SHOWING SOLUTIONS

Monday, 8 December 2026
9:30 – 11:30

EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE

Physics 3 – Physics with Astrophysics 3

PHYS3021

[PHYS3021]

Classical Mechanics

Candidates should answer **all** questions. Each question carries the marks shown.

Answer each question in a separate booklet

Candidates are reminded that devices able to store or display text or images may not be used in examinations without prior arrangement.

Approximate marks are indicated in brackets as a guide for candidates.

Author: J. Halliday

1 (a) A particle of mass m moves in one dimension under a restoring force $F(x) = -kx$. Write down its equation of motion and give the general solution for $x(t)$. **[6]**

Solution: $m\ddot{x} = -kx$, so $x(t) = A\cos(\omega t) + B\sin(\omega t)$ with $\omega = \sqrt{k/m}$.

(b) The particle starts at rest at $x_0 = 0.2\,\mathrm{m}$ with $k/m = 4\,\mathrm{s}^{-2}$. Find $x(t)$ explicitly. **[8]**

Solution: $\omega = 2\,\mathrm{s}^{-1}$; with $x(0) = x_0$ and $\dot{x}(0) = 0$ this gives $x(t) = 0.2\,\mathrm{m}\cos(2t)$.

(c) State the period of the oscillation found above. **[6]**

Solution: $T = 2\pi/\omega = \pi\,\mathrm{s} \approx 3.14\,\mathrm{s}$.

[Total: 20 OK]

Author: J. Halliday

2 A satellite of mass m orbits a planet of mass M in a circular orbit of radius r.

(a) Derive an expression for the orbital speed v in terms of G, M and r. **[10]**

Solution: Setting gravitational force equal to centripetal force, $GMm/r^2 = mv^2/r$, so $v = \sqrt{GM/r}$.

(b) Derive Kepler's third law, $T^2 \propto r^3$, from the result above. **[10]**

Solution: $T = 2\pi r/v = 2\pi r^{3/2}/\sqrt{GM}$, so $T^2 = (4\pi^2/GM)\,r^3$, i.e. $T^2 \propto r^3$.

(c) A second satellite orbits at $4r$. Find the ratio of its period to that of the first satellite. **[10]**

Solution: $T_2/T_1 = (4r/r)^{3/2} = 4^{3/2} = 8$.

[Total: 30 OK]

Author: J. Halliday

3 **Check numeric answer against the solutions key before final print.** A rigid rod of length L and mass m is pivoted at one end and released from rest in a horizontal position. **[5]**

(a) Write down the moment of inertia of the rod about the pivot.

$$I = \tfrac{1}{3}mL^2.$$

(b) Using energy conservation, find the angular speed ω of the rod as it passes through the vertical position. **[12]**

Solution: The centre of mass falls a height $L/2$, so $mg(L/2) = \frac{1}{2}I\omega^2$, giving $\omega = \sqrt{3g/L}$.

(c) Find the linear speed of the free end of the rod at that instant. **[8]**

Solution: $v = \omega L = \sqrt{3gL}$.

[Total: 25 OK]

End of Draft Paper

NOTE: SHOWING SOLUTIONS

NOTE: Check numeric answer against the solutions key before final print.