5. Work, Energy and Power

5.1 Energy conservation

Paper 1

Question Paper

1 A box of weight 40 N is pushed with a horizontal force of 20 N along level ground for a distance of 2.4 m.

The box is then lifted at constant velocity through a height of 1.6 m by a vertical force.

What is the total work done on the box by the two forces?

A 80 J **B** 110 J **C** 120 J **D** 160 J

2 Which statement about efficiency is correct?

A Efficiency does **not** have a unit.

B The joule is a unit of efficiency.

C The metre is a unit of efficiency.

D The watt is a unit of efficiency.

3 The force resisting the motion of a car is proportional to the square of the car's speed. The magnitude of the force at a speed of 20.0 m s^{-1} is 800 N.

What useful output power is required from the car's engine to maintain a steady speed of 40.0 m s^{-1}?

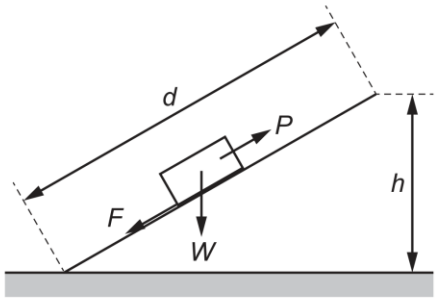
A 32 kW **B** 64 kW **C** 128 kW **D** 512 kW

4 A box of weight W is pulled by a force P along a slope.

The length of the slope is d, and the box rises a height h.

The frictional force between the box and the slope is F.

The diagram shows the directions of the forces.

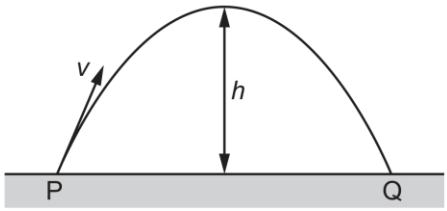


The purpose of the slope is to raise the box vertically.

Which expression gives the efficiency of the slope?

A $\frac{Fd}{Wh}$ **B** $\frac{Pd}{Wh}$ **C** $\frac{Wh}{Fd}$ **D** $\frac{Wh}{Pd}$

5 A ball of mass m is thrown up to height h in air with an initial velocity v, as shown.



Air resistance is negligible. The acceleration of free fall is g.

What is the **total** work done by the gravitational force on the ball during its flight from P to Q?

A zero **B** $\frac{1}{2}mv^2$ **C** mgh **D** $2mgh$

6 What is the definition of power?

A work done in one second

B work done in unit time

C work done per second

D work done per unit time

7 A model car travels at a constant velocity of $12\,m\,s^{-1}$ in a straight horizontal line. The input power to the engine of the car is 800 W. The efficiency of the engine is 60%.

What is the total horizontal resistive force on the car?

A 27 N **B** 40 N **C** 67 N **D** 110 N

8 Which statement represents the principle of conservation of energy?

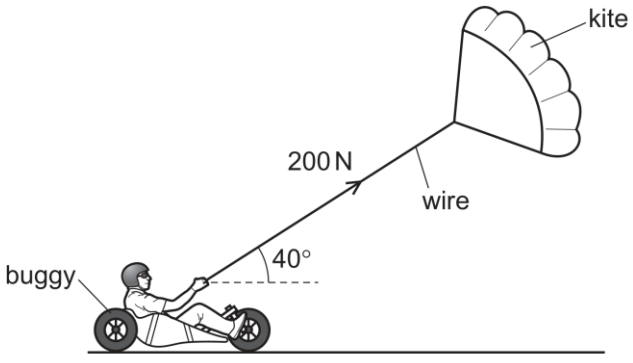
A Energy cannot be used faster than it is created.

B The supply of energy is limited, so energy must be conserved.

C The total energy in a closed system is constant.

D The total energy input to a system is equal to the useful energy output.

9 A man sits on a buggy that is pulled along by a wire attached to a kite. The wire is at an angle of 40° to the horizontal and has a constant tension of 200 N. The man and buggy travel a distance of 20 m along a straight horizontal path. The wire and the path of the buggy are in the same vertical plane.



What is the work done by the tension force on the man and buggy?

A 2.6 kJ **B** 3.1 kJ **C** 3.4 kJ **D** 4.0 kJ

10 A ball is thrown vertically upwards from the surface of the Earth.

Which statement describes the energy of the ball as it rises through the air?

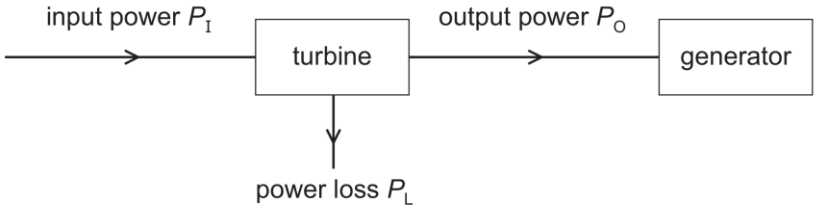
A The kinetic energy of the ball decreases as the gravitational potential energy decreases.

B The kinetic energy of the ball decreases as the gravitational potential energy increases.

C The kinetic energy of the ball increases as the gravitational potential energy decreases.

D The total energy of the ball increases.

11 A steam turbine is used to drive a generator. The input power to the turbine is P_I and the output power is P_O. The power loss in the turbine is P_L, as shown.

