PSI AP Physics C – Rotational Dynamics

Multiple Choice Questions

1. Torque is the rotational analogue of:
   (A) kinetic energy      (B) linear momentum      (C) acceleration      (D) force
   (E) mass

Questions 2-4

A wooden square of side length 1 m is on a horizontal tabletop and is free to rotate about its center axis. The square is subject to two forces and rotates.

2. Find the net torque of the system.
   (A) 2 N·m      (B) 12 N·m      (C) 4√2 N·m      (D) 2√2 N·m      (E) √2 N·m

3. Where should another 4N force be applied to maximize its rotational torque?

4. Where should another 4N force be applied to set the wooden square to equilibrium?
5. Two wheels are fixed to each other and are free to rotate about a frictionless axis through their concentric center. As shown above, four forces are exerted tangent to the wheels. The magnitude of the net torque is:

(A) zero   (B) FR   (C) 2FR   (D) 4FR   (E) 8FR

6. A baseball player swings his bat with his arms fully extended. If his arms are pulled in closer to the body, and he swings again, which of the following is true about the angular momentum and kinetic energy of the player?

<table>
<thead>
<tr>
<th>Angular Momentum</th>
<th>Kinetic Energy</th>
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</thead>
<tbody>
<tr>
<td>(A) Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>(B) Increases</td>
<td>Remains Constant</td>
</tr>
<tr>
<td>(C) Remains Constant</td>
<td>Increases</td>
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<tr>
<td>(D) Remains Constant</td>
<td>Remains Constant</td>
</tr>
<tr>
<td>(E) Decreases</td>
<td>Remains Constant</td>
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</table>

7. A tire of mass M and radius R rolls on a flat track without slipping. If the angular velocity of the wheel is $\omega$, what is its linear momentum?

(A) $M\omega R$   (B) $M\omega^2 R$   (C) $M\omega R^2$   (D) $M\omega^2 R^2/2$   (E) Zero

8. A toy car drives around a circular track with a radius of 10 m. When the car’s velocity is instantaneously directed south, its acceleration is directed west at 10 m/s$^2$. When viewed from above, the car moves:

(A) clockwise at 1 rad/s   (B) clockwise at 10 rad/s   (C) counterclockwise at 1 rad/s   (D) counterclockwise at 10 rad/s   (E) with constant velocity

9. Two masses, one with mass m and the other with mass 2m, are attached to a light rigid rod as shown above. When the system is released from rest, the rod begins to rotate with an angular acceleration magnitude of:

(A) $\frac{g}{7L}$   (B) $\frac{g}{5L}$   (C) $\frac{g}{4L}$   (D) $\frac{5g}{7L}$   (E) $\frac{g}{9L}$
10. A rubber band ball of mass $M$ and radius $R$ (moment of inertia $(2/5)MR^2$) rolls without slipping up an incline with an initial speed $v$. The ball reaches a maximum vertical height of:

(A) $\frac{v^2}{5g}$  
(B) $\frac{2v^2}{5g}$  
(C) $\frac{v^2}{2g}$  
(D) $\frac{7v^2}{10g}$  
(E) $\frac{v^2}{g}$

11. A dart of mass $m$ moves with a constant speed $v_o$ along the dashed line. The dart strikes a uniform disk of radius $R$. What is the magnitude of the angular momentum of the dart with respect to the center of the disk?

(A) zero       (B) $mv_oR$       (C) $mv_oR\sin\theta$       (D) $mv_oR\cos\theta$       (E) $mv_o$

Questions 12-13

A wheel with rotational inertia $I$ is placed on an axle and is free to rotate without friction. The angular speed $\omega$ of the wheel is increased from zero to $\omega_f$ in a time interval $t$.

