S4 Physics Practice Paper: Newton's Laws and Friction, Momentum and Collisions, Work and Power, Circular Motion and Satellite Periods, Gas Laws, Lenses and Total Internal Reflection

S4 | Physics | Time: 75 minutes | Total: 100 marks | 24 questions

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Forces and Motion

Part A: Newton's laws and friction (16 marks)

1. A 2.0 kg trolley on a frictionless track is acted on by a horizontal net force of 6.0 N. Find its acceleration. [4]

Answer: a = F/m = 6.0/2.0 = 3.0 m/s^2 in the direction of the net force.

2. A 5.0 kg box rests on a horizontal floor. The coefficient of kinetic friction is 0.30 and a horizontal push of 20 N is applied (g = 9.8 m/s^2). Find the friction, the net force and the acceleration. [4]

Answer: Normal force = 5.0 x 9.8 = 49 N, friction = 0.30 x 49 = 14.7 N; net force = 20 - 14.7 = 5.3 N; a = 5.3/5.0 = 1.1 m/s^2.

3. A 10 kg mass hangs from a rope inside a lift that accelerates upwards at 2.0 m/s^2. Find the tension in the rope. [4]

Answer: T - mg = ma, so T = m(g + a) = 10 x (9.8 + 2.0) = 118 N.

4. A 0.15 kg ball hits a wall at 8.0 m/s and rebounds at 6.0 m/s. The contact time is 0.050 s. Find the magnitude of the change in momentum and the average force from the wall. [4]

Answer: dp = 0.15 x (8.0 + 6.0) = 2.1 kg m/s; average force = 2.1/0.050 = 42 N away from the wall.

Momentum and Collisions

Part B: Momentum and collisions (16 marks)

5. A 2.0 kg object moving at 3.0 m/s collides with a stationary 1.0 kg object and they stick together. Find the common velocity. [4]

Answer: By conservation of momentum: 2.0 x 3.0 = (2.0 + 1.0) x v, so v = 6.0/3.0 = 2.0 m/s.

6. Two 2.0 kg objects make an elastic collision: the first moves at 3.0 m/s and hits the second, which is at rest. Find their velocities after the collision. [4]

Answer: In an elastic collision between equal masses the velocities are exchanged: the first stops (0 m/s) and the second moves at 3.0 m/s.

7. Using the situation in question 5 (2.0 kg at 3.0 m/s sticks to a stationary 1.0 kg), find the kinetic energy lost and its percentage of the initial kinetic energy. [4]

Answer: Initial KE = 0.5 x 2.0 x 3.0^2 = 9.0 J; final KE = 0.5 x 3.0 x 2.0^2 = 6.0 J; loss = 3.0 J, i.e. 33%.

8. A 3.5 kg rifle fires a 0.020 kg bullet horizontally at 400 m/s. Find the recoil speed of the rifle and the ratio of the bullet kinetic energy to the rifle kinetic energy. [4]

Answer: Momentum: 0.020 x 400 = 3.5 x v, so v = 8.0/3.5 = 2.3 m/s; KE ratio = 3.5/0.020 = 175, i.e. 175 : 1.

Work, Power and Energy

Part C: Work, power and energy (17 marks)

9. A 45 kg person runs up stairs to a height of 12 m in 8.0 s (g = 9.8 m/s^2). Find the average power used against gravity. [4]

Answer: W = 45 x 9.8 x 12 = 5292 J; P = 5292/8.0 = 662 W (about 6.6 x 10^2 W).

10. A 1200 kg car accelerates from rest to 25 m/s. Find the kinetic energy gained. [4]

Answer: KE = 0.5 x 1200 x 25^2 = 3.75 x 10^5 J.

11. A motor takes in 4800 J of energy and raises a load whose gravitational potential energy increases by 1680 J. Find the efficiency of the motor. [4]

Answer: Efficiency = 1680/4800 x 100% = 35%.