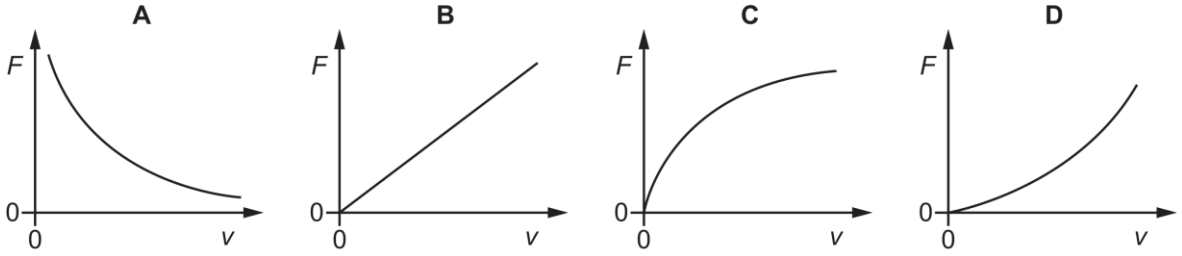


What is the efficiency of the turbine?

A $\frac{P_L}{P_O}$ **B** $\frac{P_I}{P_O}$ **C** $\frac{P_L}{P_I}$ **D** $\frac{P_O}{P_I}$

12 A variable force is applied to ensure that a constant power is supplied to a train.

Which graph best shows the variation of the force F applied with the velocity v of the train?



13 A crate of mass 50 kg is pushed a distance of 6.0 m along a horizontal surface against a constant resistive force of 70 N. The crate moves at a constant speed. It is then lifted, at a constant speed, through a vertical distance of 1.2 m onto the back of a lorry.

What is the total work done in this process?

A 420 J **B** 480 J **C** 590 J **D** 1000 J

14 The input power to a television is P_{in}. The useful sound and light power emitted by the television is P_{out}.

What is the efficiency of the television?

A $\frac{P_{out}}{P_{in}}$ **B** $\frac{P_{in} - P_{out}}{P_{in}}$ **C** $\frac{P_{in}}{P_{out}}$ **D** $\frac{P_{out}}{P_{in} - P_{out}}$

15 An electric car travels at a constant speed of 70 km h^{-1} for 80 km on a straight horizontal road and uses energy E from its battery.

The total resistive force acting on the car is proportional to (speed)^2. Assume that the electric motor is 100% efficient.

How much energy is used from the battery when the car travels at a constant speed of 60 km h^{-1} for 80 km on the straight horizontal road?

A 0.73E **B** 0.86E **C** 1.2E **D** 1.4E

16 What is meant by the efficiency of a system?

A the total energy input to the system divided by the useful energy output by the system

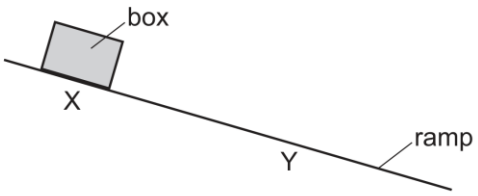
B the useful energy output from the system divided by the energy wasted by the system

C the useful energy output from the system divided by the total energy input to the system

D the energy wasted by the system divided by the total energy input to the system

17 A box slides down a rough ramp.

The change in the gravitational potential energy of the box is 16 J as it moves between positions X and Y. The box has 24 J of kinetic energy at X and 35 J of kinetic energy at Y.



How much work is done against the frictional force?

A 5 J **B** 19 J **C** 27 J **D** 43 J

18 The total energy supplied to an electric motor is *E*. Energy *Q* is wasted and the remaining energy does useful work.

What is the efficiency of the motor?

A $\frac{Q}{E}$ **B** $\left(\frac{Q}{E}\right) - 1$ **C** $1 - \left(\frac{Q}{E}\right)$ **D** $\frac{(1-Q)}{E}$

19 Which product of two quantities is equal to power?

A force × distance

B force × velocity

C work done × time

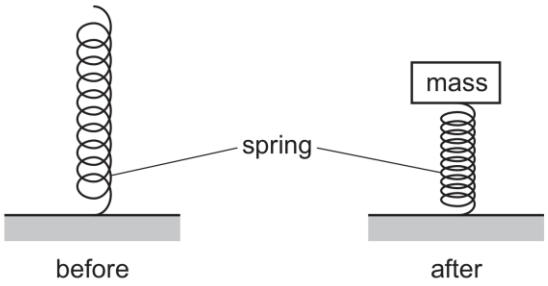
D work done × velocity

20 Researchers have developed a new type of filament lamp with an efficiency of 40%. Old-type filament lamps have an efficiency of 5.0%. The two types of lamp produce the same useful output power.

What is the ratio $\frac{\text{input power to new type of lamp}}{\text{input power to old type of lamp}}$?

A 0.13 **B** 0.63 **C** 1.6 **D** 8.0

21 A spring is compressed by a mass, as shown.



Which statement describes the changes to the energy of the spring when it is compressed by the mass?

A The spring gains both gravitational potential energy and elastic potential energy.

B The spring gains gravitational potential energy and loses elastic potential energy.

C The spring loses both gravitational potential energy and elastic potential energy.

D The spring loses gravitational potential energy and gains elastic potential energy.