12. What is the average net torque on the wheel during this time interval?

(A) $\frac{\omega_f}{t}$       (B) $\frac{\omega_f}{t^2}$       (C) $\frac{I\omega_f^2}{t}$       (D) $\frac{I\omega_f}{t^2}$       (E) $\frac{I\omega_f}{t}$

13. What is the average power input to the wheel during this time interval?

(A) $\frac{I\omega_f}{2t}$       (B) $\frac{I\omega_f^2}{2t}$       (C) $\frac{I\omega_f^2}{2t^2}$       (D) $\frac{I^2\omega_f}{2t^2}$       (E) $\frac{I^2\omega_f^2}{2t^2}$
14. A satellite of mass $m$ moves with a constant speed $v$ in a circular orbit of radius $r$. Which of the following statements are true?

I. Its angular speed is $v/r$.

II. Its tangential acceleration is zero.

III. The magnitude of its centripetal acceleration is constant.

(A) I only  (B) II only  (C) I and III only  (D) II and III only  (E) I, II, and III

15. A planet moves in an elliptical orbit around the Sun. As it moves from point A to point B, which of the following is true about its speed and angular momentum?

<table>
<thead>
<tr>
<th>Speed</th>
<th>Angular Momentum</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Remains constant</td>
<td>Remains constant</td>
</tr>
<tr>
<td>(B) Increases</td>
<td>Increases</td>
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<tr>
<td>(C) Decreases</td>
<td>Decreases</td>
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<tr>
<td>(D) Increases</td>
<td>Remains constant</td>
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<tr>
<td>(E) Decreases</td>
<td>Remains constant</td>
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16. In which of the following diagrams is the torque about point C equal in magnitude to the torque about point C in the diagram above? All forces lie in the plane of the paper.

(A) \[ \begin{array}{c}
C \\
\text{60°}
\end{array} \]

(B) \[ \begin{array}{c}
C \\
\text{120°}
\end{array} \]

(C) \[ \begin{array}{c}
C \\
3F
\end{array} \]

(D) \[ \begin{array}{c}
C \\
4F
\end{array} \]

(E) \[ \begin{array}{c}
C \\
30°
\end{array} \]

Questions 17-18

A clay blob of mass m is stuck to a wheel of radius R rotates clockwise with constant angular velocity \( \omega \). The clay mass passes through points 1, 2, 3, and 4 before making a full revolution.

17. At which point will the net force on the mass be greatest?

(A) Point 1  (B) Point 2  (C) Point 3  (D) Point 4  (E) At all points the net force is the same

18. What is the minimum adhesive force necessary for the clay to stay attached to the wheel at point 3?

(A) mg  (B) \( m\omega^2R \)  (C) \( m\omega^2R^2 + mg \)  (D) \( m\omega^2R - mg \)  (E) \( m\omega^2R + mg \)
Questions 19-20

Two masses of mass 10.0 kg and 6.0 kg are hung from massless strings at the end of a light rod. The rod itself is virtually weightless. A pivot is placed off center and the system is free to rotate.

19. If the rod is at equilibrium (not rotating) and the 6 kg mass is 4 m away from the pivot how far away is the 10 kg mass?
   (A) 0.42 m   (B) 2.4 m   (C) 4.8 m   (D) 6.3 m   (E) 9.8 m

20. The string supporting 6 kg block is cut. Find the magnitude of the net torque of the system.
   (A) 60 N-m   (B) 120 N-m   (C) 240 N-m   (D) 480 N-m   (E) 0

21. Which of the following must be true for the above system to be at equilibrium?
   (A) $m_1 = m_2$   (B) $R_1 m_1 = R_2 m_2$   (C) $R_1 m_2 = R_2 m_1$
   (D) $R_1^2 m_1 = R_2^2 m_2$   (E) $R_2^2 m_1 = R_1^2 m_2$
A ball of rotational inertia $(2/5)MR^2$ is released from rest at the top of an incline of height $H$ at an angle $\theta$. There is no friction between the ball and the surface of the incline.

