S4 Physics Practice Paper: Uniformly Accelerated Motion and v-t Graphs, Newton's Laws and Friction, Work and Power, Conservation of Momentum and Collisions, Pressure and Upthrust, Specific Heat Capacity and Heating

S4 Physics | 100 marks | 75 minutes

Question 1 Uniformly Accelerated Motion and v-t Graphs

Answer all parts. Show the formula and the steps of calculation.

A car starts from rest and accelerates uniformly at 2.0 m/s² for 8.0 s. Find its final velocity. *(4 marks)*

Answer: $v = u + at = 0 + 2.0 \times 8.0 = 16$ m/s

Find the distance travelled during the acceleration stage. *(4 marks)*

Answer: $s = \frac{1}{2}at^2 = 0.5 \times 2.0 \times 8.0^2 = 64$ m

The car then travels at a constant 16 m/s for 10 s and finally decelerates uniformly to rest in 4 s. Find the distance travelled during the deceleration stage. *(3 marks)*

Answer: Mean speed = (16 + 0)/2 = 8 m/s; $s = 8 \times 4 = 32$ m

Find the total distance and the average speed for the whole journey. *(5 marks)*

Answer: Total distance = 64 + 160 + 32 = 256 m; total time = 22 s; average speed = 256 ÷ 22 = 11.6 m/s

Question 2 Newton's Laws and Friction

Take $g = 9.8$ m/s².

A block of mass 5.0 kg rests on a horizontal table. Find its weight and the normal force from the table. *(4 marks)*

Answer: $W = mg = 5.0 \times 9.8 = 49$ N; normal force $N = 49$ N

The coefficient of kinetic friction between the block and the table is 0.35. Find the friction acting on the sliding block. *(4 marks)*

Answer: $f = \mu N = 0.35 \times 49 = 17.15 \approx 17.1$ N

A horizontal force of 30 N is now applied to push the block. Find its acceleration. *(5 marks)*

Answer: Net force = 30 − 17.15 = 12.85 N; $a = F/m = 12.85 \div 5.0 = 2.57$ m/s²

Starting from rest, the block is pushed for 3.0 s. Find its velocity and displacement. *(5 marks)*

Answer: $v = at = 2.57 \times 3.0 = 7.7$ m/s; $s = \frac{1}{2}at^2 = 0.5 \times 2.57 \times 3.0^2 = 11.6$ m

Question 3 Work, Energy and Power

Take $g = 9.8$ m/s².

A student of mass 60 kg climbs 5.0 m up a staircase in 12 s. Find the work done against gravity. *(4 marks)*

Answer: $W = mgh = 60 \times 9.8 \times 5.0 = 2940$ J

Find the average power of the student against gravity. *(4 marks)*

Answer: P = W/t = 2940 ÷ 12 = 245 W

A lift of mass 1,500 kg rises 20 m at constant speed in 8.0 s. Find its output power. *(4 marks)*

Answer: W = mgh = 1,500 × 9.8 × 20 = 294000 J; P = 294000 ÷ 8.0 = 36750 W

If the efficiency of the lift system is 70%, find its input power. *(4 marks)*

Answer: Efficiency = output ÷ input; input power = 36750 ÷ 0.70 = 52500 W

Question 4 Conservation of Momentum and Collisions

All collisions take place on a horizontal frictionless track.

A trolley of mass 2.0 kg moving at 3.0 m/s collides with a stationary trolley of mass 1.0 kg. Find the total momentum before the collision. *(4 marks)*

Answer: p = mu = 2.0 × 3.0 = 6.0 kg m/s

After the collision the two trolleys move together. Find their common velocity. *(5 marks)*

Answer: By conservation of momentum: 6.0 = (2.0 + 1.0)v; v = 6.0 ÷ 3.0 = 2.0 m/s

Find the total kinetic energy before and after the collision, and the kinetic energy lost. *(5 marks)*

Answer: Before = ½ × 2.0 × 3.0^2 = 9.0 J; after = ½ × 3.0 × 2.0^2 = 6.0 J; lost = 3.0 J

If the stationary trolley has a mass of 4.0 kg instead, find the common velocity and the kinetic energy lost. *(4 marks)*

Answer: v = 6.0 ÷ (2.0 + 4.0) = 1.0 m/s; after = ½ × 6.0 × 1.0^2 = 3.0 J; lost = 6.0 J

Question 5 Pressure and Upthrust

The density of water is 1,000 kg/m^3. Take g = 9.8 m/s^2.

A cubical wooden block of side 0.20 m has a density of 600 kg/m^3. Find its volume, mass and weight. *(5 marks)*

Answer: V = 0.20^3 = 0.0080 m^3; m = 600 × 0.0080 = 4.8 kg; W = 4.8 × 9.8 = 47.04 N

The block floats in equilibrium on water. Find the upthrust and the volume of water displaced. *(5 marks)*

Answer: Upthrust = weight = 47.04 N; V = upthrust ÷ (ρg) = 47.04 ÷ (1,000 × 9.8) = 0.0048 m^3

Find the depth of the block that is submerged. *(3 marks)*

Answer: Base area = 0.20^2 = 0.04 m^2; depth = 0.0048 ÷ 0.04 = 0.12 m

What mass must be placed on the block so that it is just completely submerged? *(3 marks)*

Answer: Extra water to be displaced = 0.0080 − 0.0048 = 0.0032 m^3; mass = 1,000 × 0.0032 = 3.2 kg

Question 6 Specific Heat Capacity and Heating Calculations

The specific heat capacity of water is 4,200 J kg^{-1} K^{-1}.

An electric heater of power 1,500 W heats 2.0 kg of water for 300 s. Find the energy supplied. *(4 marks)*

Answer: E = Pt = 1,500 × 300 = 450000 J

Neglecting heat loss, find the rise in temperature of the water. *(4 marks)*

Answer: $\Delta T = E \div (mc) = 450000 \div (2.0 \times 4{,}200) = 53.6\ °C$

If 20% of the energy is actually lost to the surroundings, find the rise in temperature. *(4 marks)*

Answer: Useful energy $= 450000 \times 0.80 = 360000$ J; $\Delta T = 360000 \div 8{,}400 = 42.9\ °C$

If the heater efficiency is 70%, how long does it take to raise the temperature of 2.0 kg of water by 30 °C? *(4 marks)*

Answer: $Q = mc\Delta T = 2.0 \times 4{,}200 \times 30 = 252000$ J; input $= 252000 \div 0.70 = 360000$ J; $t = 360000 \div 1{,}500 = 240$ s

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