

AP Physics C: Mechanics Practice Worksheet

Fifty questions across calculus-based kinematics, Newton's laws, energy, momentum, rotation, and oscillations/gravitation. Questions 45 to 50 ask for written explanations.

QUESTIONS	50	MULTIPLE CHOICE	11	WRITTEN	39
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Instructions

Show the calculus setup, not just the final number. Use $g = 9.8 \text{ m/s}^2$.

- 1** Position is $x(t) = t^3 - 2t$. Find $v(t)$.

- 2** Using $x(t) = t^3 - 2t$, find $v(2)$.

- 3** Velocity is $v(t) = 4t + 1$. Find $a(t)$.

- 4** Acceleration is $a(t) = 6t$. Given $v(0)=0$, find $v(t)$.

- 5** Using $v(t) = 3t^2$ and $x(0) = 5$, find $x(t)$.

- 6** If $x(t)$ is position, what does d^2x/dt^2 represent?

A) Velocity
B) Acceleration
C) Jerk
D) Displacement

- 7** Find the work done by a variable force $F(x) = 3x$ from $x=0$ to $x=4$. ($W = \text{INT } F \, dx$)

- 8** Newton's second law in calculus form is written as:

A) $F = m \, dx/dt$
B) $F = m \, d^2x/dt^2$
C) $F = m \, \text{INT } v \, dt$
D) $F = m/a$

- 9** A potential energy function is $U(x) = 5x^2$. Find $F(x) = -dU/dx$.

- 10** Power is defined as:

A) Work times time
B) The rate of doing work (dW/dt)
C) Force times distance only
D) Mass times velocity

- 11** Two point masses: 2 kg at $x=0$ and 6 kg at $x=4$. Find the center of mass. ($x_{cm} = \frac{\sum(m \times x)}{\sum(m)}$)

- 12** Three masses: 1 kg at $x=0$, 2 kg at $x=2$, 3 kg at $x=6$. Find the center of mass. (round to 2 decimals)

- 13** A variable force acts for 3 seconds with impulse $J = 15 \text{ kg}\cdot\text{m/s}$. Find the change in momentum.

- 14** A 2 kg object's momentum changes from $4 \text{ kg}\cdot\text{m/s}$ to $10 \text{ kg}\cdot\text{m/s}$ over 2 s. Find the average force. ($F = \frac{\Delta p}{\Delta t}$)

- 15** Momentum is conserved in a system when:
- A) Kinetic energy is conserved
 - B) No net external force acts on the system
 - C) The collision is elastic
 - D) The objects have equal mass

- 16** Find the moment of inertia of a point mass of 3 kg at radius 2 m from the axis. ($I = mr^2$)

- 17** The rotational analog of Newton's second law is:
- A) $F = ma$
 - B) $\tau = I \alpha$
 - C) $p = mv$
 - D) $W = Fd$

- 18** Find the rotational kinetic energy of an object with $I=6 \text{ kg}\cdot\text{m}^2$ rotating at 4 rad/s.

- 19** An object has angular momentum $L=12 \text{ kg}\cdot\text{m}^2/\text{s}$ and moment of inertia $I=4 \text{ kg}\cdot\text{m}^2$. Find its angular velocity.

- 20** Angular momentum is conserved when:
- A) A constant torque acts
 - B) No net external torque acts
 - C) The moment of inertia is constant
 - D) The object is not rotating

- 21** A system is in simple harmonic motion if its acceleration is:
- A) Constant
 - B) Proportional to displacement and opposite in direction
 - C) Proportional to velocity
 - D) Always zero

- 22** A spring has $k=200 \text{ N/m}$ and a mass of 2 kg is attached. Find the period. ($T=2\pi\sqrt{m/k}$, round to 2 decimals)

- 23** Find the gravitational force between two 5 kg masses separated by 2 m. ($F=G \times m_1 \times m_2 / r^2$, $G=6.674 \times 10^{-11}$)

24 As the separation between two masses doubles, the gravitational force between them:

- A) Doubles
- B) Halves
- C) Quarters
- D) Stays the same

25 Find the orbital velocity for a satellite where $G \times M/r = 4.0 \times 10^7 \text{ m}^2/\text{s}^2$. ($v = \sqrt{G \times M/r}$)

26 Differentiate $x(t) = 5t^2 - 3t + 2$ to find velocity.

27 Differentiate $v(t) = 10t - 3$ to find acceleration.

28 Integrate $a(t) = 4$ (constant) with $v(0)=2$ to find $v(t)$.

29 Which best describes work done by a constant force over a straight-line displacement?

- A) $W = F/d$
- B) $W = F \times d \times \cos(\theta)$
- C) $W = F + d$
- D) $W = m \times d$

30 A 3 kg object falls from rest under gravity for 2 s (ignore air resistance). Use calculus ($a=g$ constant) to find $v(2)$. ($v = \int g \, dt$ from 0 to 2)

31 Using the same object, find the distance fallen in 2 s. ($x = \int v(t) \, dt$)

32 Which of these is NOT part of the AP Physics C: Mechanics curriculum?

- A) Rotational dynamics
- B) Simple harmonic motion
- C) Fluids and buoyancy
- D) Center of mass

33 A force does work $W = \int_0^3 (2x + 1) \, dx$. Evaluate this integral.

34 The center of mass of a uniform rod of length L (measured from one end) is located at:

- A) 0
- B) $L/4$
- C) $L/2$
- D) L

35 A 4 kg cart moving at 3 m/s collides elastically with an identical stationary 4 kg cart and stops completely. Find the velocity of the second cart after collision (by momentum conservation).

