AQA A-Level Physics: Force, Energy & Momentum – Calculation Questions

Praneel Physics

1. Calculate the momentum of a 2.5 kg object moving at 4 m/s. **(P)**

Working and Answer:

Use $p = mv$.
$p = 2.5 \times 4 = 10\,\mathrm{kg\,m/s}$.

2. Calculate the work done by a force of 12 N moving an object 5 m. **(P)**

Working and Answer:

Use $W = Fd$.
$W = 12 \times 5 = 60\,\text{J}$.

3. Calculate the kinetic energy of a 3 kg object moving at 6 m/s. **(P)**

Working and Answer:

Use $E_k = \frac{1}{2}mv^2$.
$E_k = \frac{1}{2} \times 3 \times 6^2 = 54\,\text{J}$.

4. Calculate the force required to accelerate a 5 kg object at $2\,\mathrm{m/s^2}$. **(P)**

Working and Answer:

Use $F = ma$.
$F = 5 \times 2 = 10\,\mathrm{N}$.

5. Calculate the gravitational potential energy of a 4 kg object raised 10 m ($g = 9.81\,\mathrm{m/s^2}$). **(P)**

Working and Answer:

Use $E_p = mgh$.
$E_p = 4 \times 9.81 \times 10 = 392.4\,\mathrm{J}$.

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6. Calculate the momentum and kinetic energy of a 0.5 kg object moving at 20 m/s. **(PP)**

Working and Answer:

Step 1: $p = mv = 0.5 \times 20 = 10\,\text{kg m/s}$.
Step 2: $E_k = \frac{1}{2} \times 0.5 \times 20^2 = 100\,\text{J}$.

7. Calculate the work done and power developed by a 30 N force moving an object 8 m in 4 s. **(PP)**

Working and Answer:

Step 1: $W = Fd = 30 \times 8 = 240\,\text{J}$.
Step 2: $P = \frac{W}{t} = \frac{240}{4} = 60\,\text{W}$.

8. Calculate the final velocity and kinetic energy of a 2 kg object accelerated from rest by a 6 N force over 3 s. **(PP)**

Working and Answer:

Step 1: $a = \frac{F}{m} = \frac{6}{2} = 3\,\text{m/s}^2$. $v = u + at = 0 + 3 \times 3 = 9\,\text{m/s}$.
Step 2: $E_k = \frac{1}{2} \times 2 \times 9^2 = 81\,\text{J}$.

9. Calculate the change in momentum and average force for a 0.1 kg ball hitting a wall at 15 m/s and rebounding at 10 m/s (time of contact = 0.02 s). **(PP)**

Working and Answer:

Step 1: $\Delta p = m(v - u) = 0.1 \times (10 - (-15)) = 2.5\,\text{kg m/s}$.
Step 2: $F = \frac{\Delta p}{t} = \frac{2.5}{0.02} = 125\,\text{N}$.

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10. Calculate the efficiency of a machine that inputs 500 J and outputs 400 J of useful work. **(PP)**

Working and Answer:

Step 1: Efficiency $= \frac{\text{Useful output}}{\text{Total input}} \times 100\%$.
Step 2: Efficiency $= \frac{400}{500} \times 100\% = 80\%$.

11. Calculate the acceleration, final velocity, and distance traveled by a 4 kg object acted upon by a 12 N force for 5 s from rest. **(PPP)**

Working and Answer:

Step 1: $a = \frac{F}{m} = \frac{12}{4} = 3\,\mathrm{m/s^2}$.
Step 2: $v = u + at = 0 + 3 \times 5 = 15\,\mathrm{m/s}$.
Step 3: $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 3 \times 25 = 37.5\,\mathrm{m}$.

12. Calculate the momentum, kinetic energy, and work done by a 0.2 kg ball falling freely for 3 s ($g = 9.81\,\mathrm{m/s^2}$). **(PPP)**

Working and Answer:

Step 1: $v = u + gt = 0 + 9.81 \times 3 = 29.43\,\mathrm{m/s}$.
Step 2: $p = mv = 0.2 \times 29.43 = 5.886\,\mathrm{kg\,m/s}$.
Step 3: $E_k = \frac{1}{2} \times 0.2 \times 29.43^2 \approx 86.6\,\mathrm{J}$. Work done $= E_k$.

13. Calculate the force, impulse, and change in kinetic energy for a 1.5 kg object accelerating from 2 m/s to 8 m/s in 3 s. **(PPP)**

Working and Answer:

Step 1: $a = \frac{v-u}{t} = \frac{8-2}{3} = 2\,\text{m/s}^2$. $F = ma = 1.5 \times 2 = 3\,\text{N}$.
Step 2: Impulse $= Ft = 3 \times 3 = 9\,\text{N s}$.
Step 3: $\Delta E_k = \frac{1}{2} \times 1.5 \times (8^2 - 2^2) = 45\,\text{J}$.

