4. Energy & Fields Problem Set

4.1 ENERGY STORES AND TRANSFERS

4.1.1 Exercises

For this section of the problem set, you should try the exercises without looking at the solutions. The solutions are there if you get stuck and you should also use it to understand how to present your work.

E1 An arrow is placed on the string of a bow and pulled back before being released from the bow. Describe the energy stores and transfers of the arrow.

4.1.2 Problem

P1. N12/1/10

The top end of a spring is attached to a fixed point and a mass of 4.2 kg is attached to its lower end. The mass is released and after bouncing up and down several times it comes to rest at a distance 0.29 m below its starting point. Which row gives the gain in the gravitational potential energy of the mass E_p and the gain in the elastic potential energy of the spring E_s?

	E_p / J	E_s / J
A	–12	+12
B	–12	+6
C	+12	+12
D	+12	+6

4.2 WORK DONE BY A FORCE

4.2.1 Exercises

E2 **(a)** Calculate the work done by Denise to drag her basket of laundry of mass 5.0 kg a distance of 5.0 m along a floor, if the force she exerts is 30.0 N at an angle of 60° with the horizontal. [75 J]

(b) Hilda holds a gardening book of weight 10 N at a height of 1.0 m above her patio for 50s.

Calculate the work done by Hilda during the 50 s? [0 J]

E3 **(a)** Can work done be positive or negative? State the condition for it.

(b) Can work done be zero? State the condition(s) for it.

E4 An object at rest is pulled by a constant horizontal force, F on a smooth floor to a displacement of x.

(a) Sketch a graph of force applied on object against the displacement. Label F and x in the graph.

(b) What does the area under force against displacement graph in **(i)** represent?

E5 An object at rest is pulled by a varying horizontal force, F_x on a smooth floor to a displacement of x.

(a) Can we still use this formula to calculate the work done by Fx, *i.e workdone* = $F_x(x)$?

(b) How can the work done by F_x be calculated?

4.2.2 Problems

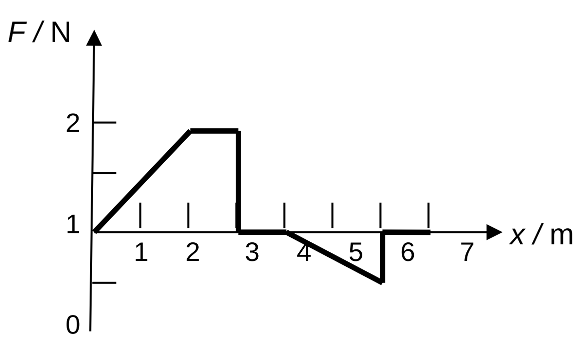
P2. 2011/P1/Q11

A constant force F is applied to a stationary object of mass m on a frictionless surface. A constant acceleration increases the velocity of the object to some value v in a time t. It covers a distance s during this time.

Which value of energy is given to the object's kinetic store?

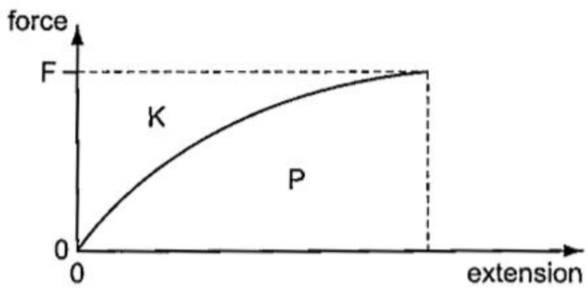
A Fst **B** Fv **C** Fs **D** $\frac{ms}{2t}$

P3. A force F that is parallel to the x-axis acts on a block of ice. The magnitude of the force varies with the x-coordinate of the block as shown. Calculate the work done on the block of ice by the force F when the block moves from x = 0 m to x = 7.0 m.

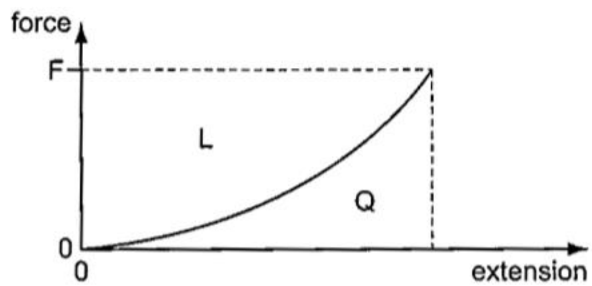


P4. N14/P1/Q17

A long nylon fibre is stretched by a force that is increased from zero to a final value F. The force-extension graph is obtained for this process is shown below.



