27\beta$
- (d)  $V_c = 3\beta N, p_c = \alpha^2/27\beta^2$

# Answer Key & Index

Complete TIFR GS Physics Paper · 2016 · 55 questions

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