TOPIC 6 Work, Energy, Power

1 The door of a working refrigerator is left open. After some hours, the temperature of the room in which the refrigerator is placed is

A unchanged, because the refrigerator absorbs as much heat as it gives out.

B lower, because the refrigerator will extract heat from the room.

C unchanged, because the refrigerator is thermostatically controlled.

D higher, because the refrigerator gives out more heat than it absorbs.

E lower, because the coolant in the refrigerator will evaporate much more rapidly. J76/II/25

2 On braking, 500 kJ of heat were produced when a vehicle of total mass 1600 kg was brought to rest on a level road. The speed of the vehicle just before the brakes were applied was

A 0.625 m s^{-1}
B 0.79 m s^{-1}
C 25 m s^{-1}
D 52.5 m s^{-1}
E 625 m s^{-1} J77/II/30

3 A piece of brass undergoes 3 different processes involving change of energy:

P : it is lifted vertically 2m
Q : it is heated from 15 °C to 20 °C
R : it is accelerated from rest to 10 m s^{-1}.

Given that the specific heat capacity of brass is 380 J K^{-1} kg^{-1} and that g = 10 m s^{-2}, the processes, arranged in order of increasing energy change, are

A PQR
B QPR
C QRP
D PRQ
E RQP N77/II/3

4 A ball released from a height h_0 above a horizontal surface rebounds to a height h_1 after one bounce. The graph that relates h_0 to h_1 is shown below (Fig. 1).

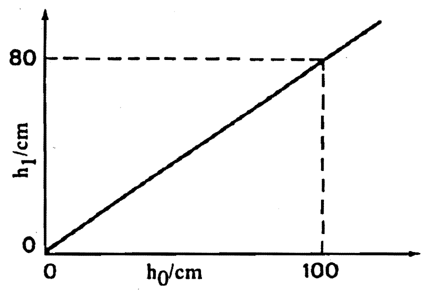


Fig. 1

If the ball (of mass m) was dropped from an initial height h and made three bounces, the kinetic energy of the ball immediately after the third impact with the surface was

A $(0.8)^3\,mgh$
B $(0.8)^2\,mgh$
C $0.8\,mg\,(h/3)$
D $[1 - (3 \times 0.2)]\,mgh$
E $[1 - (0.8)^3]\,mgh$ N81/II/2

5 A mass is projected vertically upwards with a given velocity. Neglecting air resistance, which one of the following statements is correct?

A The kinetic energy of the mass is a maximum at the maximum height attained.

B In accordance with the principle of conservation of energy, the total energy of the mass is constant throughout the motion.

C in accordance with the principle of conservation of momentum, the momentum of the mass is constant throughout the motion.

D The mass travels equal distances during equal periods of time during both ascent and descent.

E The potential energy increases uniformly with time during ascent. J83/II/1; J86/I/4

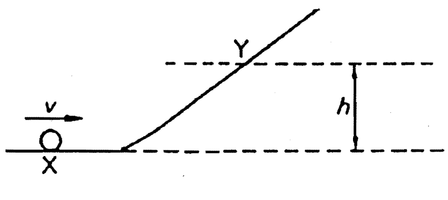
6 The potential energy of a body when it is at point P a distance x from a reference point O is given by $V = kx^2$, where k is a constant. What is the force acting on the body when it is at P?

A $2kx$ in the direction OP
B kx in the direction OP
C zero
D kx in the direction PO
E $2kx$ in the direction PO J84/II/2

7 A car of mass m has an engine which can deliver power P. What is the minimum time in which the car can be accelerated from rest to a speed v?

A $\dfrac{mv}{P}$
B $\dfrac{P}{mv}$
C $\dfrac{mv^2}{2P}$
D $\dfrac{2P}{mv^2}$
E $\dfrac{mv^2}{4P}$ N86/I/4

8 An object of mass m passes a point **X** with a velocity v and slides up a frictionless incline to stop at point **Y** which is at a height h above **X**.



A second object of mass $\frac{1}{2}m$ passes **X** with a velocity of $\frac{1}{2}v$. To what height will it rise?