36 Explain why the derivative of position with respect to time gives velocity, using the definition of a derivative as a limit.

- 37** Explain why $F(x) = -dU/dx$, using the relationship between conservative forces and potential energy.

- 38** Explain why integrating over a variable force is necessary to find work, rather than simply using $W=Fd$.

- 39** Explain why moment of inertia depends on how mass is distributed relative to the axis, not just total mass.

- 40** A rotating skater pulls their arms in and speeds up. Explain this using calculus-based reasoning about angular momentum $L = I \times \omega$.

- 41** Explain why the period of a mass on a spring ($T=2\pi \times \sqrt{m/k}$) does not depend on amplitude.

- 42** Explain why Newton's law of gravitation follows an inverse-square relationship, in terms of how gravitational influence spreads through space.

- 43** A block slides down a frictionless incline. Explain, using energy methods rather than forces, how to find its speed at the bottom.

- 44** Explain the difference between center of mass motion and rotational motion for a spinning, translating object like a thrown wrench.

- 45** A 20 N force is applied at a 30-degree angle to a lever arm of length 0.5 m. Find the torque. ($\tau = F r \sin(\theta)$)

- 46** A 2 kg object's kinetic energy changes from 10 J to 40 J due to a net force. Find the work done by the net force, using the work-energy theorem.

- 47** Find the gravitational potential energy between two masses ($U=-G \times m_1 \times m_2 / r$) with $m_1=10$ kg, $m_2=20$ kg, $r=5$ m, $G=6.674 \times 10^{-11}$. (round to 2 significant figures in scientific notation)

- 48** Two objects collide: 3 kg moving at 4 m/s and 2 kg moving at -1 m/s. Find the velocity of their center of mass. ($v_{cm} = (m_1 v_1 + m_2 v_2) / (m_1 + m_2)$)

49

In a damped oscillator, describe what happens to the amplitude over time and why.

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A torque of $10 \text{ N}\cdot\text{m}$ acts through an angular displacement of 3 radians. Find the rotational work done. ($W = \tau \times \theta$)

Answer key

Direct answers only, in question order. Work the set first, then check.

1. $3t^2 - 2$	2. 10	3. 4	4. $3t^2$	5. $t^3 + 5$
6. B) Acceleration	7. 24 J (INT[0,4] $3x dx = 1.5x^2$ evaluated = 24)	8. B) $F = m d^2x/dt^2$	9. -10x	10. B) The rate of doing work (dW/dt)
11. 3.0	12. 3.67	13. 15	14. 3.0	15. B) No net external force acts on the system
16. 12	17. B) $\tau = I \alpha$	18. 48.0	19. 3.0	20. B) No net external torque acts
21. B) Proportional to displacement and opposite in direction	22. 0.63	23. $4.17e-10$	24. C) Quarters	25. 6324.6
26. $10t - 3$	27. 10	28. $4t + 2$	29. B) $W = F \times d \times \cos(\theta)$	30. 19.6
31. 19.6	32. C) Fluids and buoyancy	33. $x^2 + x$ evaluated from 0 to 3 = 12	34. C) $L/2$	35. 3
36. Velocity is the instantaneous rate of change of position, which is precisely what a derivative measures: the limit of the average rate of change (displacement over a shrinking time interval) as that interval approaches zero	37. A conservative force always points in the direction that decreases potential energy most steeply; the derivative dU/dx gives the rate of increase of U, so the negative of that slope gives the direction and magnitude of the restoring force	38. $W = Fd$ only applies when force is constant; if force varies with position, the work done over each infinitesimal displacement dx must be summed (integrated) as $F(x)dx$ across the entire path to account for the changing force	39. Moment of inertia is $I = \int r^2 dm$, so mass located farther from the axis (larger r) contributes more to I than the same mass located closer to the axis, even though total mass is unchanged	40. With no external torque, $L = I \times \omega$ remains constant; decreasing I (by pulling arms in) requires ω to increase proportionally to keep the product L constant, so the skater's rotation speeds up

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| <p>41. The differential equation for SHM, $d^2x/dt^2 = -(k/m)x$, has a period determined entirely by the ratio k/m; amplitude affects how far the mass travels but not how quickly it completes each cycle, since both the restoring force and the distance traveled scale together with amplitude</p> | <p>42. As distance from a mass increases, its gravitational influence spreads out over the surface of an expanding sphere, whose area grows with the square of the radius, so the force per unit area (and thus the gravitational pull) decreases with the square of the distance</p> | <p>43. Using conservation of energy, the gravitational potential energy lost (mgh) converts entirely into kinetic energy ($\frac{1}{2} m v^2$) since there is no friction to dissipate energy, so setting $mgh = \frac{1}{2} m v^2$ and solving for v gives the speed regardless of the incline's angle or shape</p> | <p>44. The center of mass follows a simple parabolic trajectory under gravity, as if all the mass were concentrated at that point, while the object simultaneously rotates about its own center of mass independently; the two motions can be analyzed separately and then combined</p> | <p>45. 5</p> |
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| <p>46. 30</p> | <p>47. $-2.7 \times 10^{-9} \text{ J}$</p> | <p>48. 2.0</p> | <p>49. The amplitude decreases (decays) over time because a resistive force, such as friction or air resistance, continuously removes mechanical energy from the system</p> | <p>50. 30</p> |
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Error log

Bring this page to your next session so the tutor can start from what actually blocked you.

Questions I answered incorrectly:

Was it the physics model, the calculus setup, or the evaluation?

The single topic I want to start the next session with:
