

# PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

## Scattering theory - CSIR NET Physics PYQs

Quantum Mechanics . All PYQs (2015-2025) with answer key

**14 questions . Answer key included**

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**Q1. [Dec 2015] . 3.5 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2015 Dec	3.5 M
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In the scattering of some elementary particles, the scattering cross-section  $\sigma$  is found to depend on the total energy  $E$  and the fundamental constants  $h$  (Planck's constant) and  $c$  (the speed of light in vacuum). Using dimensional analysis, the dependence of  $\sigma$  on these quantities is given by

1.  $\sqrt{\frac{hc}{E}}$
2.  $\frac{hc}{E^{3/2}}$
3.  $\left(\frac{hc}{E}\right)^2$
4.  $\frac{hc}{E}$

**Q2. [June 2015] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2015 June	5 M
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The differential cross-section for scattering by a

target is given by  $\frac{d\sigma}{d\Omega}(\theta, \varphi) = a^2 + b^2 \cos^2 \theta$ .

If  $N$  is the flux of the incoming particles, the number of particles scattered per unit time is

1.  $\frac{4\pi}{3} N(a^2 + b^2)$
2.  $4\pi N \left( a^2 + \frac{1}{6} b^2 \right)$
3.  $4\pi N \left( \frac{1}{2} a^2 + \frac{1}{3} b^2 \right)$
4.  $4\pi N \left( a^2 + \frac{1}{3} b^2 \right)$

**Q3. [June 2015] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2015 June	5 M
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A particle of energy  $E$  scatters off a repulsive spherical potential

$$V(r) = \begin{cases} V_0 & \text{for } r < a \\ 0 & \text{for } r \geq a \end{cases}$$

where  $V_0$  and  $a$  are positive constants. In the low energy limit, the total scattering crosssection is

$$\sigma = 4\pi a^2 \left( \frac{1}{ka} \tanh ka - 1 \right)^2, \text{ where}$$

$k^2 = \frac{2m}{\hbar^2} (V_0 - E) > 0$ . In the limit  $V_0 \rightarrow \infty$  the ratio of  $\sigma$  to the classical scattering cross-section off a sphere of radius  $a$  is

1. 4
2. 3
3. 1
4. 1/2

## Q4. [Dec 2016] . 5.0 marks

Quantum Mechanics &gt; Scattering theory

CSIR NET	2016 Dec	5M
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A particle is scattered by a central potential

$V(r) = V_0 r e^{-\mu r}$ , where  $V_0$  and  $\mu$  are positive constants. If the momentum transfer  $\vec{q}$  is such that  $q = |\vec{q}| \gg \mu$ , the scattering cross-section in the Born approximation, as  $q \rightarrow \infty$ , depends on  $q$  as

[You may use  $\int x^n e^{ax} dx = \frac{d^n}{da^n} \int 1 e^{ax} dx$ ]

1.  $q^{-8}$
2.  $q^{-2}$
3.  $q^2$
4.  $q^6$

**Q5. [Dec 2017] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2017 Dec	5M
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A phase shift of  $30^\circ$  is observed when a beam of particles of energy 0.1 MeV is scattered by a target. When the beam energy is changed, the observed phase shift is  $60^\circ$ . Assuming that only *s*-wave scattering is relevant and that the cross-section does not change with energy, the beam energy is

1. 0.4 MeV
2. 0.3 MeV
3. 0.2 MeV
4. 0.15 MeV

**Q6. [June 2017] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2017 June	5M
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Consider the potential

$$V(\vec{r}) = \sum_i V_0 a^3 \delta^{(3)}(\vec{r} - \vec{r}_i)$$

where  $\vec{r}_i$  are the position vectors of the vertices of a cube of length  $a$  centered at the origin and  $V_0$  is a constant. If  $V_0 a^2 \ll \frac{\hbar^2}{m}$ , the total scattering cross-section, in the low-energy limit, is

1.  $16a^2 \left( \frac{mV_0 a^2}{\hbar^2} \right)$
2.  $\frac{16a^2}{\pi^2} \left( \frac{mV_0 a^2}{\hbar^2} \right)^2$
3.  $\frac{64a^2}{\pi} \left( \frac{mV_0 a^2}{\hbar^2} \right)^2$
4.  $\frac{64a^2}{\pi^2} \left( \frac{mV_0 a^2}{\hbar^2} \right)$

## Q7. [June 2018] . 5.0 marks

Quantum Mechanics &gt; Scattering theory

CSIR NET	2018 June	5M
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The differential scattering cross-section  $\frac{d\sigma}{d\Omega}$  for the central potential  $V(r) = \frac{\beta}{r} e^{-\mu r}$ , where  $\beta$  and  $\mu$  are positive constants, is calculated in the first Born approximation. Its dependence on the scattering angle  $\theta$  is proportional to ( $A$  is a constant below)

