# AP Physics C Exam Cram Sheet (Ver. 1.0)

## General Reminders

1. Look elsewhere for most of the equations, and remember: concepts come before the equations, not the other way around.
2. Choose a coordinate system that best suits Newton's Laws. Try and get one of the axes to be so that $\Sigma F = 0$ in that direction. Otherwise, use $\Sigma F_x = a_x$, and $\Sigma F_y = a_y$, and $a_{resultant}$ = vector sum of the components.
3. For FR problems that require a solution in terms of given variables, use the variables given, not your own.
4. For FR problems where you have to draw a graph, be able to determine and understand the significance of the x-intercept, y-intercept, the slope and the area under the graph. Also, be able to map x to y and y to x. I know it sounds simple, but students overlook it every year.
5. For FR problems, show all work (including verbalizing your thought processes in arriving at a deduction or assumption).
6. Work done by a force is ALWAYS POSITIVE if the force and the direction the force goes are in the same direction.
7. Remember the things that are conserved: Mass and energy, linear momentum, angular momentum, electric charge.

## Mechanics

1. The direction an object accelerates is not necessarily the same direction it moves.
2. If acceleration and velocity are parallel, the object speeds up; antiparallel, slow down. Right angles, circular constant speed. Anything else is some kind of curved path.
3. Parabolas on position-time graphs mean non-zero-slope straight lines on velocity-time graphs which mean zero-slope (horizontal) lines on acceleration-time graphs.
4. If you're asked to write a differential or integral equation, don't forget the differential.
5. Area under a velocity time graph is displacement (change in position). Areas below the time axis represent negative displacements.
6. The derivative of position is velocity; the derivative of velocity is acceleration.
7. Area under an acceleration time graph is change in velocity.
8. Watch out for using the equations for constant acceleration when the acceleration is not constant.
9. Be able to go backwards and forwards with differentiation and integration from position to velocity to acceleration.
10. The direction of the acceleration vector is the same direction as that of the change in velocity vector.
11. If you have a non-linear velocity function, the only way to get the average velocity is to integrate the area and then divide by time.
12. As a falling object approaches terminal velocity, speed increases and acceleration decreases.
13. Newton's 1st or 2nd Law always applies. Newton's 3rd Law always applies.
14. If the object is at rest or moving at a constant velocity, N1 applies. Otherwise N2 applies.
15. You may think Newton's 2nd Law says $F = ma$, but it really says $F = \frac{dp}{dt}$. Sometimes the **mass** changes in addition to the speed. (Think rockets and spaceships).
16. Moving through air or water introduces a drag force, which typically is proportional to speed. Know how to determine the terminal velocity, and then know how to get from a differential equation describing the acceleration to an equation for the velocity as a function of time.
17. If an object is moving in a curve, there must be a net force towards the inside of the curve.
18. If an object is moving in a circle, there must be a component of the net force towards the center equal to $F_\perp = m\frac{u^2}{r}$.
19. The centripetal force is always a force easily identified (or the component of one…), e.g., friction, tension, gravity, normal, or combinations.
20. The only force on any projectile (neglecting air friction) is the projectile's weight (directed downwards).
21. Watch out for variations on projectiles where there is a constant acceleration in a direction other than downwards.
22. A ball rolled off a horizontal table will take the same amount of time to hit the ground as another dropped from the same height.
23. The tension in a rope holding an object in equilibrium is equal to the weight of the object. If the object is accelerating upwards, $T > mg$. If the object is accelerating downwards, $T < mg$.
24. The angle of an inclined plane is the same as the angle between the line of weight of the object on the incline and the normal line.
25. For circular motion, choose a coordinate system that uses radial and tangential lines as axes.
26. Static friction is a range of values such that $0 \le f_s \le \mu N$. Kinetic (sliding) friction is just $f_k = \mu N$.
27. The center of mass is calculated by using the general equation $M_{total} x_{c.m.} = \sum m_i x_i$.
28. To find the center of mass of an irregularly shaped object, split it up into regular objects and add 'em up.

