S4 Physics Practice Paper

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

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Part 1: Kinematics and Newton's Laws (18 marks)

Show the formula, the substitution and the unit in every answer. Take g = 10 m/s2.

1. A car starts from rest and accelerates uniformly at 2.5 m/s2 for 8 s. Find (a) its speed after 8 s, and (b) the distance it travels in 8 s.

Answer: Given u = 0, a = 2.5 m/s2 and t = 8 s. (a) v = u + at = 0 + 2.5 × 8 = 20 m/s. (b) s = ut + 1/2 at^2 = 0.5 × 2.5 × 8^2 = 80 m.

2. A car travelling at 20 m/s decelerates uniformly at 5 m/s2 until it stops. Find the braking time and the braking distance, and explain why the real braking distance is usually longer than the calculated value.

Answer: Take deceleration a = -5 m/s2 and final speed v = 0. Time: t = (v - u)/a = (0 - 20)/(-5) = 4 s. Distance: s = u^2/(2a) = 20^2/(2 × 5) = 40 m. The real distance is longer because the calculation assumes constant deceleration and no reaction time; in practice the car keeps moving during the driver reaction time, a wet road reduces the deceleration, and brake fade weakens the braking force.

3. A car of mass 1,200 kg accelerates at 1.5 m/s2. If the resistive force is 400 N, find (a) the net force on the car, and (b) the driving force produced by the engine.

Answer: (a) From F = ma, net force = 1200 × 1.5 = 1800 N. (b) Net force = driving force - resistive force, so driving force = 1800 + 400 = 2200 N.

4. Two forces of 6 N and 8 N act at the same point and are perpendicular to each other. Find (a) the magnitude of the resultant, and (b) the angle between the resultant and the 8 N force.

Answer: (a) Perpendicular vectors add by Pythagoras: R = sqrt(6^2 + 8^2) = sqrt(100) = 10 N. (b) tan θ = 6/8, so θ = tan^-1(0.75) = 36.9°, measured from the 8 N force.

Part 2: Momentum, Moments and Pressure (17 marks)

Take the initial direction of motion as positive; for collisions state both momentum conservation and the change in energy.

5. A ball of mass 0.5 kg hits a wall at 8 m/s and rebounds at 6 m/s along the same line. If the contact time is 0.05 s, find (a) the change in momentum of the ball, and (b) the average force exerted by the wall on the ball.

Answer: Take the initial direction as positive: u = +8 m/s and v = -6 m/s. (a) Δp = m(v - u) = 0.5 × (-6 - 8) = -7 kg m/s, size 7 N s, opposite to the initial velocity. (b) F = Δp/Δt = 7/0.05 = 140 N, directed away from the wall.

6. A 2 kg object moving at 3 m/s collides with a stationary 1 kg object and they stick together. Find (a) their common velocity, and (b) the kinetic energy before and after the collision, and explain where the energy goes.

Answer: (a) Momentum is conserved: 2 × 3 = (2 + 1)v, so v = 2 m/s. (b) Before: KE = 0.5 × 2 × 3^2 = 9 J. After: KE = 0.5 × 3 × 2^2 = 6 J, a loss of 3 J. The lost kinetic energy becomes heat and sound and permanently deforms the objects, which is the signature of a perfectly inelastic collision.

7. A 30 kg child sits 1.6 m from the pivot on one side of a see-saw. How far from the pivot on the other side must a 40 kg adult sit to balance it?

Answer: Take moments: 30 × 10 × 1.6 = 40 × 10 × x. x = (30 × 1.6)/40 = 1.2 m from the pivot. (g cancels on both sides, so the mass ratio alone also gives the answer.)

8. A person weighing 600 N stands on both feet with a total contact area of 0.03 m2. Find (a) the pressure on the ground, and (b) the water pressure on him at a depth of 2.5 m (water density 1,000 kg/m3, g = 10 m/s2).

Answer: (a) p = F/A = 600/0.03 = 20000 Pa. (b) p = ϱgh = 1000 × 10 × 2.5 = 25000 Pa. Water pressure depends only on depth, density and g, not on the person's weight or posture.

Part 3: Work, Energy and Power (17 marks)

In energy conservation questions state which form of energy changes into which. Ignore air resistance.

9. A student of mass 50 kg runs up a staircase of height 12 m in 20 s. Find (a) the work done against gravity, and (b) the average power output.

Answer: (a) W = mgh = 50 × 10 × 12 = 6000 J. (b) P = W/t = 6000/20 = 300 W. The real power output is larger because the body also accelerates the legs and overcomes internal friction.

10. A ball of mass 0.2 kg moves at 15 m/s. Find its kinetic energy, and state how many times larger the kinetic energy becomes if its speed doubles.

Answer: KE = 1/2 mv^2 = 0.5 × 0.2 × 15^2 = 22.5 J. When the speed doubles, v^2 becomes four times larger and the mass is unchanged, so the kinetic energy becomes four times larger.

11. A motor with an input power of 1,500 W lifts a 40 kg load at a steady speed of 1.2 m/s. Find (a) the useful power output, and (b) the efficiency of the motor.

Answer: (a) At steady speed the lifting force equals the weight: useful power = mgv = 40 × 10 × 1.2 = 480 W. (b) Efficiency = useful/input × 100% = 480/1500 × 100% = 32%. The remaining input energy is lost as heating in the coils and as sound.

12. A 0.5 kg object falls freely from a height of 1.8 m. Find its speed when it reaches the ground and state which conservation law you used.

Answer: All the potential energy becomes kinetic energy: mgh = 1/2 mv^2, so v = sqrt(2gh) = sqrt(2 × 10 × 1.8) = 6 m/s. The law used is conservation of energy (mechanical energy is conserved); the mass 0.5 kg cancels on both sides, so the answer does not depend on it.