1.  $\left(A^2 + \sin^2 \frac{\theta}{2}\right)$
2.  $\left(A^2 + \sin^2 \frac{\theta}{2}\right)^{-1}$
3.  $\left(A^2 + \sin^2 \frac{\theta}{2}\right)^{-2}$
4.  $\left(A^2 + \sin^2 \frac{\theta}{2}\right)^2$

Q8. [June 2019] . 5.0 marks

Quantum Mechanics &gt; Scattering theory

CSIR NET

2019 June

5M

In the partial wave expansion, the differential scattering cross-section is given by

$$\frac{d\sigma}{d(\cos\theta)} = \left| \sum_l (2l + 1) e^{i\delta_l} \sin\delta_l P_l(\cos\theta) \right|^2$$

where  $\theta$  is the scattering angle. For a certain neutron-nucleus scattering, it is found that the two lowest phase shifts  $\delta_0$  and  $\delta_1$  corresponding to  $s$ -wave and  $p$ -wave, respectively, satisfy  $\delta_1 \approx \frac{\delta_0}{2}$ .

Assuming that the other phase shifts are negligibly small, the differential cross-section reaches its minimum for  $\cos\theta$  equal to

1. 0
2.  $\pm 1$
3.  $-\frac{2}{3} \cos^2 \delta_1$
4.  $\frac{1}{3} \cos^2 \delta_1$

## Q9. [June 2019] . 5.0 marks

Quantum Mechanics &gt; Scattering theory

CSIR NET	2019 June	5M
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The elastic scattering of a charged particle of mass  $m$  off an atom can be approximated by the potential

$$V(r) = \frac{\alpha}{r} e^{-r/R} \text{ where } \alpha \text{ and } R \text{ are positive}$$

constants. If the wave number of the incoming particle is  $k$  and the scattering angle is  $2\theta$ , the differential cross-section in the Born approximation is

(a)  $\frac{m^2 \alpha^2 R^4}{4\hbar^4 (1 + k^3 R^2 \sin^2 \theta)}$

(b)  $\frac{m^2 \alpha^2 R^4}{\hbar^4 (2k^2 R^2 \sin^2 \theta)^2}$

(c)  $\frac{2m^2 \alpha^2 R^4}{\hbar^4 (2k^2 R^2 2\sin^2 \theta)}$

(d)  $\frac{4m^2 \alpha^2 R^4}{\hbar^4 (1 + 4k^2 R^2 \sin^2 \theta)^2}$

**Q10. [June 2019] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2019 June	5M
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The range of the inter-atomic potential in gaseous hydrogen is approximately  $5\text{\AA}$ . In thermal equilibrium, the maximum temperature for which the atom-atom scattering is dominantly  $s$  wave, is

1. 500 K
2. 100 K
3. 1 K
4. 1 mK

**Q11. [June 2020] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2020 June	5M
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A particle with incoming wave vector  $\vec{k}$ , after being scattered by the potential  $V(r) = \frac{C}{r^2}$ , goes out with wave vector  $\vec{k}'$ . The differential scattering cross-section, calculated in the first Born approximation, depends on

$q = |\vec{k} - \vec{k}'|$ , as

1.  $1/q^2$
2.  $1/q^4$
3.  $1/q$
4.  $1/q^{3/2}$

**Q12. [June 2021] . 5.0 marks**

Quantum Mechanics &gt; Scattering theory

CSIR NET	2021 June	5M
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In an elastic scattering process at an energy  $E$ , the phase shifts satisfy  $\delta_0 \approx 30^\circ$ ,  $\delta_1 \approx 10^\circ$ , while the other phase shifts are zero. The polar angle at which the differential cross section peaks is closest to

1.  $20^\circ$
2.  $10^\circ$
3.  $0^\circ$
4.  $30^\circ$

## Q13. [Dec 2023] . 5.0 marks

Quantum Mechanics &gt; Scattering theory

CSIR NET	2023 Dec	5 M
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An incident plane wave with wavenumber  $k$  is scattered by a spherically symmetric soft potential. The scattering occurs only in  $S$  - and  $P$ -waves. The approximate scattering amplitude at angles  $\theta = \frac{\pi}{3}$  and  $\theta = \frac{\pi}{2}$  are

$$f\left(\theta = \frac{\pi}{3}\right) \approx \frac{1}{2k} \left(\frac{5}{2} + 3i\right) \text{ and } f\left(\theta = \frac{\pi}{2}\right) \approx \frac{1}{2k} \left(1 + \frac{3i}{2}\right)$$

Then the total scattering cross-section is closest to

1.  $\frac{37\pi}{4k^2}$
2.  $\frac{10\pi}{k^2}$
3.  $\frac{35\pi}{4k^2}$
4.  $\frac{9\pi}{k^2}$