When the force is subsequently reduced from F to zero, the force-extension graph obtained is shown below.



Which combination of areas from these graphs give the net work done on the fibre?

A K – L **B** K + L **C** P – Q **D** P + Q

4.3 KINETIC ENERGY

4.3.1 Exercises

E6 Sam pushes a 10 kg sack of rice on a frictionless surface with a constant horizontal force of 2.0 N starting from rest.

(a) What is the energy in the kinetic store of the sack after Sam has pushed it a distance of 35 cm?

(b) What is the speed of the sack after Sam has pushed it a distance of 35 cm?

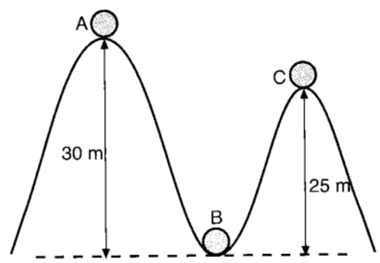
[0.70 J; 0.37 m s^{-1}]

4.4 CONCEPT OF A FIELD

4.5 POTENTIAL ENERGY

4.5.1 Exercises

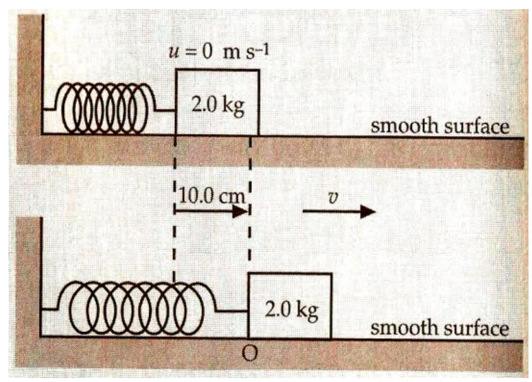
E7. A roller coaster is shown in figure below. Assuming no friction, and that the coaster has a speed of 2.80 m s^{-1} at point A, calculate



(a) the speed at point B, and [24.4 m s^{-1}]

(b) the speed at point C. [10.3 m s^{-1}]

E8. A block of mass 2.0 kg placed on a smooth table is pressed against a spring as shown below. The spring is compressed by a distance of 10.0 cm from its unstretched length. The block is released and it accelerates until it leaves the spring at O. The spring has a spring constant of 500 N m^{-1}.



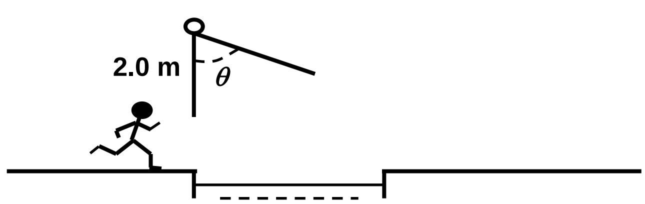
Calculate

(a) the work done in compressing the spring. [2.5 J]

(b) the speed of the block when it leaves O. [1.6 m s^{-1}]

4.5.2 Problems

P5. In the process of crossing an obstacle course, a 65 kg student running at 5.0 m s^{-1} grabs a hanging rope of length 2.0 m, and swings out over a pit of water. He releases the rope when his speed is 2.0 m s^{-1}. What is the angle θ when he releases the rope?



P6. N13/P1/Q10

Which row in the table gives the gravitational potential energy, the elastic potential energy and the kinetic energy of a bungee jumper during the first fall? Air resistance is negligible.

		gravitational potential energy/ kJ	elastic potential energy/ kJ	kinetic energy/ kJ
A	top	120	0	0
	middle	60	10	50
	bottom	0	120	0
B	top	120	0	0
	middle	60	30	30
	bottom	0	60	60
C	top	120	0	0
	middle	60	30	60
	bottom	0	120	0
D	top	120	0	0
	middle	60	60	0
	bottom	0	120	0

P7. An 80.0 kg sky diver jumps out of a balloon at an altitude of 1000 m and opens the parachute at an altitude of 200 m. The total retarding force on the diver is constant at 50.0 N with the parachute closed and constant at 3600 N with the parachute open.

(a) What is the speed of the diver when he lands on the ground?

(b) At what height should the parachute be opened so that the final speed of the sky diver when he hits the ground is 5.00 m s^{-1}?

P8. 2009 H1 P2 Q7

Fig. 8.1 shows a man doing a bungee jump.

