

Work as an integral and potential energy curves

AP Physics C (Mechanics and E&M, calculus-based) · Test answers (mark scheme)

Model answers and marking guidance. Method marks are given for correct setting-up of integrals and derivatives even when the arithmetic is wrong. Do not penalise a unit slip twice, and apply error carried forward where later parts use an earlier incorrect number.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 3

Question 1 Conservative force (2 marks)

a. A force whose work between two points is independent of the path taken. b. $\mathbf{F} = -dU/dx$.
Marking: 1 mark each.

Question 2 Variable force (3 marks)

a. $W = \int_0^2 (2.0x + 3.0x^2) dx = x^2 + x^3 = 4.0 + 8.0 = \mathbf{12\ J}$. b. $v = \sqrt{(2 \times 12/1.5)} = \sqrt{16} = \mathbf{4.0\ m/s}$.

Marking: 1 mark for the integral set-up, 1 for 12 J, 1 for the speed.

Question 3 Energy diagram (4 marks)

a. The minimum is at $\mathbf{x = 3.0\ m}$. b. $2.0(x - 3.0)^2 = 8.0$ gives $x - 3.0 = \pm 2.0$, so $\mathbf{x = 1.0\ m}$ and $\mathbf{5.0\ m}$. c. $K_{\max} = 8.0\ J$, so $v = \sqrt{(2 \times 8.0/0.50)} = \mathbf{5.7\ m/s}$. d. $F = -dU/dx = -4.0(x - 3.0) = \mathbf{-4.0\ N}$ at $x = 4.0\ m$ (towards the minimum).

Marking: 1 mark per part.

Question 4 Equilibrium (3 marks)

a. $dU/dx = 6.0x - 6.0x^2 = 0$, so $\mathbf{x = 0}$ and $\mathbf{x = 1.0\ m}$. b. $d^2U/dx^2 = 6.0 - 12x$: at $x = 0$ it is $+6.0$, so **stable**; at $x = 1.0\ m$ it is -6.0 , so **unstable**.

Marking: 1 mark for positions, 1 mark for each classification with the second derivative.

Question 5 Spring launcher (2 marks)

a. $\frac{1}{2}kx^2 = \frac{1}{2} \times 300 \times (0.12)^2 = \mathbf{2.2\ J}$. b. $v = \sqrt{(2 \times 2.16/0.20)} = \mathbf{4.6\ m/s}$.

Marking: 1 mark each; accept 2.16 J carried forward.

Question 6 Leaving the Moon (2 marks)

a. $W = GMm/R = (6.67 \times 10^{-11} \times 7.35 \times 10^{22})/(1.74 \times 10^6) = \mathbf{2.8 \times 10^6 \text{ J}}$. b. $v = \sqrt{(2 \times 2.82 \times 10^6)} = \mathbf{2.4 \times 10^3 \text{ m/s}}$.

Marking: 1 mark each.

Question 7 Turning points (2 marks)

Since $E = K + U$ and $K \geq 0$, a position with $U > E$ would need negative kinetic energy, which is impossible. At $U = E$ the kinetic energy is zero, so the particle is momentarily at rest and **reverses direction**.

Marking: 1 mark for K cannot be negative; 1 mark for the stop and reversal.

Question 8 Engine power (2 marks)

a. $P = Fv$. b. $F = P/v = 15\,000/25 = \mathbf{6.0 \times 10^2 \text{ N}}$.

Marking: 1 mark each.