22 A man of mass 75 kg runs up a staircase consisting of 30 steps. Each step is 20 cm high.

The man takes a time of 7.0 s to run from the bottom of the staircase to the top.

What is the average rate of increase of gravitational potential energy of the man?

A 64 W **B** 450 W **C** 630 W **D** 4400 W

23 A motor is used to lift a load vertically upwards.

The load has weight W.

The motor produces useful power output P.

The load is lifted at constant velocity v.

Which expression gives the time taken for the motor to lift the load vertically upwards through a distance d?

A $\frac{P}{Wd}$ **B** $\frac{Wv}{P}$ **C** $\frac{Wd}{P}$ **D** $\frac{Pv}{W}$

24 A lamp is switched on for 2.0 hours. The power input to the lamp is 1.0 W. The energy given out by the lamp as light is 7.0×10^3 J.

How much energy is converted to other forms by the lamp?

A 120 J **B** 200 J **C** 3400 J **D** 7200 J

25 A rocket is fired upwards.

As it accelerates upwards after leaving the launch pad, which forms of energy are changing?

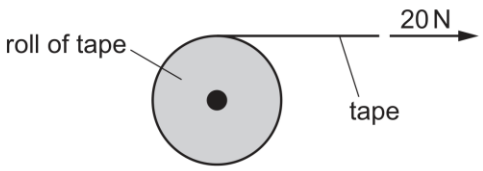
A chemical energy, gravitational potential energy and kinetic energy

B chemical energy and gravitational potential energy only

C chemical energy and kinetic energy only

D gravitational potential energy and kinetic energy only

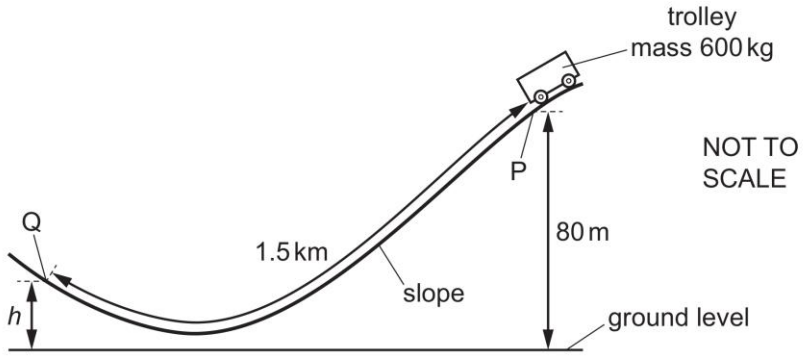
26 A roll of tape of length 50 m requires a constant force of 20 N to unwrap it.



What is the work done in unwrapping the whole roll?

A 0.4 J **B** 2.5 J **C** 500 J **D** 1000 J

27 A trolley of mass 600 kg is initially at point P on a slope, at a height of 80 m above ground level, as shown. The trolley is released from rest and moves along the slope, first coming to rest at point Q, at height *h* above ground level.



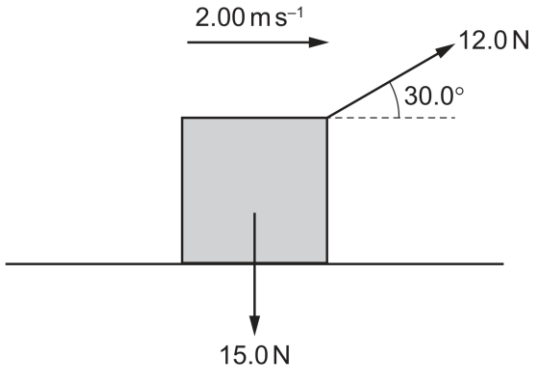
The total distance PQ moved by the trolley along the slope is 1.5 km. A constant resistive force of 300 N opposes the motion of the trolley on the slope.

What is *h*?

A 3.5 m **B** 76 m **C** 79 m **D** 80 m

28 An object of weight 15.0 N is pulled along a horizontal surface at a constant velocity of 2.00 m s^{-1}.

The force pulling the object is 12.0 N at 30.0° to the horizontal, as shown.



What is the power used to move the object?

A 12.0 W **B** 20.8 W **C** 24.0 W **D** 30.0 W

29 A stone is falling vertically through the air at a constant (terminal) velocity.

Which energy change is occurring?

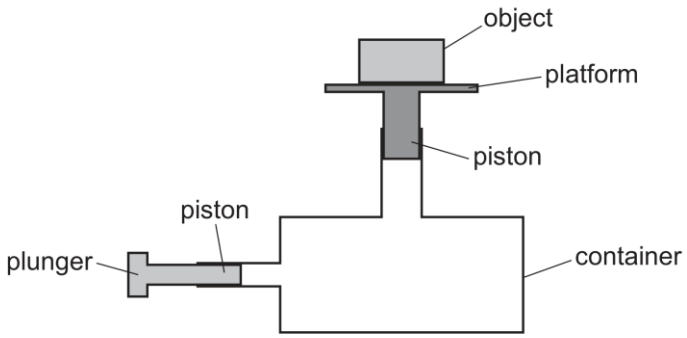
A gravitational potential energy to thermal energy

B gravitational potential energy to kinetic energy of the stone

C kinetic energy to gravitational potential energy of the stone

D kinetic energy of the stone to thermal energy

30 An object of weight 12 N rests on a platform on top of a container with two pistons, as shown. The container contains a fixed mass of gas, and the pistons are free to move.

