

# PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

## Central forces - CSIR NET Physics PYQs

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

**19 questions . Answer key included**

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

Classical Mechanics &gt; Central forces

CSIR NET	2015 Dec	3.5 M
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A particle moves in three dimensional space in a central potential  $V(r) = kr^4$  where  $k$  is a constant. The angular frequency  $\omega$  for a circular orbit depends on its radius  $R$  as

1.  $\omega \propto R$
2.  $\omega \propto R^{-1}$
3.  $\omega \propto R^{1/4}$
4.  $\omega \propto R^{-2/3}$

**Q2. [June 2015] . 3.5 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2015 June	3.5 M
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A particle of unit mass moves in the  $xy$  plane in such a way that  $\dot{x}(t) = y(t)$  and  $\dot{y}(t) = -x(t)$ . We can conclude that it is in a conservative force-field which can be derived from the potential

1.  $\frac{1}{2}(x^2 + y^2)$
2.  $\frac{1}{2}(x^2 - y^2)$
3.  $x + y$
4.  $x - y$

**Q3. [Dec 2016] . 5.0 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2016 Dec	5M
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Consider circular orbits in a central force potential

$V(r) = -\frac{k}{r^n}$ , where  $k > 0$  and  $0 < n < 2$ . If the time period of a circular orbit of radius  $R$  is  $T_1$  and that of radius  $2R$  is  $T_2$ , then  $T_2/T_1$  is

1.  $2^{\frac{n}{2}}$
2.  $2^{\frac{2}{3}n}$
3.  $2^{\frac{n}{2}+1}$
4.  $2^n$

**Q4. [Dec 2017] . 5.0 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2017 Dec	5M
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Consider a set of particles which interact by a pair potential  $V = ar^6$  where  $r$  is the interparticle separation and  $a > 0$  is a constant. If a system of such particles has reached virial equilibrium, the ratio of the kinetic to the total energy of the system is

1.  $\frac{1}{2}$
2.  $\frac{1}{3}$
3.  $\frac{3}{4}$
4.  $\frac{2}{3}$

## Q5. [Dec 2018] . 3.5 marks

Classical Mechanics &gt; Central forces

CSIR NET	2018 Dec	3.5M
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In the attractive Kepler problem described by the central potential  $V(r) = \frac{-k}{r}$  (where  $k$  is a positive constant), a particle of mass  $m$  with a non-zero angular momentum can never reach the center due to the centrifugal barrier. If we modify the potential to

$$V(r) = -\frac{k}{r} - \frac{\beta}{r^3}$$

one finds that there is a critical value of the angular momentum  $\ell_c$  below which there is no centrifugal barrier. This value of  $\ell_c$  is