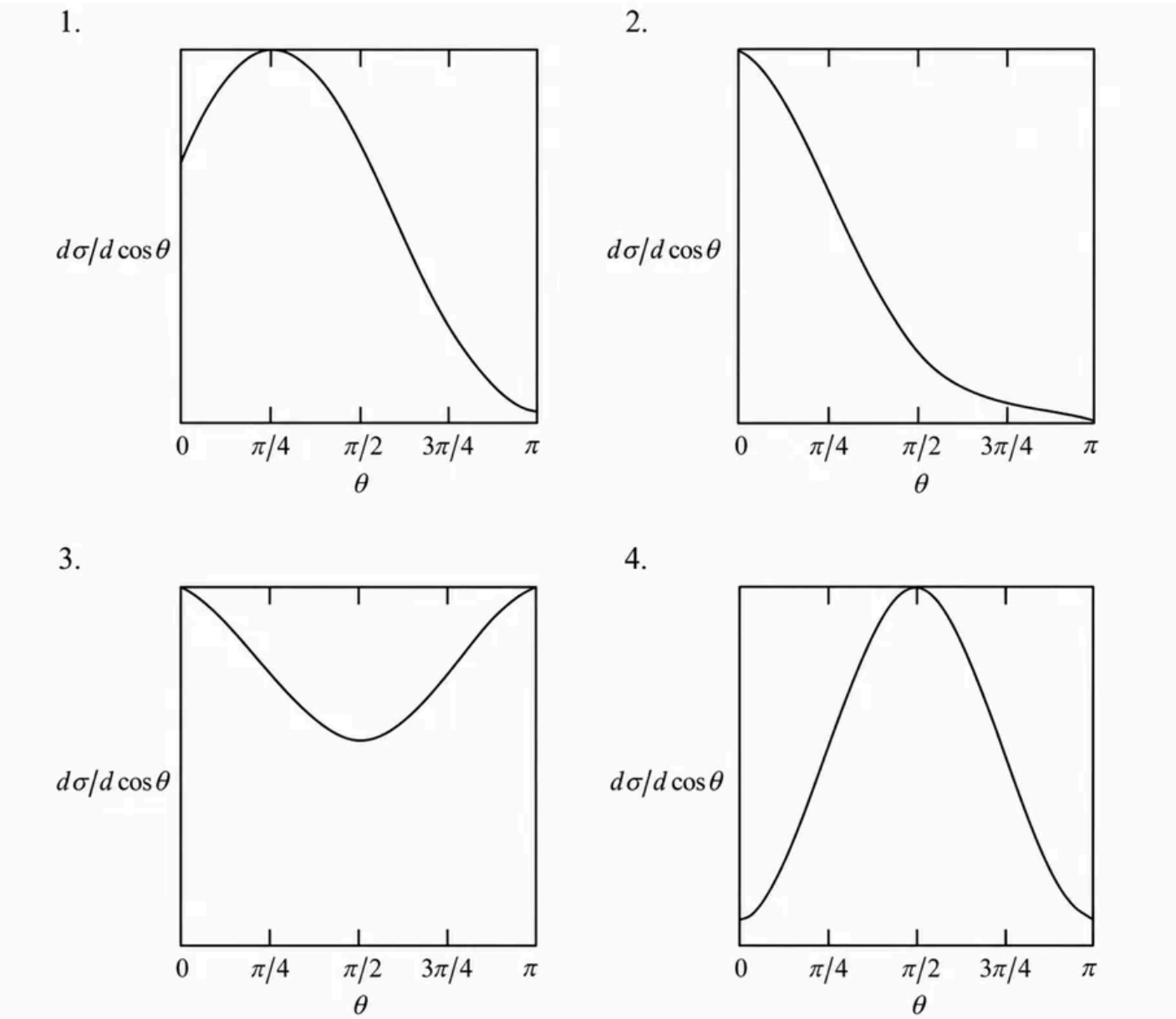
**Q14. [June 2023] . 5.0 marks**

Quantum Mechanics > Scattering theory

CSIR NET	2023 June	5M
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The phase shifts of the partial waves in an elastic scattering at energy  $E$  are  $\delta_0 = 12^\circ$ ,  $\delta_1 = 4^\circ$  and  $\delta_{\ell \geq 2} \approx 0^\circ$ . The best qualitative depiction of  $\theta$ -dependence of the differential scattering

cross-section  $\frac{d\sigma}{d\cos\theta}$  is



## Answer Key

14 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Quantum Mechanics	Scattering theory	3
Q2	Quantum Mechanics	Scattering theory	4
Q3	Quantum Mechanics	Scattering theory	1
Q4	Quantum Mechanics	Scattering theory	1
Q5	Quantum Mechanics	Scattering theory	2
Q6	Quantum Mechanics	Scattering theory	3
Q7	Quantum Mechanics	Scattering theory	3
Q8	Quantum Mechanics	Scattering theory	3
Q9	Quantum Mechanics	Scattering theory	4
Q10	Quantum Mechanics	Scattering theory	3
Q11	Quantum Mechanics	Scattering theory	1
Q12	Quantum Mechanics	Scattering theory	3
Q13	Quantum Mechanics	Scattering theory	1
Q14	Quantum Mechanics	Scattering theory	2

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