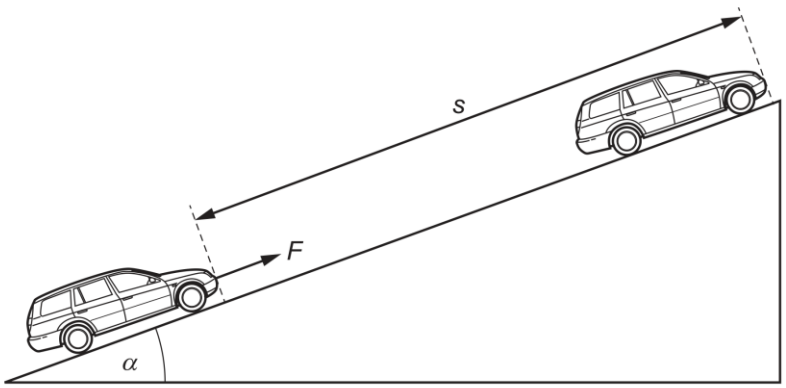


The plunger is slowly pushed 4.0 cm to the right. As a result, the object slowly moves upwards a distance 0.50 cm.

How much work is done on the object?

A 0.060 J **B** 0.48 J **C** 6.0 J **D** 48 J

31 A constant force F, acting on a car of mass m, moves the car up a slope through a distance s at constant velocity v. The angle of the slope to the horizontal is α.



The acceleration of free fall is g.

What is the ratio $\frac{\text{gravitational potential energy gained by car}}{\text{work done by force } F}$?

A $\frac{mgs\sin\alpha}{Fv}$ **B** $\frac{mv}{Fs}$ **C** $\frac{mv^2}{2Fs}$ **D** $\frac{mg\sin\alpha}{F}$

32 What is the definition of power?

A Power is the product of force and velocity.

B Power is the product of force and work done per unit time.

C Power is the product of force per unit time and velocity.

D Power is the rate at which work is done.

33 Which statement about energy is **not** correct?

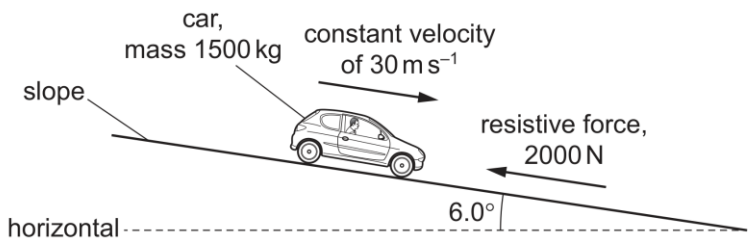
A Energy is never lost but it may be transferred between different forms.

B In an inelastic collision, the total energy is constant.

C The efficiency of a system is the ratio of the useful energy output to the total energy input.

D When a machine does work, friction reduces the total energy.

34 A car of mass 1500 kg travels at a constant velocity of 30 m s^{-1} down a slope. The slope is at an angle of 6.0° to the horizontal, as shown.



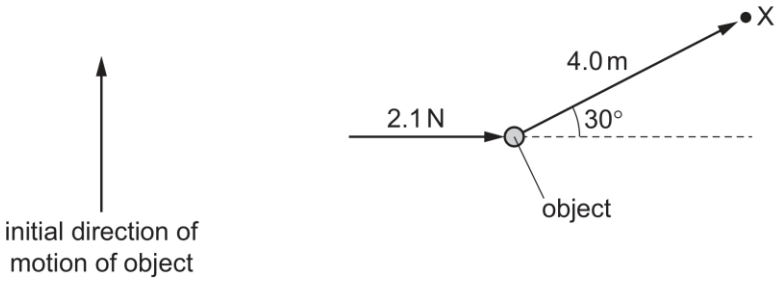
The magnitude of the total resistive force acting on the car is 2000 N.

What is the power output of the car's engine?

A 14 kW **B** 60 kW **C** 110 kW **D** 380 kW

35 An object slides with constant velocity across a horizontal sheet of ice. Friction is negligible.

A constant horizontal force of 2.1 N is then applied to the object as shown.



A short time after applying the force, the object reaches point X at a displacement of 4.0 m from its position when the force was first applied.

What is the work done by the force on the object as it travels to point X?

A 4.2 J **B** 4.8 J **C** 7.3 J **D** 8.4 J

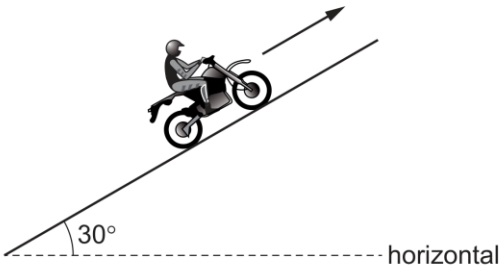
36 The energy conversions inside a power station burning fossil fuel can be simplified as shown.

chemical energy $W \rightarrow$ thermal energy $X \rightarrow$ electrical energy Y

Which expression gives the efficiency of the power station?

A $\frac{Y}{W}$ **B** $\frac{Y}{(W+X)}$ **C** $\frac{Y}{X}$ **D** $\frac{Y}{(W+X+Y)}$

37 The total weight of a motorbike and rider is 1800 N. The motorbike travels in a straight line at constant speed up a hill at an angle of 30° to the horizontal.