22. What is the acceleration of the ball as it slides down the incline?
(A) $g/2$     (B) $gsin\theta$     (C) $2gcos\theta$     (D) $gsin^2\theta$     (E) 0

23. How fast does the ball travel at the bottom of the incline?
(A) $2gH$     (B) $gH$     (C) $4sin\theta gH$     (D) $\sqrt{2gH}$     (E) $\sqrt{H/g}$

In another scenario there is friction between the ball and incline so that the ball rolls down without slipping.

24. How fast does the ball travel at the bottom of the incline?
(A) $2gH$     (B) $gH$     (C) $\sqrt{10gH/7}$     (D) $\sqrt{2gH}$     (E) $\frac{H}{\sqrt{g}}$

25. What is the acceleration of the ball as it rolls down the incline?
(A) $g/2$     (B) $gsin\theta$     (C) $\mu mgcos\theta$     (D) $mgsin^2\theta$     (E) $5(gsin\theta)/7$

26. Which of the following is true about the energy of the ball as it rolls down the inclined?

(A) Initial potential energy is equally divided between translational and rotational kinetic energies
(B) The rotational kinetic energy is always greater than translational kinetic energy
(C) The translational kinetic energy is zero when the ball rolls down the inclined
(D) The amount of the rotational kinetic energy gained by the ball depends on its mass
(E) The amount of the rotational kinetic energy gained by the ball depends on its moment of inertia
27. Three objects of the same mass and radius are released at the top of an inclined plane: a disk with moment of inertia \((1/2) MR^2\), a hoop with moment of inertia \(MR^2\) and a sphere with moment of inertia \(2/5 MR^2\). How will the speed at the bottom of the incline be different for all three objects as they roll down without slipping?

(A) The disk will travel faster
(B) The hoop will travel faster
(C) The sphere will travel faster
(D) They have the same speed at the bottom of the inclined
(E) None of the above

Questions 28-29

A rod of length L is rotated about its center which has a moment of inertia \((1/12)ML^2\).

28. What is the moment of inertia at a point L/4 away from the center?

(A) \((1/12)ML^2\)  (B) \((3/4)ML^2\)  (C) \((7/48)ML^2\)  (D) \((15/29)ML^2\)  (E) \(ML^2\)

29. What is the moment of inertial with respect to the end of the rod?

(A) \((1/12)ML^2\)  (B) \((1/3)ML^2\)  (C) \((7/12)ML^2\)  (D) \((1/6)ML^2\)  (E) \((19/26)ML^2\)

30. The system above rotates with an angular velocity \(\omega\). If the masses of the rod supports are negligible, what is the ratio of the angular momentum of the two upper spheres to the angular momentum of the two lower spheres?

(A) 2/1  (B) 4/3  (C) 3/4  (D) 1/4  (E) 1/1
31. The moment of inertia of a cylinder of mass M and radius R is $\frac{1}{2} MR^2$ when the axis of rotation passes through its center. The moment of inertia of the cylinder about the axis of rotation tangent to the cylinder is

(A) $\frac{1}{2} MR^2$  (B) $\frac{1}{4} MR^2$  (C) $\frac{3}{4} MR^2$  (D) $\frac{3}{2} MR^2$  (E) $\frac{5}{2} MR^2$

32. A uniform beam of length L and mass m is mounted by a hinge on a wall. The beam is held in a horizontal position by a wire that makes an angle $\theta$ with the horizontal. Which of the following is equal to the tension force T in the wire?

(A) $\frac{mg}{2\cos \theta}$  (B) $\frac{mg}{2\sin \theta}$  (C) $\frac{mg}{2\tan \theta}$  (D) $\frac{mg}{\cos \theta}$  (E) $\frac{mg}{\sin \theta}$

33. A disk is free to rotate about an axis perpendicular to the disk and passing through its center. If the disk starts from rest and accelerates uniformly at the rate of 5 rad/s² for 4 s, what is its angular displacement during this time?

(A) 10 rad  (B) 20 rad  (C) 30 rad  (D) 40 rad  (E) 50 rad

34. A circular platform of mass M and radius R rotates about a fixed pivot at its center with an initial angular velocity $\omega$. A boy of mass m initially standing at the edge of the platform jumps off the platform with a velocity v with respect to the ground. What is the new angular velocity of the platform?