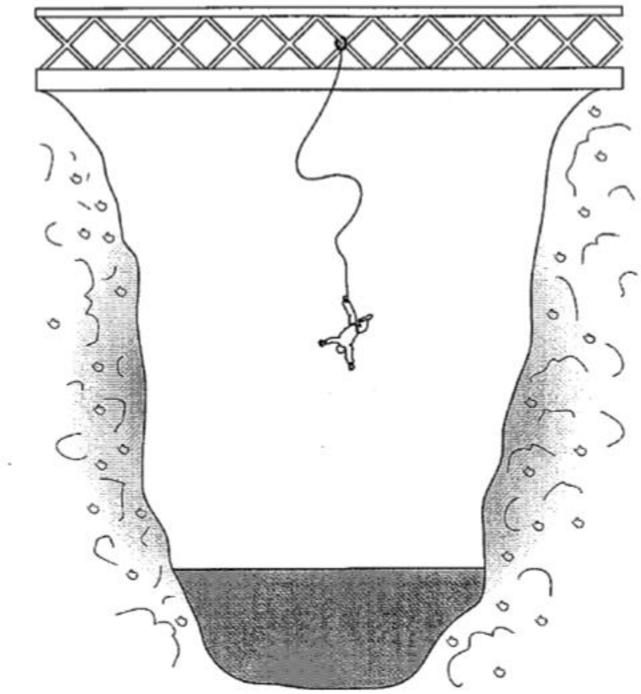


Fig. 8.1

The man has a mass of 75 kg and falls a distance of 41 m before the elastic rope attached to him starts to exert a force on him.

(a) **(i)** Calculate the theoretical time for a fall of this distance. [2]

(ii) The actual time taken for the fall is 2.9 s. State the deduction you can make by comparing the actual time with your answer to **(i)**. [1]

(b) A force-extension graph for the elastic rope used for the bungee jump is shown in Fig. 8.2.

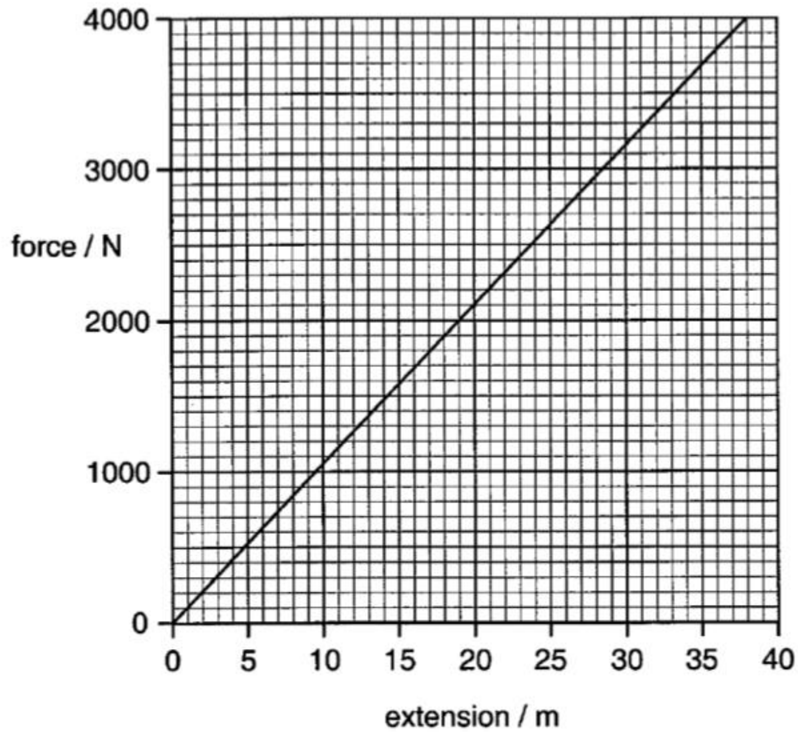


Fig. 8.2

The total distance of fall for the man before he stops for the first time is 73 m. Deduce

(i) the extension of the rope when the man stops for the first time, [1]

(ii) the energy in the potential store in the rope at this time. [1]

(c) **(i)** Complete Fig. 8.3 to show the gravitational potential energy and the kinetic energy of the man at the three points stated, together with the elastic potential energy stored in the rope. The gravitational potential energy at the bottom of the fall is taken to be zero.

	at the top	after falling 41 m	after falling 73 m (i.e. when stopped)
gravitational potential energy /J			0
elastic potential energy /J			
kinetic energy /J			

[5]

Fig. 8.3

(ii) Calculate

1. how far the man has fallen from the top when he has maximum kinetic energy,

2. the maximum kinetic energy of the man during the fall.