29. Know how to integrate to find the center of mass: $M\vec{r} = \int \vec{r}\, dm$.
30. The mass of a satellite doesn't matter. The only thing that matters is the mass of the thing being orbited and the orbital radius.
31. Geosynchronous orbit is approximately 22,300 mi. above the earth's surface on the equatorial plane.
32. The closer a satellite is to what it orbits, the faster its orbital speed.
33. For satellites, the centripetal force is gravity: $F = \frac{GMm}{r^2} = \frac{m\upsilon^2}{r}$ (assuming the orbit is circular and $M >>> m$).
34. For satellites and planets (and other objects considered to be point masses), angular momentum ($L = m\upsilon r$) is always conserved (in the absence of any outside forces/torques). In other words, the closer a planet is to the sun, the faster it goes.
35. The paths of planets and satellites are approximately circular, but are actually elliptical.
36. The gravitational force (and the resulting acceleration) due to a planet varies directly with the distance from the center of the planet when the object is INSIDE the planet.
37. The gravitational force (and the resulting acceleration) due to a planet varies inversely with the square of the distance from the center of the planet when the object is outside the planet.
38. A planet's gravitational field is greatest at its surface (assuming it's spherical).
39. A planet's measured gravitational field is less at the equator than at the poles due to the planet's rotation.
40. The tension in a string holding up an object is not always equal to the object's weight.
41. The normal force exerted on an object (even on a horizontal surface) is not always equal to the object's weight.
42. The direction an object will go is the same as the direction of the unbalanced force that makes it go, only if the initial speed is zero.
43. For (modified) Atwood's machines, consider a general direction for the acceleration, even if it's not obvious.
44. Conical pendulums: $T_y = mg$, $T_x = m\upsilon^2/r$.
45. In N3, the reaction force is always the same kind of force as the first one (the reaction to a frictional force is another frictional force, the reaction to a gravitational force is another gravitational force).
46. The Law of Conservation of Momentum is based on the action-reaction pair of forces in Newton's 3rd Law.
47. If conservative forces are the only forces doing work, mechanical energy is conserved.
48. Work done by conservative forces is path independent.
49. Power is the time rate of change of work or energy, but it can also be calculated using force × speed.
50. spring : pendulum :: spring constant : gravity :: mass attached : length.
51. If a mass on a spring hangs at rest a distance *d*, it will fall a distance 2*d* (measured from where the spring has no potential energy).
52. In a collision between massive particles, momentum is ALWAYS conserved.
53. "Inelastic collisions" mean kinetic energy is not conserved.
54. "Completely inelastic" only means the objects stick together, not that all energy is lost (although some must be lost or gained – hence the term "inelastic").
55. "Perfectly elastic" means kinetic energy is conserved.
56. The first step in any torque problem is to determine the point about which torques are calculated.
57. The work done by any centripetal force is always zero.
58. The mass of a simple pendulum doesn't matter.
59. If an object strikes a surface, the normal force exerted on the object must include the force required to change the object's momentum.
60. Normal forces generally don't do work.
61. If two objects with mass collide, you MUST use momentum conservation at some point.
62. Consider variations on the ballistic pendulum (e.g., 1995:1).
63. The area under a force-position (displacement) graph is work (energy).
64. The work done in stopping an object is equal to its initial kinetic energy (likewise, the work done in getting an object up to speed is equal to its final kinetic energy).
65. In any before-after situation, if there is a change in kinetic energy, work must have been done by some force somewhere.
66. Conservative fields are defined by potential energy functions (gravitational, elastic, electric). Watch out for the hypothetical conservative field.
67. A force is conservative if the work it does on a particle is zero when the particle moves around ***any*** closed path, returning to its initial position.
68. The restoring force is the negative of the integral of the potential energy with respect to position $F_{restoring} = -\frac{dU}{dx}$.
69. Potential energy is generally considered an assigned (arbitrary) energy due to position.