A $\frac{1}{4}h$ **D** h
B $\frac{1}{2}h$ **E** $h\sqrt{2}$
C $\frac{1}{\sqrt{2}}h$

J87/I/5

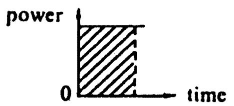
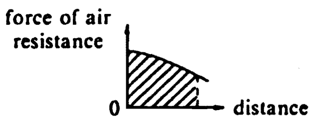
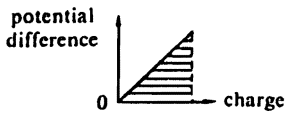
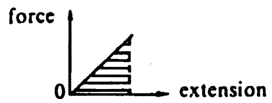
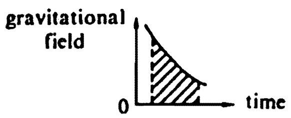
9 An electric motor is required to haul a cage of mass 400 kg up a mine shaft through a vertical height of 1200 m in 2.0 minutes. What will be the electrical power required if the overall efficiency is 80%?

[Take g is 10 m s^{-2}]

A 3.2 kW **D** 50 kW
B 5.0 kW **E** 3000 kW
C 32 kW

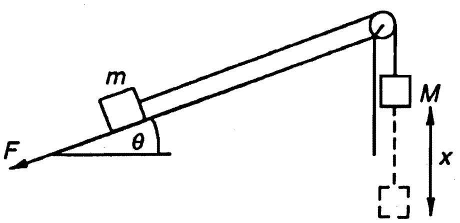
J87/I/8

***10** The graphs below were obtained from five different experiments. All but one of the shaded areas on the graphs have units of energy. Which shaded area does not have units of energy?

	experiment	*graph obtained*
A	power output of a lamp	
B	a ball thrown horizontally	
C	charging a capacitor	
D	stretching a spring	
E	motion of a space-craft away from the Earth	

N87/I/6

11 A mass m moves on a rough plane inclined at an angle θ to the horizontal and, when moving, experiences a constant frictional force F. Mass M is attached to it by means of a light inelastic cord running over a smooth pulley. Mass M is allowed to fall a vertical distance x, causing m to move up the plane as shown in the diagram below.



How much heat is generated by friction in this process?

A Fx **D** $Mgx \sin\theta - Fx$
B mgx **E** $Mgx \sin + Fx$
C $Mgx \sin\theta$

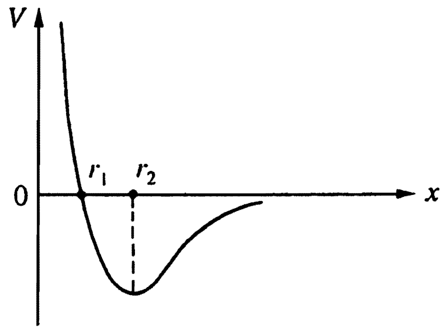
J88/I/6

12 What is the power required to give a body of mass m a forward acceleration a when it is moving with velocity v up a frictionaless track inclined at an angle θ to the horizontal?

A $mavg \sin\theta$ **D** $(mav + mgv) \sin\theta$
B $mav \sin\theta + mgv$
C $mav + mgv \sin\theta$ **E** $\dfrac{mav + mgv}{\sin\theta}$

N88/I/5

13 The mutual potential energy V of two molecules separated by distance x is shown in the diagram.

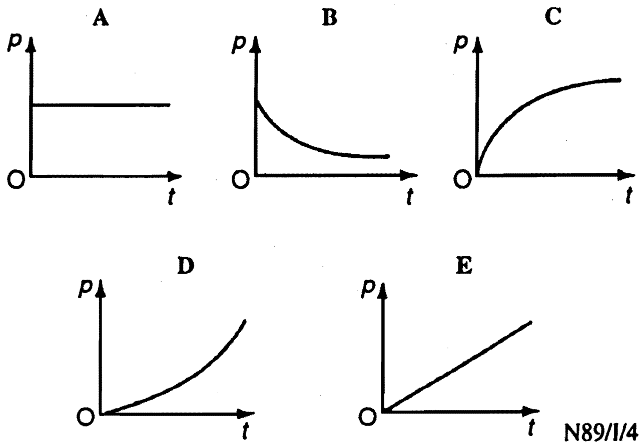


Which of the following correctly describes the force between the molecules?

	attractive for	*repulsive for*
A	$x < r_1$	$x > r_1$
B	$x > r_1$	$x < r_1$
C	$x < r_1$	$x > r_2$
D	$x < r_2$	$x > r_2$
E	$x > r_2$	$x < r_2$

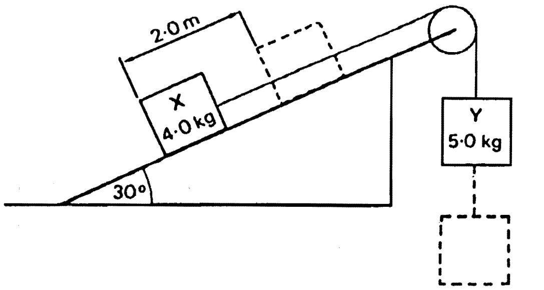
J89/I/6

14 A constant force is applied to a body which is initially stationary but free to move in the direction of the force. Assuming that the effects of friction are negligible, which of the following graphs best represents the variation of P, the power supplied, with time t?