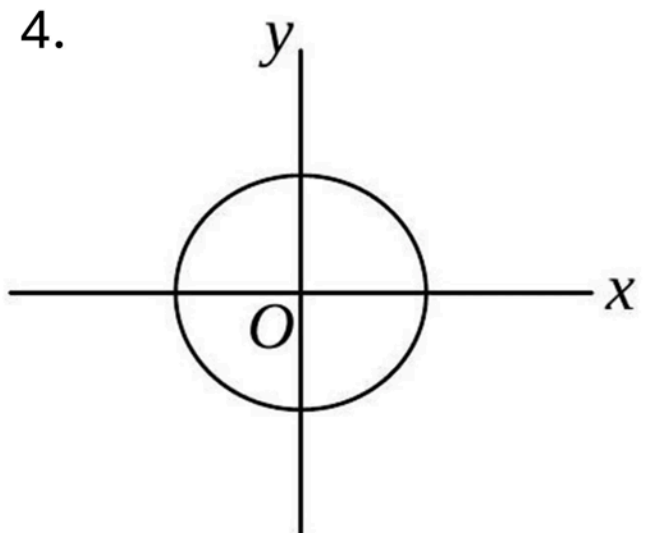
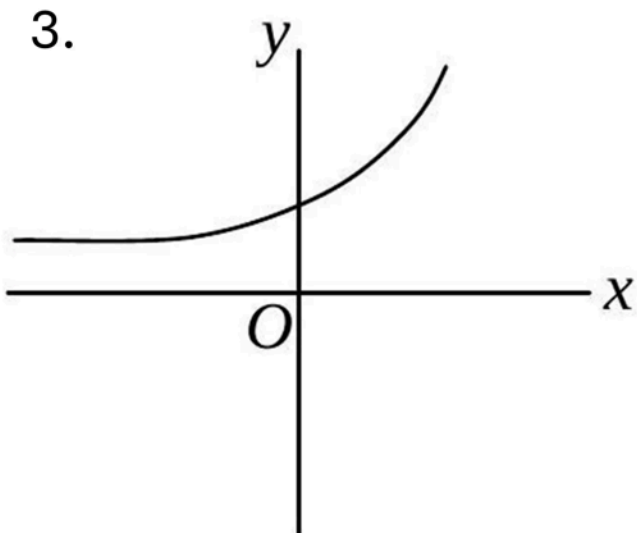
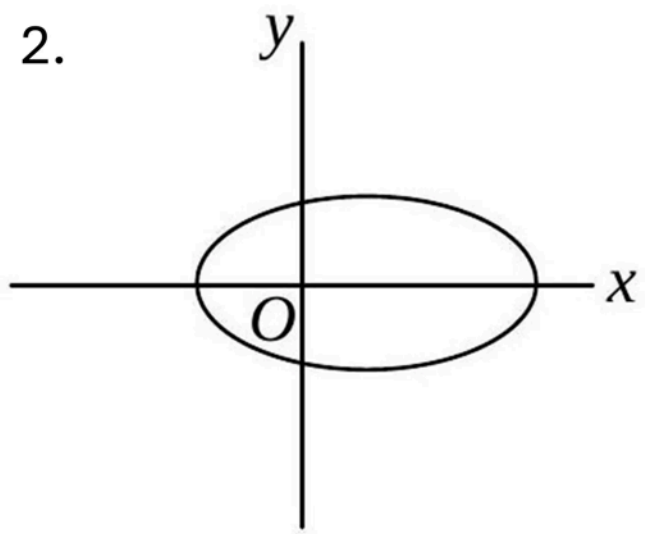
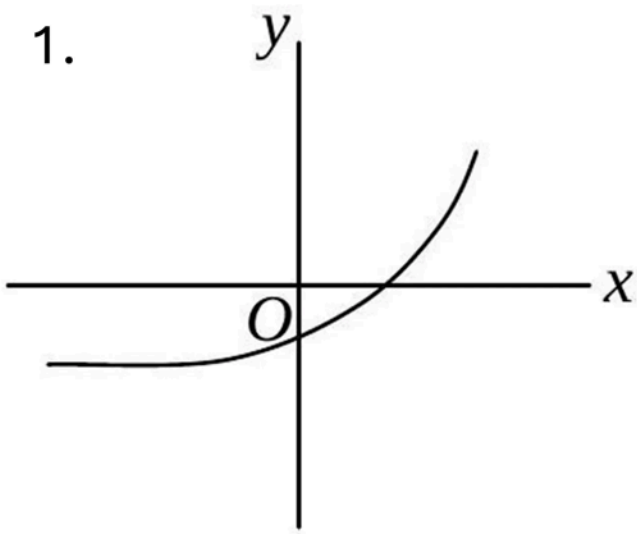
1.  $[12km^2\beta]^{1/2}$
2.  $[12 km^2\beta]^{-1/2}$
3.  $[12 km^2\beta]^{1/4}$
4.  $[12km^2\beta]^{-1/4}$

**Q6. [June 2018] . 3.5 marks**

Classical Mechanics > Central forces

CSIR NET	2018 June	3.5M
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Which of the following figures best describes the trajectory of a particle moving in a repulsive central potential  $V(r) = \frac{a}{r}$  ( $a > 0$  is a constant)?