70. If you’re being asked for the kinetic energy of an object, don’t be too quick to use $K = \frac{1}{2}mu^2$ unless the mass and speed are obvious and available. Think about using work-energy considerations.
71. Also, don’t forget the relation between kinetic energy and momentum: $K = \frac{p^2}{2m}$ .
72. Torque is a vector cross product. $\vec{\Gamma} = \vec{r} \times \vec{F} = rF\sin\theta$.
73. Work is a dot scalar product. $W = \vec{F} \cdot \Delta\vec{x} = F\Delta x\cos\theta$.
74. An object can be in translational or rotational equilibrium or both or neither.
75. Work done by kinetic friction is negative.
76. This equation goes a long way: $\omega = 2\pi f = \frac{2\pi}{T} = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{l}}$; know what $\omega$ means in different situations.
77. $\omega$ for SHM is angular frequency – how is that related to angular velocity?
78. For rotation, torque and SHM, make sure all angles are measured in radians.
79. Most linear quantities are the angular quantities× the radius (or moment arm). Notable exceptions are force/torque and linear/angular momentum (for example).
80. All of the equations that we use for constant linear acceleration can be used for constant angular acceleration, substituting $\theta$ for $x$, $\omega$ for $v$ and $\alpha$ for $a$.
81. Know how to derive the moment of inertia of a system of particles or an extended object. Of course, memorizing the moments of inertia comes in handy for a solid sphere, hollow sphere, solid cylinder or disk, point mass, cylindrical shell or ring, rod about center, and rod about end.
82. The parallel-axis theorem comes in real handy $I = I_{cm} + MR^2$. The moment of inertia of the center of mass must be about an axis that is parallel to the axis about which you wish to find the total moment of inertia.
83. Don’t let massive pulleys throw you off – it’s just another equation using torque. The tensions on either side are NOT the same. That’s what produces the unbalanced torque making the pulley rotate.
84. If gravity causes something to rotate (e.g., a falling rod pivoted at one end), gravity is constant, but the unbalanced torque caused by gravity is not.
85. Angular momentum, torque and moment of inertia are expressed relative to a chosen axis or point of rotation.

| Translation | | | Rotation | |
|---|---|---|---|---|
| **Symbol** | **Quantity** | **Relationship** | **Symbol** | **Quantity** |
| $x, y, r, s, d, l$ | Position, distance | $s = ru$ | $u$ | Angular position |
| $\bar{y} = \frac{Dx}{Dt}$ | Average velocity | | $\bar{v} = \frac{Du}{Dt}$ | Average angular velocity |
| $y = \frac{dx}{dt}$ | Instantaneous velocity | $y = rv$ | $v = \frac{du}{dt}$ | Inst angular velocity |
| $a = \frac{dy}{dt}$ | Instantaneous acceleration | $a_P = ra$ | $a = \frac{dv}{dt}$ | Instantaneous angular acceleration |
| $a_c = \frac{y^2}{r}$ | Centripetal acceleration | $a_c = v^2 r$ | NA | |
| $s = s_0 + y_0 t + \frac{1}{2}at^2$ | Constant acceleration | | $u = u_0 + v_0 t + \frac{1}{2}at^2$ | Constant angular acceleration |
| $y = y_0 + at$ | | | $v = v_0 + at$ | |
| $y^2 = y_0^2 + 2aDs$ | | | $v^2 = v_0^2 + 2aDu$ | |
| $\bar{y} = \frac{Ds}{Dt} = \frac{y + y_0}{2}$ | | | $\bar{v} = \frac{Du}{Dt} = \frac{v + v_0}{2}$ | |
| $m$ | mass | $I = \text{ò}\, r^2 dm$ | I | Moment of inertia |
| F | force | $\overset{v}{G} = \overset{v}{r} ' \overset{v}{F}$ | $G$ | torque |
| $F = ma$ | 2nd Law | | $G = Ia$ | 2nd Law |
| $p = my$ | Linear momentum | $\overset{uv}{L} = \overset{v}{r} ' \overset{uv}{p}$ | $L = Iv$ | Angular momentum |
| $J = \text{ò}\, Fdt$ | Linear impulse | | $J_u = \text{ò}\, Gdt$ | Angular impulse |
| $J = Dp$ | Impulse-momentum theorem | | $J_u = DL$ | Impulse-momentum theorem |
| $F = \frac{dp}{dt}$ | 2nd Law (original) | | $G = \frac{dL}{dt}$ | 2nd Law (original) |
| $F = - \frac{dU}{dx}$ | Conservative force | | $G = - \frac{dU}{du}$ | Conservative torque |
| $W = \text{ò}\, F \times dx$ | Work | | $W = \text{ò}\, G \times du$ | Work |
| $K = \frac{1}{2} my^2$ | Translational Kinetic Energy | | $K = \frac{1}{2} Iv^2$ | Rotational Kinetic Energy |
| $P = F\bar{y}$ | Power | | $P = G\bar{v}$ | Power |
| $F = - kx$ | Spring force | | $r_{cm} = \frac{S\, mr}{S\, m}$ | Center of mass |
| $U = \frac{1}{2} kx^2$ | Elastic Potential Energy | | | |
| $x = A\cos(vt + d)$ | Simple Harmonic Motion | | | |
| $y = - Av\sin(vt + d)$ | | | | |
| $a = - Av^2\cos(vt + d)$ | | | | |
| $U = - \frac{GMm}{r}$ | Gravitational Potential Energy | | | |
| $f \text{ £ } mN$ | friction | | | |