N89/I/4

15 The diagram shows two bodies **X** and **Y** connected by a light cord passing over a light, free-running pulley, **X** starts from rest and moves on a smooth plane inclined at 30° to the horizontal.



What will be the total kinetic energy of the system when **X** has travelled 2.0 m along the plane? ($g = 9.8$ ms^{-2}).

A 20 J
B 59 J
C 64 J
D 132 J
E 137 J

J90/I/7

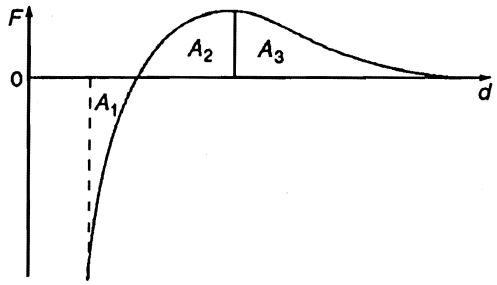
16 A crate is pushed 10 m along a horizontal surface by a force of 80 N. The frictional force opposing the motion is 60 N.

What are the correct values for the increase in internal energy of the system and the additional kinetic energy of the crate?

	increase in internal energy/J	additional kinetic energy/J
A	200	600
B	200	800
C	600	200
D	600	800

J90/I/7; J99/I/6

17 The graph shows how F, the attractive force between two atoms, varies with d, their separation.

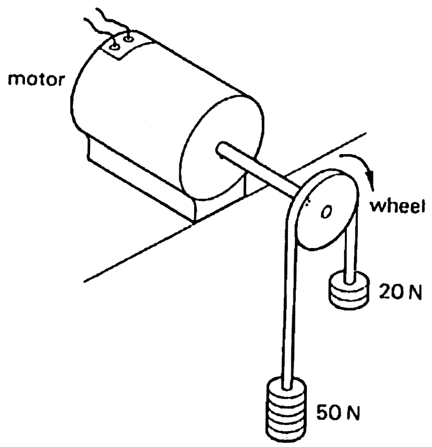


Which area represents the energy required to separate the atoms to infinity assuming that they are originally at their equilibrium spacing?

A A_2
B A_3
C $A_1 + A_2 + A_3$
D $A_2 + A_3 - A_1$
E $A_2 + A_3$

N90/I/8

18 The diagram shows an arrangement used to find the output power of an electric motor. The wheel attached to the motor's axle has a circumference of 0.5 m and the belt which passes over it is stationary when the weights have the values shown.



If the wheel makes 20 revolutions per second, what is the output power?

A 300 W
B 500 W
C 600 W
D 700 W

J91/I/5; J96/I/6

***19** A mass m, attached to the end of an unstretched spring, is initially supported by a platform as shown in Fig. 2. This platform is then removed and the mass falls, eventually coming to rest at the position shown in Fig. 3.

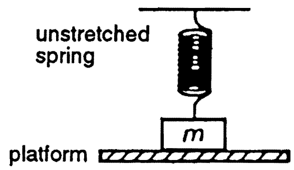


Fig. 2

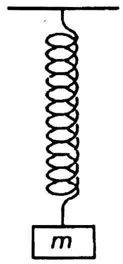


Fig. 3

Which of the following correctly relates the changes in potential energy and heat dissipation which may occur during this process?

A decrease of gravitational potential energy = increase of strain energy

B decrease of gravitational potential energy = increase of strain energy + energy dissipated as heat

C decrease of gravitational potential energy = decrease of strain energy + energy dissipated as heat

D decrease of gravitational potential energy+ energy dissipated as heat = increase of strain energy

E decrease of gravitational potential energy+ decrease of strain energy = energy dissipated as heat

N91/I/7

20 A body of mass m moves at constant speed v for a distance s against a constant force F.

What is the power required to sustain this motion?