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14. Calculate the recoil velocity, kinetic energy of the recoil, and momentum conservation check for a 0.02 kg bullet fired at 400 m/s from a 3 kg gun. **(PPP)**

Working and Answer:

Step 1: Recoil $v = -\frac{m_{\text{bullet}} v_{\text{bullet}}}{m_{\text{gun}}} = -\frac{0.02 \times 400}{3} \approx -2.67\,\text{m/s}$.
Step 2: $E_k = \frac{1}{2} \times 3 \times 2.67^2 \approx 10.7\,\text{J}$.
Step 3: Momentum check: $0.02 \times 400 + 3 \times (-2.67) = 0$ (conserved).

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15. Calculate the power, work done, and efficiency of a motor lifting a 10 kg mass 5 m in 2 s (input energy = 600 J). **(PPP)**

Working and Answer:

Step 1: $W = mgh = 10 \times 9.81 \times 5 = 490.5\,\text{J}$.
Step 2: $P = \frac{W}{t} = \frac{490.5}{2} = 245.25\,\text{W}$.
Step 3: Efficiency $= \frac{490.5}{600} \times 100\% \approx 81.8\%$.

16. Calculate the final velocity, momentum, kinetic energy, and force for a 2 kg object sliding down a 30° frictionless incline of length 5 m. **(PPPP)**

Working and Answer:

Step 1: $a = g \sin 30° = 4.905\,\text{m/s}^2$.
Step 2: $v^2 = u^2 + 2as \Rightarrow v = \sqrt{0 + 2 \times 4.905 \times 5} \approx 7\,\text{m/s}$.
Step 3: $p = mv = 2 \times 7 = 14\,\text{kg m/s}$.
Step 4: $E_k = \frac{1}{2} \times 2 \times 7^2 = 49\,\text{J}$. $F = ma = 2 \times 4.905 = 9.81\,\text{N}$.

17. Calculate the impulse, average force, change in kinetic energy, and final velocity for a 0.5 kg ball hitting a wall at 10 m/s and rebounding at 6 m/s (contact time = 0.1 s). **(PPPP)**

Working and Answer:

Step 1: $\Delta p = m(v - u) = 0.5 \times (6 - (-10)) = 8\,\text{kg m/s}$.
Step 2: $F = \frac{\Delta p}{t} = \frac{8}{0.1} = 80\,\text{N}$.
Step 3: $\Delta E_k = \frac{1}{2} \times 0.5 \times (6^2 - 10^2) = -16\,\text{J}$.
Step 4: Final velocity = 6 m/s (given).

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18. Calculate the tension, acceleration, work done by tension, and power for a 1 kg mass lifted vertically by a rope with constant force 15 N for 4 s. **(PPPP)**

Working and Answer:

Step 1: Net force $= T - mg = 15 - 9.81 = 5.19\,\text{N}$. $a = \frac{F}{m} = 5.19\,\text{m/s}^2$.
Step 2: $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 5.19 \times 16 \approx 41.5\,\text{m}$.
Step 3: $W = T \times s = 15 \times 41.5 \approx 622.5\,\text{J}$.
Step 4: $P = \frac{W}{t} = \frac{622.5}{4} \approx 155.6\,\text{W}$.

19. Calculate the coefficient of restitution, kinetic energy loss, and final velocities for a 2 kg ball ($u_1 = 5\,\text{m/s}$) colliding with a stationary 3 kg ball ($e = 0.8$). **(PPPP)**

Working and Answer:

Step 1: Conservation of momentum: $2 \times 5 + 0 = 2v_1 + 3v_2$.
Step 2: $e = \frac{v_2 - v_1}{u_1 - u_2} \Rightarrow 0.8 = \frac{v_2 - v_1}{5}$.
Step 3: Solve simultaneous equations: $v_1 = -1.4\,\text{m/s}$, $v_2 = 2.6\,\text{m/s}$.
Step 4:
$\Delta E_k = \frac{1}{2} \times 2 \times 5^2 - \left(\frac{1}{2} \times 2 \times 1.4^2 + \frac{1}{2} \times 3 \times 2.6^2\right) = 25 - 11.48 = 13.52\,\text{J}$.

20. Calculate the spring constant, maximum compression, velocity at equilibrium, and acceleration at maximum compression for a 0.5 kg mass on a spring ($k = 200\,\text{N/m}$) released from 0.1 m extension. **(PPPP)**

Working and Answer:

Step 1: $k = 200\,\text{N/m}$ (given).
Step 2: $E_p = \frac{1}{2}kx^2 = \frac{1}{2} \times 200 \times 0.1^2 = 1\,\text{J}$. At max compression, $E_p = E_k \Rightarrow x = 0.1\,\text{m}$.
Step 3: At equilibrium: $v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2\times1}{0.5}} = 2\,\text{m/s}$.
Step 4: $F = -kx \Rightarrow a = \frac{F}{m} = \frac{200\times0.1}{0.5} = 40\,\text{m/s}^2$.