12. A 6.0 kg object is pushed 3.0 m up a ramp to rise 1.2 m. The efficiency of the ramp is 60%. Find the push needed and the energy lost to friction. [5]

Answer: Useful work = 6.0 x 9.8 x 1.2 = 70.6 J; input work = 70.6/0.60 = 117.6 J; push = 117.6/3.0 = 39 N; loss about 47 J.

Circular Motion and Satellites

Part D: Circular motion and satellite periods (17 marks)

13. A 0.50 kg object moves at 2.0 m/s in a circle of radius 0.80 m. Find the centripetal force and the period. [4]

Answer: F = mv^2/r = 0.50 x 2.0^2/0.80 = 2.5 N; T = 2 pi r/v = 2 pi x 0.80/2.0 = 2.5 s.

14. A 900 kg car goes round a flat bend of radius 60 m; the maximum friction between tyres and road is 5400 N. Find the maximum safe speed. [4]

Answer: mv^2/r = f, so v = sqrt(5400 x 60/900) = sqrt(360) = 19 m/s.

15. Two satellites have orbital radii in the ratio 1 : 4; the nearer one has a period of 3.0 hours. Find the period of the other (use T proportional to r^1.5). [4]

Answer: Four times the radius gives 4^1.5 = 8 times the period, i.e. 3.0 x 8 = 24 hours.

16. A geostationary satellite has an orbital radius of 4.2 x 10^7 m and a period of 24 hours. Find its orbital speed. [5]

Answer: T = 86400 s; v = 2 pi r/T = 2 pi x 4.2 x 10^7/86400 = 3.1 x 10^3 m/s.

Gas Laws

Part E: Gas laws (17 marks)

17. A fixed mass of gas has a volume of 2.0 L at 300 K. It is heated to 450 K at constant pressure. Find the new volume. [4]

Answer: V/T is constant: V = 2.0 x 450/300 = 3.0 L.

18. A fixed mass of gas at 2.0 L has a pressure of 1.0 x 10^5 Pa. It is compressed to 0.50 L at constant temperature. Find the new pressure. [4]

Answer: pV is constant: p = 1.0 x 10^5 x 2.0/0.50 = 4.0 x 10^5 Pa.

19. Find the number of moles in 2.0 L of gas at 300 K and 1.0 x 10^5 Pa (R = 8.31 J mol^-1 K^-1). [4]

Answer: n = pV/RT = (1.0 x 10^5 x 2.0 x 10^-3)/(8.31 x 300) = 0.080 mol.

20. A 3.0 L container holds 0.10 mol of gas at 300 K. Find the pressure of the gas. [5]

Answer: p = nRT/V = 0.10 x 8.31 x 300/(3.0 x 10^-3) = 8.3 x 10^4 Pa.

Lenses and Refraction

Part F: Lenses and total internal reflection (17 marks)

21. A convex lens of focal length 10 cm has an object 30 cm in front of it. Find the image distance and magnification, and state the nature of the image. [4]

Answer: 1/v = 1/10 - 1/30 = 1/15, so v = 15 cm; m = 15/30 = 0.50, giving an inverted, diminished real image.

22. For the same convex lens (f = 10 cm) the object is 15 cm in front of the lens. Find the image distance and magnification. [4]

Answer: 1/v = 1/10 - 1/15 = 1/30, so v = 30 cm; m = 30/15 = 2.0, giving an inverted, magnified real image.

23. For the same convex lens (f = 10 cm) the object is 5.0 cm in front of the lens. Find the image distance, magnification and nature of the image. [4]

Answer: 1/v = 1/10 - 1/5 = -1/10, so v = -10 cm; m = 10/5 = 2.0, giving a virtual, upright, magnified image on the same side as the object.

24. Light travels from glass (refractive index 1.50) into air. Find the critical angle and decide whether total internal reflection occurs at an angle of incidence of 45 degrees. [5]

Answer: sin(theta_c) = 1/1.50, so theta_c = 41.8 degrees; 45 degrees exceeds the critical angle, so total internal reflection occurs.