## Q7. [June 2018] . 5.0 marks

Classical Mechanics &gt; Central forces

CSIR NET	2018 June	5M
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A particle of mass  $m$  moves in a central potential

$V(r) = -\frac{k}{r}$  in an elliptic orbit  $r(\theta) = \frac{a(1-e^2)}{1+e\cos\theta}$ , where

$0 \leq \theta < 2\pi$  and  $a$  and  $e$  denote the semi-major axis and eccentricity, respectively. If its total energy is

$E = -\frac{k}{2a}$ , the maximum kinetic energy is

1.  $E(1 - e^2)$
2.  $E \frac{(e+1)}{(e-1)}$
3.  $E/(1 - e^2)$
4.  $E \frac{(e-1)}{(e+1)}$

**Q8. [June 2019] . 3.5 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2019 June	3.5M
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Assume that the earth revolves in a circular orbit around the sun. Suppose the gravitational constant  $G$  varies slowly as a function of time. In particular, it decreases to half its initial value in the course of one million years. Then during this time the

1. radius of the earth's orbit will increase by a factor of two
2. total energy of the earth remains constant
3. orbital angular momentum of the earth will increase
4. radius of the earth's orbit remains the same.

**Q9. [June 2021] . 3.5 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2021 June	3.5M
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A particle, thrown with a speed  $v$  from the earth's surface, attains a maximum height  $h$  (measured from the surface of the earth). If  $v$  is half the escape velocity and  $R$  denotes the radius of earth, then  $h/R$  is

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

**Q10. [June 2021] . 5.0 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2021 June	5M
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A particle in two dimensions is found to trace an orbit  $r(\theta) = r_0\theta^2$ . If it is moving under the influence of a central potential  $V(r) = c_1r^{-a} + c_2r^{-b}$ , where  $r_0, c_1$  and  $c_2$  are constants of appropriate dimensions, the values of  $a$  and  $b$ , respectively, are

1. 2 and 4
2. 2 and 3
3. 3 and 4
4. 1 and 3

**Q11. [June 2021] . 5.0 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2021 June	5M
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A satellite of mass  $m$  orbits around earth in an elliptic trajectory of semi-major axis  $a$ . At a radial distance  $r = r_0$ , measured from the centre of the earth, the kinetic energy is equal to half the magnitude of the total energy. If  $M$  denotes the mass of the earth and the total energy is  $-\frac{GMm}{2a}$ , the value of  $r_0/a$  is nearest to

1. 1.33
2. 1.48
3. 1.25
4. 1.67

**Q12. [June 2022] . 3.5 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2022 June	3.5M
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The periods of oscillation of a simple pendulum at the sea level and at the top of a mountain of height 6 km are  $T_1$  and  $T_2$ , respectively. If the radius of earth is approximately 6000 km, then  $\frac{(T_2 - T_1)}{T_1}$  is

closest to

1.  $-10^{-4}$
2.  $-10^{-3}$
3.  $10^{-4}$
4.  $10^{-3}$

## Q13. [Dec 2023] . 3.5 marks

Classical Mechanics &gt; Central forces

CSIR NET	2023 Dec	3.5 M
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A particle of mass  $m$  is moving in a stable circular orbit of radius  $r_0$  with angular momentum  $L$ . For a potential energy  $V(r) = \beta r^k$  ( $\beta > 0$  and  $k > 0$ ), which of the following options is correct?

1.  $k = 3, r_0 = \left(\frac{3L^2}{5m\beta}\right)^{1/5}$

2.  $k = 2, r_0 = \left(\frac{L^2}{2m\beta}\right)^{1/4}$

3.  $k = 2, r_0 = \left(\frac{L^2}{4m\beta}\right)^{1/4}$

4.  $k = 3, r_0 = \left(\frac{5L^2}{3m\beta}\right)^{1/5}$

Q14. [Dec 2023] . 3.5 marks

Classical Mechanics > Central forces

CSIR NET	2023 Dec	3.5 M
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A particle moves in a circular orbit under a force field given by  $\vec{F}(\vec{r}) = -\frac{k}{r^2} \hat{r}$ , where  $k$  is a positive constant. If the force changes suddenly to

$\vec{F}(\vec{r}) = -\frac{k}{2r^2} \hat{r}$ , the shape of the new orbit would be