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21. Calculate the tension, angular velocity, centripetal force, kinetic energy, and power for a 0.2 kg mass on a 1 m string rotating at 2 rev/s. **(PPPPP)**

Working and Answer:

Step 1: $\omega = 2 \times 2\pi = 4\pi\,\text{rad/s}$.
Step 2: $F_c = m\omega^2 r = 0.2 \times (4\pi)^2 \times 1 \approx 31.6\,\text{N}$.
Step 3: $v = \omega r = 4\pi \times 1 \approx 12.6\,\text{m/s}$. $E_k = \frac{1}{2} \times 0.2 \times (12.6)^2 \approx 15.9\,\text{J}$.
Step 4: Power $= 0$ (no work done in circular motion at constant speed).
Step 5: Tension $= F_c \approx 31.6\,\text{N}$.

22. Calculate the final velocities, kinetic energy loss, impulse on each object, and coefficient of restitution for a 3 kg object ($u_1 = 4\,\text{m/s}$) colliding with a 2 kg object ($u_2 = -1\,\text{m/s}$) in a perfectly inelastic collision. **(PPPPP)**

Working and Answer:

Step 1: Momentum conservation: $3 \times 4 + 2 \times (-1) = (3 + 2)v \Rightarrow v = 2\,\text{m/s}$.
Step 2: $\Delta E_k = \frac{1}{2} \times 3 \times 4^2 + \frac{1}{2} \times 2 \times (-1)^2 - \frac{1}{2} \times 5 \times 2^2 = 24 + 1 - 10 = 15\,\text{J}$.
Step 3: Impulse on 3 kg: $\Delta p = 3 \times (2 - 4) = -6\,\text{kg m/s}$.
Step 4: Impulse on 2 kg: $\Delta p = 2 \times (2 - (-1)) = 6\,\text{kg m/s}$.
Step 5: $e = 0$ (perfectly inelastic).

23. Calculate the work done, power output, efficiency, tension, and acceleration for a 500 kg elevator rising 20 m in 10 s with constant velocity (input energy = 150 kJ). **(PPPPP)**

Working and Answer:

Step 1: $W = mgh = 500 \times 9.81 \times 20 = 98.1\,\text{kJ}$.
Step 2: $P = \frac{W}{t} = \frac{98.1\times10^3}{10} = 9.81\,\text{kW}$.
Step 3: Efficiency $= \frac{98.1}{150} \times 100\% \approx 65.4\%$.
Step 4: $T = mg = 500 \times 9.81 = 4.905\,\text{kN}$ (constant velocity).
Step 5: $a = 0\,\text{m/s}^2$ (constant velocity).

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24. Calculate the maximum height, time of flight, range, initial velocity components, and kinetic energy at launch for a projectile launched at 30° with speed $20\,\mathrm{m/s}$ ($g = 9.81\,\mathrm{m/s^2}$). **(PPPPP)**

Working and Answer:

Step 1: $v_y = 20 \sin 30^\circ = 10\,\mathrm{m/s}$. $h = \frac{v_y^2}{2g} = \frac{100}{19.62} \approx 5.1\,\mathrm{m}$.
Step 2: Time of flight $= \frac{2v_y}{g} = \frac{20}{9.81} \approx 2.04\,\mathrm{s}$.
Step 3: $v_x = 20 \cos 30^\circ \approx 17.3\,\mathrm{m/s}$. Range $= v_x \times t \approx 35.3\,\mathrm{m}$.
Step 4: $E_k = \frac{1}{2} \times m \times 20^2 = 200m$ J (mass m not given).

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25. Calculate the spring potential energy, maximum speed, acceleration at maximum compression, period of oscillation, and frequency for a 0.4 kg mass on a spring ($k = 50\,\text{N/m}$) compressed 0.2 m. **(PPPPP)**

Working and Answer:

Step 1: $E_p = \frac{1}{2}kx^2 = \frac{1}{2} \times 50 \times 0.2^2 = 1\,\text{J}$.
Step 2: $v_{\text{max}} = \sqrt{\frac{2E_p}{m}} = \sqrt{\frac{2\times1}{0.4}} \approx 2.24\,\text{m/s}$.
Step 3: $a_{\text{max}} = \frac{kx}{m} = \frac{50\times0.2}{0.4} = 25\,\text{m/s}^2$.
Step 4: $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.4}{50}} \approx 0.56\,\text{s}$.
Step 5: $f = \frac{1}{T} \approx 1.79\,\text{Hz}$.

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