The useful output power of the motorbike is 36 000 W. The total resistive force due to air resistance and friction on the motorbike and rider is 2400 N.

What is the speed of the motorbike?

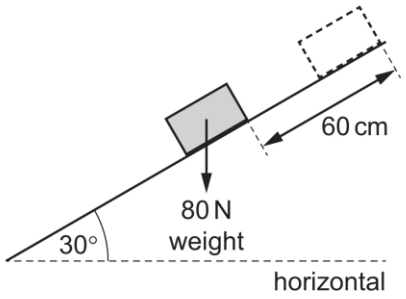
A $8.6\,m\,s^{-1}$ **B** $11\,m\,s^{-1}$ **C** $15\,m\,s^{-1}$ **D** $24\,m\,s^{-1}$

38 A mass attached to the lower end of a spring bounces up and down.

At which points in the path of the mass do the gravitational potential energy of the mass (GPE), the elastic potential energy in the spring (EPE) and the kinetic energy of the mass (KE) have their highest values?

	GPE	EPE	KE
A	bottom	middle	top
B	bottom	top	middle
C	top	bottom	middle
D	top	bottom	top

39 A block of weight 80 N is pushed a distance of 60 cm up a slope inclined at 30° to the horizontal. There is a frictional force of 25 N between the block and the surface of the slope.

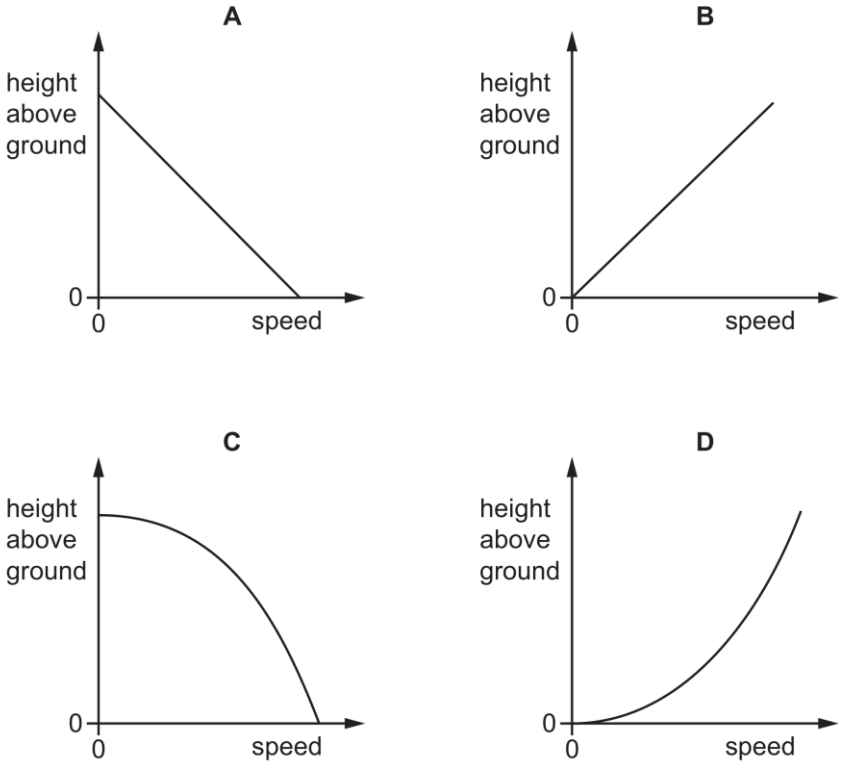


What is the work W_g done against the gravitational force and the work W_f done against the frictional force?

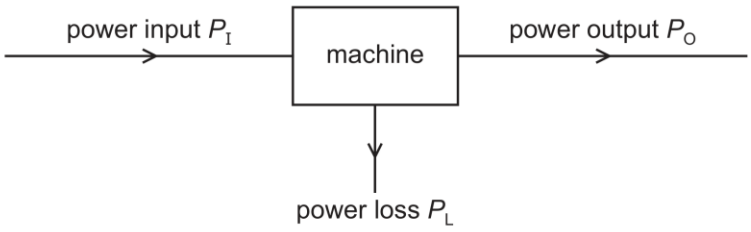
	W_g / J	W_f / J
A	24	7.5
B	24	15
C	48	7.5
D	48	15

40 A ball is dropped from rest and falls towards the ground. Air resistance is negligible.

Which graph shows the variation with speed of the height of the ball above the ground?



41 Power is transferred through a machine as shown.



What is the efficiency of the machine?

A $\frac{P_I}{P_O + P_L}$ **B** $\frac{P_L}{P_I}$ **C** $\frac{P_L}{P_O}$ **D** $\frac{P_O}{P_I}$

42 During an interval of time, fuel supplies energy X to a car.

Some of this energy is converted into kinetic energy as the car accelerates.

The rest of the energy Y is lost as thermal energy.

What is the efficiency of the car?

A $\frac{X}{X - Y}$ **B** $\frac{Y}{X - Y}$ **C** $\frac{X - Y}{X}$ **D** $\frac{X - Y}{Y}$

43 In which situation is work done on an object?

A The object slides with a constant velocity along a horizontal frictionless surface in a vacuum.

B A person holds the object at arm's length and at a fixed height above the ground.

C A person pushes the object up a frictionless ramp.