Part 4: Waves and Optics (16 marks)

For refraction and lens questions take the speed of light in air as c = 3.0 x 10^8 m/s and the speed of sound as 340 m/s.

13. A source emits sound of frequency 680 Hz; the speed of sound in air is 340 m/s. Find (a) the wavelength, and (b) the new wavelength if the frequency doubles while the speed stays the same.

Answer: (a) From v = fλ, λ = v/f = 340/680 = 0.5 m. (b) With the frequency doubled to 1360 Hz, λ = 340/1360 = 0.25 m, so the wavelength halves; wavelength is inversely proportional to frequency.

14. Light passes from air into a medium at an angle of incidence of 45° and is refracted at 30°. Find (a) the refractive index of the medium, and (b) the speed of light in the medium.

Answer: (a) By Snell law, n = sin i / sin r = sin 45° / sin 30° = 1.414. (b) n = c/v, so v = c/n = 3.0 x 10^8/1.414 = 2.12 x 10^8 m/s. A larger refractive index means slower light in the medium and a smaller critical angle, so total internal reflection is easier to obtain.

15. A convex lens has a focal length of 10 cm and an object is placed 15 cm in front of it. Find (a) the image distance, and (b) the magnification, and state whether the image is real or virtual.

Answer: (a) Using 1/f = 1/u + 1/v: 1/10 = 1/15 + 1/v, so 1/v = 1/10 - 1/15 = 1/30 and v = 30 cm. (b) Magnification m = v/u = 30/15 = 2. Since v is positive the image forms on the far side of the lens: it is inverted, magnified and real, so it can be caught on a screen.

16. A person shouts towards a cliff and hears the echo 0.6 s later. If the speed of sound is 340 m/s, find the distance to the cliff.

Answer: The sound travels twice the distance: 2d = vt = 340 × 0.6 = 204 m. d = 204/2 = 102 m. Indoors the wall is so close that the echo overlaps the original sound, so the sound just seems louder or blurred.

Part 5: Heat and Gases (16 marks)

Take the specific heat capacity of water as 4,200 J/(kg °C) and the latent heat of fusion of ice as 334,000 J/kg; assume no heat loss.

17. 2 kg of water is heated from 25 °C to 75 °C. Find the heat required and explain why more energy is needed in practice.

Answer: Temperature rise ΔT = 75 - 25 = 50 °C. Q = mcΔT = 2 × 4200 × 50 = 420000 J. More energy is needed in practice because heat also warms the container and the surrounding air and is lost by evaporation and convection.

18. 0.3 kg of water at 90 °C is added to 0.6 kg of water at 20 °C. Assuming no heat loss, find the final temperature.

Answer: Let the final temperature be T: 0.3 × 4200 × (90 - T) = 0.6 × 4200 × (T - 20). The c cancels: 39.0 = 0.9T, so T = 43.33 °C. It is close to the cold temperature because the cold water has twice the mass and can absorb more heat.

19. A fixed mass of gas at 100 kPa, 2 L and 300 K is compressed to 250 kPa and 1 L. Find the final temperature in K and state which gas law you used.

Answer: Use the combined gas law P1V1/T1 = P2V2/T2: T2 = T1 × P2V2/(P1V1) = 300 × (250 × 1)/(100 × 2) = 375 K. (That is 102 °C.) The volume halves while the pressure rises 2.5 times, so the product raises the temperature by 25%.

20. A 500 W heater melts 0.5 kg of ice at 0 °C. Find (a) the energy needed to melt the ice, and (b) the time taken to melt it completely.

Answer: (a) Q = mL = 0.5 × 334000 = 167000 J. (b) Assuming all the energy melts the ice: t = Q/P = 167000/500 = 334 s. The temperature stays at 0 °C during melting because the energy breaks the crystal structure instead of raising the temperature.

Part 6: Electricity and Circuits (16 marks)

Assume the internal resistance of the supply and the resistance of connecting wires are negligible, and take the power factor as 1.

21. A resistor is connected to a 12 V supply and carries a current of 0.4 A. Find its resistance and the energy it dissipates in 1 minute.

Answer: R = V/I = 12/0.4 = 30 ohm. P = VI = 12 × 0.4 = 4.8 W, so in 60 s the energy is E = Pt = 4.8 × 60 = 288 J.

22. Resistors of 6 ohm and 9 ohm are connected in series across a 12 V supply. Find (a) the current in the circuit, and (b) the voltage across the 9 ohm resistor.

Answer: (a) Total series resistance R = 6 + 9 = 15 ohm, so I = V/R = 12/15 = 0.8 A. (b) V = IR = 0.8 × 9 = 7.2 V. In series the current is the same and the voltage divides in proportion to resistance, so the 6 ohm resistor takes 4.8 V.

23. Resistors of 6 ohm and 12 ohm are connected in parallel across a 12 V supply. Find (a) the equivalent resistance, and (b) the total current from the supply.

Answer: (a) 1/R = 1/6 + 1/12 = 3/12, so R = 4 ohm. (b) I = V/R = 12/4 = 3 A, which is 2 A + 1 A. A parallel equivalent resistance is always smaller than the smallest branch, which is a fast check on the answer.

24. An electric kettle rated 1,500 W at 240 V is used on a 240 V supply for 5 minutes. Find (a) the current, (b) the resistance of the heating element, and (c) the energy used in kWh.

Answer: (a) I = P/V = 1500/240 = 6.25 A. (b) R = V^2/P = 240^2/1500 = 38.4 ohm. (c) E = Pt = 1.5 kW × (5/60) h = 0.125 kWh. At 1.2 dollars per kWh this use costs about 0.15 dollar.