(A) $\frac{(M+2m)\omega R - 2mv}{MR}$  (B) $\frac{(M-2m)\omega R - 2mv}{MR}$  (C) $\frac{(M+2m)\omega R + 2mv}{MR}$  (D) $\frac{(M+2m)\omega R - 2mv}{R}$

(E) $\frac{(M+2m)\omega R - 2mv}{M}$
35. A uniform ladder of length $L$ is supported by a person holding end A so the ladder makes an angle $\theta$ with the horizontal. There is no friction between the ladder and the floor. When the ladder is dropped it falls down because of gravity. Which of the following correctly describes the movement of end B as the ladder falls?

(A) It stays at rest  (B) It moves a distance $L\sin\theta$ to the right  
(C) It moves a distance $L\cos\theta$ to the right  (D) It moves a distance $L\sin\theta$ to the left  
(E) It moves a distance $L\cos\theta$ to the left

36. A disk with mass $M$ and radius $R$, and moment of inertia $I = \frac{1}{2} MR^2$ rotates at a constant angular velocity $\omega_0$ about its center. A piece of clay with mass $m$ is dropped and lands on the surface of the disk at a point $R/2$ from the center of the disk. What is the new angular velocity of the disk-clay system?

(A) $\frac{4M\omega_0}{M+m}$  (B) $\frac{3M\omega_0}{M+m}$  
(C) $\frac{5M\omega_0}{M+m}$  (D) $\frac{M\omega_0}{M+m}$  
(E) $\frac{9M\omega_0}{M+m}$

37. Two disks with radii $R$ and $3R$ are connected by a rubber belt which doesn't slip on the surface of each disk. If the small disk rotates with an angular velocity $\omega_0$, what is the angular velocity of the larger disk?

(A) $\omega_0$  (B) $3\omega_0$  (C) $\frac{1}{3}\omega_0$  (D) $\frac{2}{3}\omega_0$  (E) $\frac{3}{2}\omega_0$
38. Two blocks with masses \( m_1 \) and \( m_2 \) are connected by a light string that passes over a pulley with moment of inertia \( I \). If \( m_2 \) is greater than \( m_1 \), what is the acceleration of the system after it was released from rest?

\[
\frac{(m_2 + m_1)g}{m_1 + m_2 + \frac{I}{R^2}} \quad \text{(A)} \quad \frac{(m_2 - m_1)g}{m_1 + m_2} \quad \text{(B)} \quad \frac{(m_2 + m_1)g}{m_1 + m_2} \quad \text{(C)} \quad \frac{(m_2 + m_1)g}{m_1 - m_2} \quad \text{(D)} \quad \frac{(2m_2 + m_1)g}{m_1 + m_2 + \frac{I}{R^2}} \quad \text{(E)}
\]

39. A disk slides at a constant speed on the top of a horizontal frictionless table. The disk collides with a stationary rod that is pivoted on one end. Which of the following must be the same for the disk-rod system before and after the collision?

I. Linear momentum
II. Angular momentum
III. Kinetic energy

(A) I only       (B) II only       (C) I and II only       (D) I and III only       (E) II and III only

40. A uniform ladder of mass \( m \) leans without slipping against a smooth wall. The coefficient of static friction between the ladder and the floor is \( \mu \). The minimum value of angle \( \theta \) that can prevent the ladder from sliding on the floor is:

\[
\tan^{-1}\left(\frac{1}{2\mu}\right) \quad \text{(A)} \quad \sin^{-1}\left(\frac{1}{2\mu}\right) \quad \text{(B)} \quad \cos^{-1}\left(\frac{1}{2\mu}\right) \quad \text{(C)} \quad \cot^{-1}\left(\frac{1}{2\mu}\right) \quad \text{(D)} \quad \frac{1}{2\mu} \quad \text{(E)}
\]
### Answer Key

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