A mv **B** $\frac{1}{2}mv^2$ **C** $\frac{1}{2}Fs$ **D** Fs **E** Fv

N92/I/6

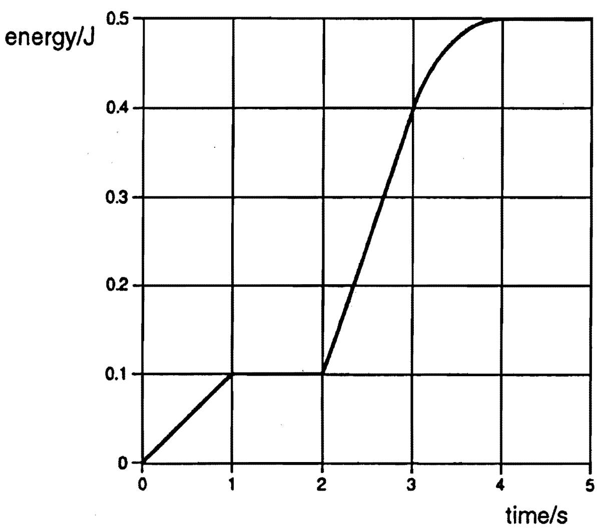
21 A small metal sphere of mass m is moving through a viscous liquid.

When it reaches a constant downward velocity v, which of the following describes the changes with time in the kinetic energy and gravitational potential energy of the sphere?

	kinetic energy	*gravitational potential energy*
A	constant and equal to $\frac{1}{2}mv^2$	decreases at a rate of mgv
B	constant and equal to $\frac{1}{2}mv^2$	decreases at a rate of $(mgv-\frac{1}{2}mv^2)$
C	constant and equal to $\frac{1}{2}mv^2$	decreases at a rate of $(\frac{1}{2}mv^2-mgv)$
D	increases at a rate of mgv	decreases at a rate of mgv
E	increases at a rate of mgv	decreases at a rate of $(\frac{1}{2}mv^2-mgv)$

J93/I/6

22 A bicycle dynamo is started at time zero. The total energy transformed by the dynamo during the first 5 seconds increases as shown in the graph.



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

A 0.10 W **C** 0.30 W
B 0.13 W **D** 0.50 W J94/I/6

23 A power station has an efficiency of 40% and generates 1000 MW of electrical power. What is the input power and the wasted power?

	input power/MW	*wasted power*/MW
A	1000	400
B	1000	600
C	1400	400
D	2500	1500

N94/I/6

24 A space vehicle of mass m re-enters the Earth's atmosphere at an angle θ to the horizontal. Because of air resistance, the vehicle travels at a constant speed v.

The heat-shield of the vehicle dissipates heat at a rate P, so that the mean temperature of the vehicle remains constant.

Taking g as the relevant value of the acceleration of free fall, which expression is equal to P?

A mgv
B $mgv \sin\theta$
C $\frac{1}{2}mv^2$
D $\frac{1}{2}mv^2 \sin^2\theta$ N95/I/6

25 A boat moving at constant speed v through still water experiences a total frictional drag F. What is the power developed by the boat?

A $\frac{1}{2}Fv$ **C** $\frac{1}{2}Fv^2$
B Fv **D** Fv^2 J97/I/6

26 A force of 1000 N is needed to lift the hook of a crane at a steady velocity. The crane is then used to lift a load of mass 1000 kg at a velocity of 0.50 m s^{-1}.

How much of the power developed by the motor of the crane is used in lifting the hook and the load? [Take g as 10 m s^{-2}.]

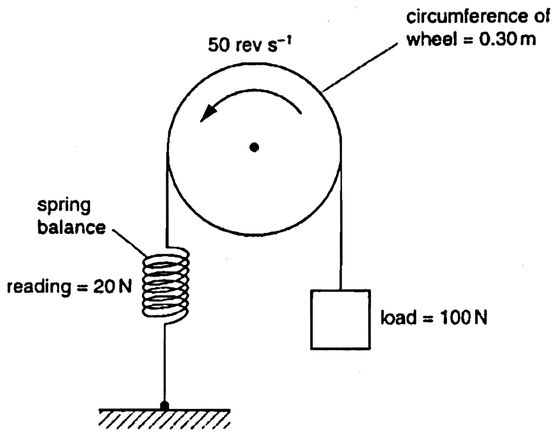
A 5.0 kW
B 5.5 kW
C 20 kW
D 22 kW N97/I/6

27 The engine of an inter-city train, travelling at 50 m s^{-1}, delivers a power of 2 MW.

What is the tractive force exerted by the engine?