1. parabolic
2. circular
3. elliptical
4. hyperbolic

**Q15. [Dec 2023] . 5.0 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2023 Dec	5 M
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A particle of mass  $m$  is moving in a 3-dimensional potential

$$\phi(r) = -\frac{k}{r} - \frac{k'}{3r^3}, k, k' > 0$$

For the particle with angular momentum  $l$ , the necessary condition to have a stable circular orbit is

1.  $kk' < \frac{l^4}{4m^2}$
2.  $kk' > \frac{l^4}{4m^2}$
3.  $kk' < \frac{l^4}{m^2}$
4.  $kk' > \frac{l^4}{m^2}$

**Q16. [June 2023] . 3.5 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2023 June	3.5M
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The minor axis of Earth's elliptical orbit divides the area within it into two halves. The eccentricity of the orbit is 0.0167. The difference in time spent by Earth in the two halves is closest to

1. 3.9 days
2. 4.8 days
3. 12.3 days
4. 0 days

## Q17. [June 2023] . 3.5 marks

Classical Mechanics &gt; Central forces

CSIR NET	2023 June	3.5M
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The trajectory of a particle moving in a plane is expressed in polar coordinates  $(r, \theta)$  by the equations  $r = r_0 e^{\beta t}$  and  $\frac{d\theta}{dt} = \omega$ , where the parameters  $r_0, \beta$  and  $\omega$  are positive. Let  $v_r$  and  $a_r$  denote the velocity and acceleration, respectively, in the radial direction. For this trajectory

1.  $a_r < 0$  at all times irrespective of the values of the parameters
2.  $a_r > 0$  at all times irrespective of the values of the parameters
3.  $\frac{dv_r}{dt} > 0$  and  $a_r > 0$  for all choices of parameters
4.  $\frac{dv_r}{dt} > 0$ , however,  $a_r = 0$  for some choices of parameters

## Q18. [June 2024] . 3.5 marks

Classical Mechanics &gt; Central forces

CSIR NET	2024 June	3.5M
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A body of mass  $m$  is acted upon by a central force  $\vec{f}(\vec{r}) = -k\vec{r}$ , where  $k$  is a positive constant. If the magnitude of the angular momentum is  $l$ , then the total energy for a circular orbit is

1.  $2\sqrt{\frac{kl^2}{m}}$

2.  $\frac{1}{2}\sqrt{\frac{kl^2}{m}}$

3.  $\frac{3}{2}\sqrt{\frac{kl^2}{m}}$

4.  $\sqrt{\frac{kl^2}{m}}$

**Q19. [June 2024] . 5.0 marks**

Classical Mechanics &gt; Central forces

CSIR NET	2024 June	5M
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A particle of mass  $m$  is moving in a potential  $V(r) = -\frac{k}{r}$ , where  $k$  is a positive constant. If  $\vec{L}$  and  $\vec{p}$  denote the angular momentum and linear momentum respectively, the value of  $\alpha$  for which  $\vec{A} = \vec{L} \times \vec{p} + \alpha mk\hat{r}$  is a constant of motion, is

1. -2
2. -1
3. 2
4. 1

## Answer Key

19 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Classical Mechanics	Central forces	1
Q2	Classical Mechanics	Central forces	1
Q3	Classical Mechanics	Central forces	3
Q4	Classical Mechanics	Central forces	3
Q5	Classical Mechanics	Central forces	3
Q6	Classical Mechanics	Central forces	3
Q7	Classical Mechanics	Central forces	2
Q8	Classical Mechanics	Central forces	1
Q9	Classical Mechanics	Central forces	2
Q10	Classical Mechanics	Central forces	2
Q11	Classical Mechanics	Central forces	1
Q12	Classical Mechanics	Central forces	4
Q13	Classical Mechanics	Central forces	2
Q14	Classical Mechanics	Central forces	1
Q15	Classical Mechanics	Central forces	1
Q16	Classical Mechanics	Central forces	1
Q17	Classical Mechanics	Central forces	4
Q18	Classical Mechanics	Central forces	4
Q19	Classical Mechanics	Central forces	4

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