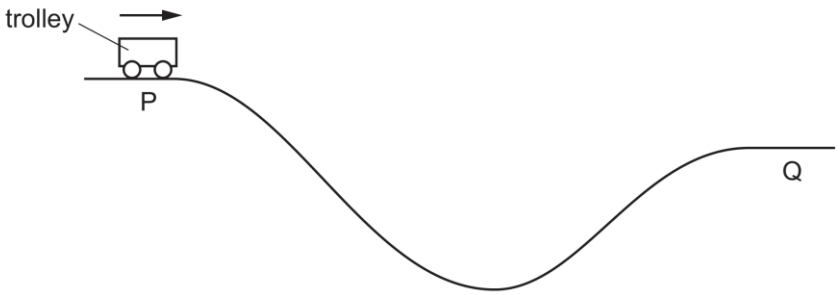
D The stationary object floats partially submerged in water.

44 An escalator in an underground station has 25 people standing on it and is moving with a speed of $4.3\,m\,s^{-1}$. The average mass of a person is 78 kg and the angle of the escalator to the horizontal is 40°.

What is the minimum power required to lift these people?

A 5.4 kW **B** 6.4 kW **C** 53 kW **D** 63 kW

45 A trolley runs from P to Q along a track. At Q its potential energy is 50 kJ less than at P.



At P, the kinetic energy of the trolley is 5 kJ. Between P and Q, the trolley does 10 kJ of work against friction.

What is the kinetic energy of the trolley at Q?

A 35 kJ **B** 45 kJ **C** 55 kJ **D** 65 kJ

46 A hydroelectric power station uses the gravitational potential energy of water to generate electrical energy.

In one particular power station, the mass of water flowing per unit time is $1.5 \times 10^5\,kg\,s^{-1}$. The water falls through a vertical height of 120 m.

The electrical power generated is 100 MW.

What is the efficiency of the power station?

A 5.6% **B** 43% **C** 57% **D** 77%

47 A train of mass 300 000 kg is accelerating at 0.80 m s^{-2}. At one instant, the speed of the train is 5.0 m s^{-1} and the resistive force to its motion is 15 kN.

At this instant, what is the rate of increase of kinetic energy of the train?

A 0.075 MW **B** 1.2 MW **C** 1.3 MW **D** 3.8 MW

48 A ball is thrown vertically upwards. Air resistance is negligible.

Which statement is correct?

A By the principle of conservation of energy, the total energy of the ball is constant throughout its motion.

B By the principle of conservation of momentum, the momentum of the ball is constant throughout its motion.

C The kinetic energy of the ball is greatest at the greatest height attained.

D The potential energy of the ball increases at a constant rate during its ascent.

49 A hammer with 10 J of kinetic energy hits a nail and pushes it 5.0 mm into a plank.

Both the hammer and nail come to rest after the collision.

What is the approximate average force that acts on the nail while it moves through 5.0 mm?

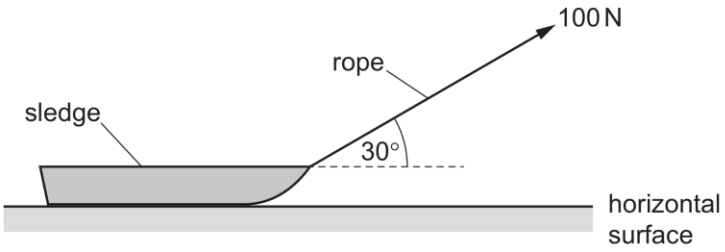
A 0.050 N **B** 2.0 N **C** 50 N **D** 2000 N

50 A racing car has an output power of 300 kW when travelling at a constant speed of 60 m s^{-1}.

What is the total resistive force acting on the car?

A 5 kN **B** 10 kN **C** 50 kN **D** 100 kN

51 A rope is attached to a sledge and a boy uses the rope to pull the sledge along a horizontal surface with a constant velocity. The tension in the rope is 100 N and the rope is held at 30° to the horizontal.



How much work does the boy do on the sledge when he pulls it a distance of 5.0 m along the surface?

A 250 J **B** 290 J **C** 430 J **D** 500 J

52 A grasshopper of mass 0.12 g jumps vertically. It uses its back legs over a time of 0.020 s to jump, leaving the ground with a velocity of 3.0 m s^{-1}.

What is the average power developed by the legs of the grasshopper?

A 9.0×10^{-3} W **B** 1.8×10^{-2} W **C** 2.7×10^{-2} W **D** 37 W

53 A parachutist is falling at constant (terminal) velocity.

Which statement is **not** correct?

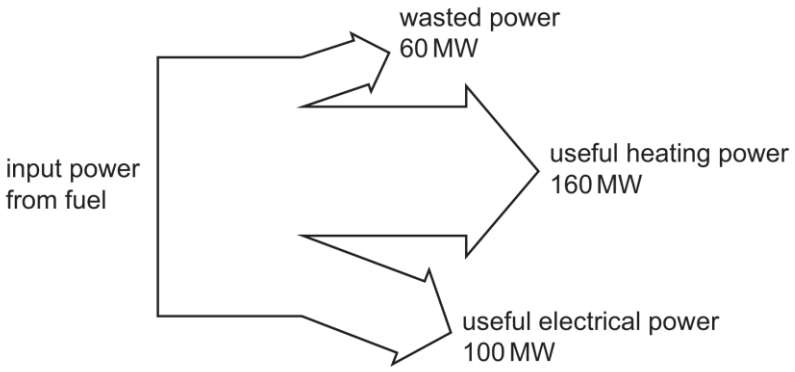
A Gravitational potential energy is converted into kinetic energy of the air.