A 4×10^4 N **C** 4×10^7 N
B 1×10^5 N **D** 1×10^8 N J98/I/6

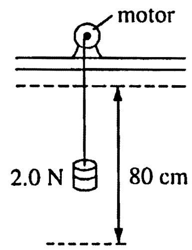
28 The diagram shows a wheel which is driven by an electric motor. A rope is fastened at one end to a spring balance. The rope passes over the wheel and supports a freely hanging load. When the wheel is turning at a steady speed, the balance reading is constant.



What is the output power of the motor?

A 0.3 kW **C** 1.5 kW
B 1.2 kW **D** 1.8 kW N98/I/6

29 A small electric motor is used to raise a weight of 2.0 N through a vertical height of 80 cm in 4.0 s.



The efficiency of the motor is 20%.

What is the electrical power supplied to the motor?

A 0.080 W **C** 2.0 W
B 0.80 W **D** 200 W N2000/I/6

30 The manufacturer claims that the maximum power delivered by the engine of a car of mass 1200 kg is 90 kW. Find the minimum time in which the car could accelerate from rest to 30 m s^{-1} (67 m.p.h.).

An independent test quotes a rest to 30 m s^{-1} time of 13.4 s. Suggest a reason for the difference from the time you have calculated. J81/I/1

31 *(a)* Define power.

(b)* Why is it that, in the SI system of units, power **cannot be defined using the equation

power = potential difference × current? [2]

N88/II/1

32 *(a)* In what way is the momentum of a body affected by the resultant force acting on it? [2]

(b) A conveyor belt travelling at a speed of 3.0 m s^{-1} and at an angle of 20° to the horizontal has 18 kg of sugar dropped on to it each second as shown in Fig. 4.

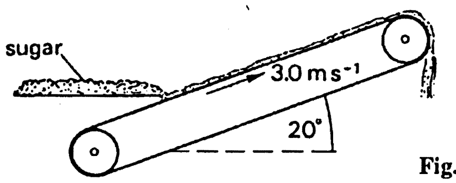


Fig. 4

Assuming that the sugar has negligible speed before reaching the belt, calculate

(i) the momentum gained in each second by the sugar,

(ii) the force which the belt must exert on the sugar to accelerate it to the speed of the belt,

(iii) the work done per second by the belt on the sugar in exerting this force.

(iv) the potential energy gained in each second by all the 36 kg of the sugar which is on the belt. [7]

(c) From your answers to *(b)* find the extra power required by the driving motor when the belt is loaded rather than unloaded. [2]

N91/II/1

33 *(b)* The strain energy stored in the bow just before release of the arrow is 95 J. When the arrow of mass 170 g is fired, 90% of the strain energy is transferred to the arrow. Show that the speed of the arrow as it leaves the bow is 32 ms^{-1}. [3]

N2000/II/2 (part)

Long Questions

34 *(c)* (i) A *perpetual motion machine* would be able to produce a continuous output of work with no energy input. State the physical principle which makes this impossible. [2]

(ii) Fig. 5 shows one suggestion put forward as a perpetual motion machine. The ball in position **A** would fall off the top of the water doing work on the pulley belt. At **B** it would move sideways doing no work and enter the bottom of the tank by a valve system which would prevent water from escaping. It would then float to the top ready to start again.

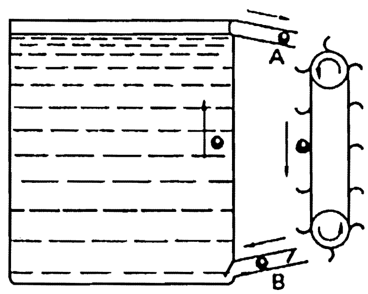


Fig. 5

Explain why this system will not behave as a perpetual motion machine. [5] J91/III/4 (part)

35 *(a)* (i) Explain what is meant by the concept of *work.*

(ii) Hence derive the equation

$$E_p = mgh,$$

for the potential energy change of a mass m moved through a vertical distance h near the Earth's surface. [4]

J98/III/5 (part)

36 *(c)* The minimum flying speed for a bird called a house-martin is 9.0 m s^{-1}. It reaches this speed by falling from its nest before swooping away. Calculate the minimum distance its nest must be above the ground. [2]

(d) A house-martin has a mass of 120 g. When it returns to its nest, it is travelling horizontally at P with a speed of 13.0 m s^{-1} and at a distance 7.5 m below its nest. It then glides upwards to the nest, as shown in Fig. 6.

