Energy, Work and Power

Cambridge International AS & A Level - Mathematics 9709
Paper 4: Mechanics - Exam-style question bank

Original Steps to Conquer practice questions in the style of recent 9709 Paper 4 examinations - not past Cambridge questions. Marks are shown in brackets [ ]. Give non-exact answers to 3 significant figures (1 d.p. for angles) and show full working.

Questions

1 A force of 20 N acts at an angle of 60° to the direction of motion of a particle. The particle moves 5 m. Find the work done by the force. [3]

2 Find the kinetic energy of a particle of mass 3 kg moving at 4 m s^{-1}. [3]

3 A particle of mass 2 kg is raised vertically through a height of 5 m. Find its gain in gravitational potential energy. [3]

4 A particle slides from rest down a smooth track, descending through a vertical height of 3 m. Find its speed at the lower point. [4]

5 Find the kinetic energy of a car of mass 1000 kg moving at 20 m s^{-1}. [3]

6 A particle of mass 5 kg starts from rest on a horizontal surface. It is pulled 10 m by a horizontal force of 30 N against a constant resistance of 5 N. Find its speed after moving 10 m. [6]

7 A car engine provides a driving force of 800 N when the car is moving at 12 m s^{-1}. Find the power output. [3]

8 A crane raises a load of mass 50 kg through a height of 4 m in 5 seconds. Find the average power used in raising the load. [4]

9 A particle of mass 2 kg slides from rest down a rough plane of length 10 m inclined at 30° to the horizontal. The coefficient of friction is 0.2. Find its speed at the bottom. [7]

10 A car of mass 1000 kg moves uphill at 10 m s^{-1} against a resistance of 500 N. The slope is such that $\sin\theta = 0.05$. The engine power is 20 kW. Find the instantaneous acceleration. [7]

Worked solutions

Full methods with final answers. Other valid methods may also earn full marks.

1 Work done $= Fd\cos\theta$.

$= 20(5)\cos 60^\circ = 50$ J.

2 Kinetic energy $= \frac{1}{2}mv^2$.

$= \frac{1}{2}(3)(4^2) = 24$ J.

3 Gain in potential energy $= mgh$.

$= 2(10)(5) = 100$ J.

4 Loss of gravitational potential energy becomes kinetic energy.

$mg(3) = \frac{1}{2}mv^2$.

$v^2 = 60$, so $v = 7.75$ m s^{-1}.

5 Kinetic energy $= \frac{1}{2}(1000)(20^2)$.

$= 200000$ J.

6 Work done by the pulling force is $30(10) = 300$ J.

Work done against resistance is $5(10) = 50$ J.

Net gain in kinetic energy is 250 J.

$\frac{1}{2}(5)v^2 = 250$.

$v = 10$ m s^{-1}.

7 Power $= Fv = 800(12)$.

$P = 9600$ W.

8 Work done $= mgh = 50(10)(4) = 2000$ J.

Average power $= \dfrac{2000}{5} = 400$ W.

9 The vertical drop is $10\sin 30^\circ = 5$ m.

Loss of potential energy $= 2(10)(5) = 100$ J.

$R = 2g\cos 30^\circ = 20\cos 30^\circ$.

Work done against friction $= 0.2R(10) = 40\cos 30^\circ = 34.6$ J.

Gain in kinetic energy $= 100 - 34.6 = 65.4$ J.

$\frac{1}{2}(2)v^2 = 65.4$, so $v = 8.09$ m s^{-1}.

10 The driving force is $F = \dfrac{P}{v} = \dfrac{20000}{10} = 2000$ N.

The component of weight down the slope is $1000(10)(0.05) = 500$ N.

Total opposing force $= 500 + 500 = 1000$ N.

Resultant force up the slope $= 2000 - 1000 = 1000$ N.

$1000a = 1000$, so $a = 1$ m s^{-2}.