B Gravitational potential energy is converted into kinetic energy of the parachutist.

C Gravitational potential energy is converted into thermal energy of the air.

D Gravitational potential energy is converted into thermal energy of the parachutist.

54 A combined heat and power (CHP) station generates electrical power and useful heat. The diagram shows the input and output powers for a CHP station.



What is the efficiency of the CHP station for producing useful power?

A 31% **B** 38% **C** 50% **D** 81%

55 A train on a mountain railway is carrying 200 people of average mass 70 kg up a slope at an angle of 30° to the horizontal and at a speed of 6.0 m s^{-1}. The train itself has a mass of 80 000 kg. The percentage of the power from the engine which is used to raise the passengers and the train is 40%.

What is the power of the engine?

A 1.1 MW **B** 2.8 MW **C** 6.9 MW **D** 14 MW

56 An electric motor produces 120 W of useful mechanical output power. The efficiency of the motor is 60%.

Which row is correct?

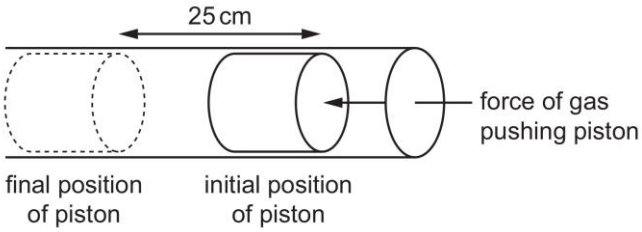
	electrical power input / W	waste heat power output / W
A	72	48
B	192	72
C	200	72
D	200	80

57 The engine of a car exerts a force of 600 N in moving the car 1.0 km in 150 seconds.

What is the average useful output power of the engine?

A 4.0 W **B** 4.0 kW **C** 90 kW **D** 90 MW

58 The gas in an engine does work on a piston of cross-sectional area 80 cm^2. The pressure on the piston has a constant value of 4.6×10^5 Pa.



How much work is done by the gas on the piston when it moves through a distance of 25 cm?

A 9.2×10^2 J **B** 9.2×10^4 J **C** 9.2×10^6 J **D** 9.2×10^8 J

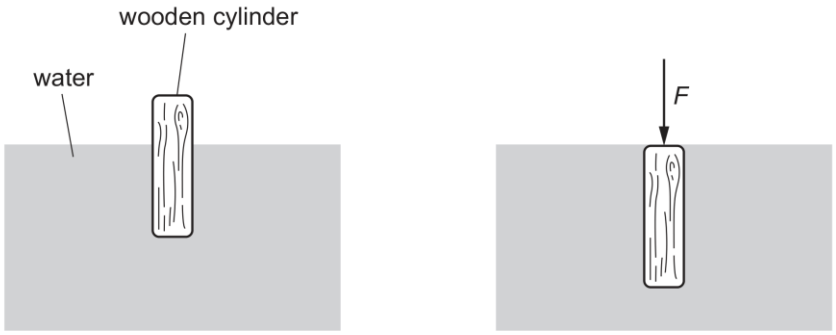
59 A power station using coal as fuel has an average power output of 3000 MW. Coal is supplied by 20 trains each day. The efficiency of the station in converting the thermal energy released from the coal to electrical energy is 26%.

A mass of 1.0 kg of coal will release 33 MJ of thermal energy when burnt.

Which mass of coal does each train bring?

A 2.5×10^4 kg **B** 6.3×10^4 kg **C** 1.5×10^6 kg **D** 3.0×10^7 kg

60 A wooden cylinder floats partially submerged in a bath of water. A force *F* is applied to the cylinder until it is just fully submerged.



Which statement is **not** correct?

A Some of the water gains gravitational potential energy.

B The cylinder loses gravitational potential energy.

C Work is done by force *F* on the cylinder.

D Work is done by the upthrust on the cylinder.

61 The motor of a crane lifts a load of mass 600 kg. The load rises vertically at a constant speed of 12 m per minute.

What is the useful power output of the motor?

A 0.12 kW **B** 1.2 kW **C** 7.2 kW **D** 71 kW

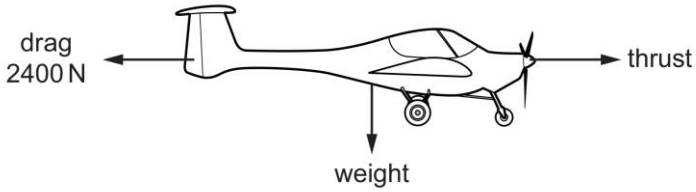
62 A train of mass 3.3×10^6 kg is moving at a constant speed up a slope inclined at an angle of 0.64° to the horizontal. The engine of the train is producing a useful output power of 14 MW.

Assume that there are no frictional forces opposing the motion of the train.

What is the speed of the train?

A $0.43\,m\,s^{-1}$ **B** $4.2\,m\,s^{-1}$ **C** $39\,m\,s^{-1}$ **D** $380\,m\,s^{-1}$

63 An aircraft travels at a constant velocity of $90\,m\,s^{-1}$ in horizontal flight. The diagram shows some of the forces acting on the aircraft.