Neglecting any air resistance, calculate

(i) the kinetic energy of the house-martin at P,

(ii) the total gain in potential energy as it glides upwards to its nest,

(iii) its kinetic energy as it reaches its nest,

(iv) its speed as it reaches its nest.

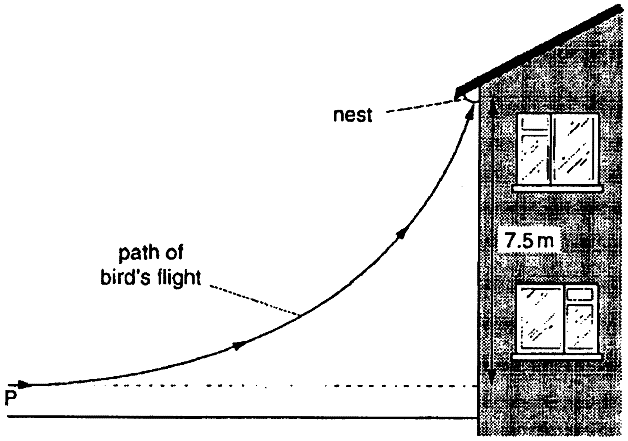


Fig. 6

(e) Discuss qualitatively how air resistance affects, if at all, each of your answers in *(d)*. [4]

N98/III/1 (part)

37 *(a)* Starting with the definition of work, deduce the change in the gravitational potential energy of a mass m, when moved a distance h upwards against a gravitational field of field strength g. [3]

(b) By using the equations of motion, show that the kinetic energy E_K of an object of mass m travelling with speed v is given by

$$E_K = \frac{1}{2}mv^2. \quad [3]$$

(c) A cyclist, together with his bicycle, has a total mass of 90 kg and is travelling with a constant speed of 15 m s^{-1} on a flat road at A, as illustrated in Fig. 7. He then goes down a small slope to B so descending 4.0 m.

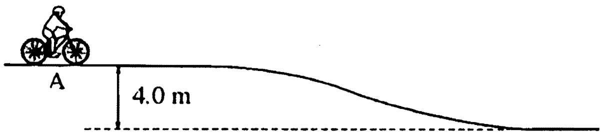


Fig. 7

Calculate

(i) the kinetic energy at A,

(ii) the loss of potential energy between A and B,

(iii) the speed at B, assuming that all the lost potential energy is transformed into kinetic energy of the cyclist and bicycle. [5]

(d) (i) A cyclist travelling at a constant speed of 15 ms^{-1} on a level road provides a power of 240 W.

Calculate the total resistive force.

(ii) The cyclist now travels at a higher constant speed. Explain why the cyclist needs to provide a greater power. [4]

(e) It is often stated that many forms of transport transform chemical energy into kinetic energy. Explain why a cyclist travelling at constant speed is not making this transformation. Explain what transformations of energy are taking place. [5]

N99/III/1

38 *(a)* Define

(i) work,

(ii) power. [3]

(b) By reference to equations of motion, derive an expression for the kinetic energy E_k of an object of mass m moving at speed v. [4]

(c) A car is travelling along a horizontal road with speed v, measured in metres per second. The power P, measured in watts, required to overcome external forces opposing the motion is given by the expression

$$P = cv + kv^3,$$

where c and k are constants.

(i) Use base units to obtain an SI unit for the constant k.

(ii) For one particular car, the numerical values, in SI units, of c and of k are 240 and 0.98 respectively. Calculate the power required to enable the car to travel along a horizontal road at 31 m s^{-1}. [6]

(d) The car in *(c)* has mass 720 kg. Using your answer to *(c)*(ii) where appropriate, calculate, for the car travelling at 31 m s^{-1},

(i) its kinetic energy,

(ii) the magnitude of the external force opposing the motion of the car,

(iii) the work done in overcoming the force in (ii) during a time of 5.0 minutes. [5]

(e) By reference to your answers to *(d)*, suggest, with a reason, whether it would be worthwhile to develop a system whereby, when the car slows down, its kinetic energy would be stored for re-use when the car speeds up again. [2]

J2000/III/2