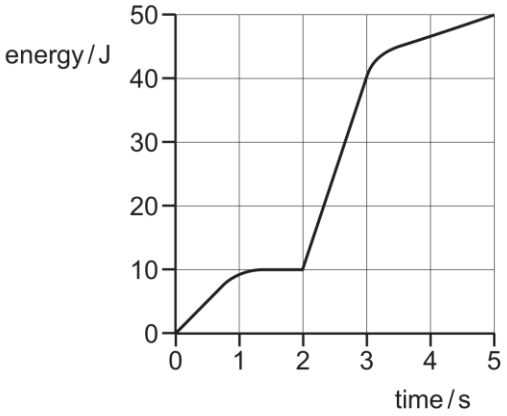


The mass of the aircraft is 2000 kg.

What is the power produced by the thrust force?

A 1.8×10^5 W **B** 2.2×10^5 W **C** 1.8×10^6 W **D** 2.0×10^6 W

64 An electrical generator is started at time zero. The total electrical energy generated during the first 5 seconds is shown in the graph.



What is the maximum electrical power generated at any instant during these first 5 seconds?

A 10 W **B** 13 W **C** 30 W **D** 50 W

65 In 'normal driving conditions', an electric car has a range of 150 km. This uses all of the 200 MJ of energy stored in its batteries.

With the batteries initially fully charged, the car is driven 100 km in 'normal driving conditions'. The batteries are then recharged from a household electrical supply delivering a constant current of 13.0 A at a potential difference of 230 V.

What is the minimum time required to recharge the batteries?

A 0.95 hours

B 12.4 hours

C 18.6 hours

D 27.9 hours

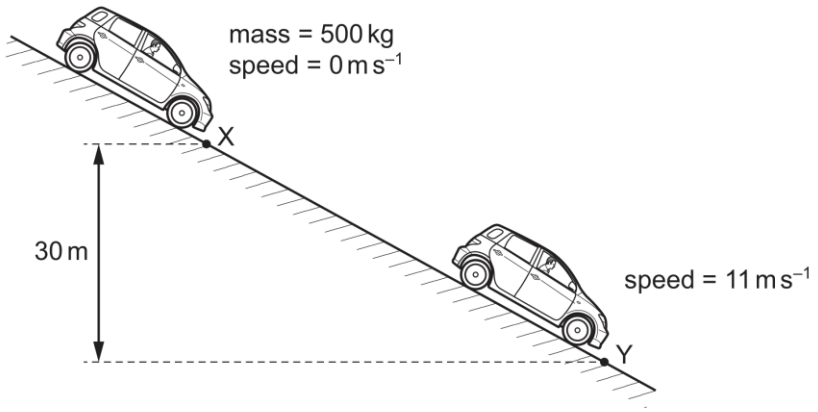
66 A steel sphere is dropped vertically onto a horizontal metal plate. The sphere hits the plate with speed u, leaves it at speed v, and rebounds vertically to half of its original height. Ignore air resistance.

Which expression gives the value of $\frac{v}{u}$?

A $\frac{1}{2^2}$ **B** $\frac{1}{2}$ **C** $\frac{1}{\sqrt{2}}$ **D** $1 - \frac{1}{\sqrt{2}}$

67 A car of mass 500 kg is at rest at point X on a slope, as shown.

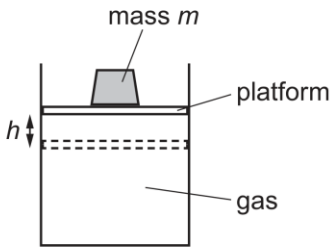
The car's brakes are released and the car rolls down the slope with its engine switched off. At point Y the car has moved through a vertical height of 30 m and has a speed of 11 m s^{-1}.



What is the energy dissipated by frictional forces when the car moves from X to Y?

A 3.0×10^4 J **B** 1.2×10^5 J **C** 1.5×10^5 J **D** 1.8×10^5 J

68 A mass m is on top of a platform that is supported by gas in a cylinder of cross-sectional area A, as shown.



The platform has negligible mass and can move freely up and down.

The gas is heated and expands so that the mass is raised through a height h. Atmospheric pressure is p.

What is the ratio $\frac{\text{gain in gravitational potential energy of the mass}}{\text{work done by the gas}}$?

A $\frac{mg}{pA}$ **B** $\frac{mg}{mg + pA}$ **C** $\frac{pA}{mg}$ **D** $\frac{mg - pA}{mg}$

69 A bungee jumper on a platform over a river is attached to an elastic rope that is 20 m long when unstretched. He falls towards the river and his lowest point is 30 m below the platform.

The initial gravitational potential energy of the jumper is transferred to other forms during the jump.

Which other forms of energy do the jumper and rope have when the jumper has fallen half-way and when he is at the lowest point of his jump?

	half-way	lowest point
A	kinetic energy and elastic potential energy	kinetic energy and elastic potential energy
B	kinetic energy and elastic potential energy	elastic potential energy only
C	kinetic energy only	kinetic energy and elastic potential energy
D	kinetic energy only	elastic potential energy only

70 A car of mass 1800 kg accelerates along a horizontal road so that its speed increases from 20 m s^{-1} to 25 m s^{-1} in a time of 5.4 s.

What is the average useful power output of the car's engine?

A 4.2 kW **B** 38 kW **C** 120 kW **D** 1100 kW