(iii) Use your values to sketch **three** graphs on Fig 8.4 showing how the three different types of energy vary with distance fallen. Label each graph.

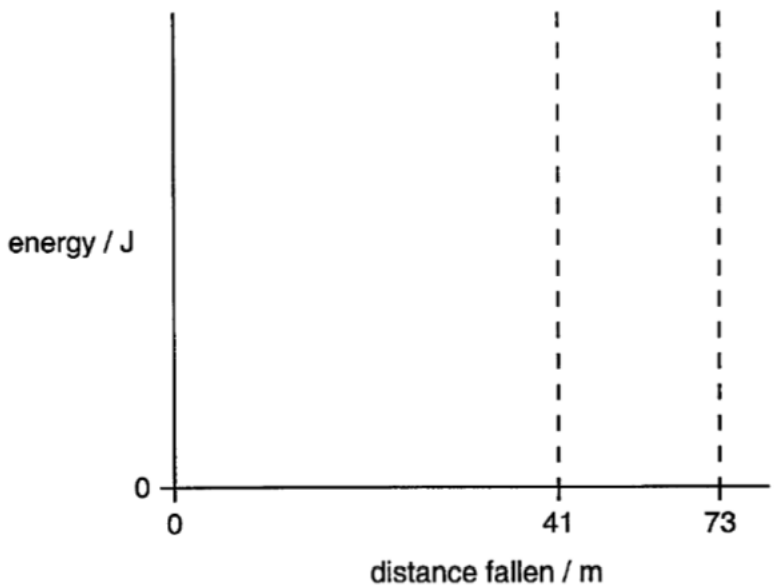


Fig. 8.4

[1]

4.6 POWER AND EFFICIENCY

4.6.1 Exercises

E9. 2009/P1/Q12

A speed boat with two engines, each of power output 36 kW, can travel at a maximum speed of 12 m s^{-1}. The total drag *D* on the boat is related to the speed *v* of the boat by the equation shown.

$$D \propto v^2$$

What is the maximum speed of the boat when only one engine is working?

A 3.0 m s^{-1} **B** 6.0 m s^{-1} **C** 8.5 m s^{-1} **D** 9.5 m s^{-1}

4.6.2 Problems

P9. A car of mass 1200 kg starts from rest at the foot of a hill inclined at an angle θ to the horizontal, where $\sin\theta = 1/5$. 3.0 minutes later, the car has a speed of 20.0 m s^{-1} and has travelled a distance of 1.8 km. The frictional forces resisting the motion are constant and of magnitude 210 N. Calculate, in this time, the average power of the engine of the car.

P10. N15/1/8

A car travels along a road at a constant speed of 20 m s^{-1}. Its power output is 23 kW. The total frictional force on the car is proportional to the square of its speed.

What power will be required to travel at a constant speed of 40 m s^{-1}?

A 46 kW **B** 92 kW **C** 184 kW **D** 368 kW

P11. A tugboat, moving by itself in calm water, requires 80 kW at the propeller to move with a steady speed of 5.0 m s^{-1}. When towing a large ship at the same steady speed, 600 kW must be delivered to the propeller. Calculate the force in the towline.

P12. N12/P1/19

A railway locomotive pulling a train delivers a constant power os 2.0×10^6 W to the wheels. The resistive forces are constant at all speeds. The maximum speed that the train can achieve on a level track is 40 m s^{-1}.

What is the resultant force accelerating the train when it is travelling at 10 m s^{-1}?

A 5.0×10^4 N **B** 1.5×10^5 N **C** 2.0×10^5 N **D** 2.5×10^5 N

P13. N16/P1/11

A small car of mass 800 kg travels at a constant speed of 20 m s^{-1} along a level road against resistive forces of 400 N. The efficiency of the car in converting the energy of the fuel into work done against the resistive forces is 16 %.

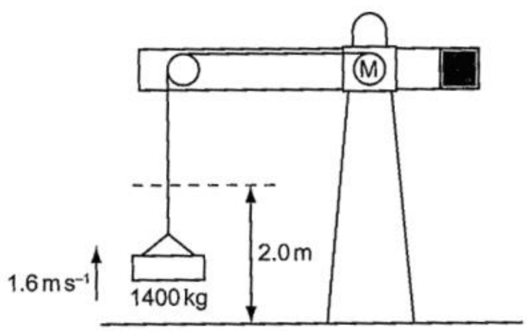
One kilogram of fuel has an energy value of 48 Mj.

How much fuel does the car use to travel one kilometre?

A 52 g **B** 85 g **C** 220 g **D** 260g

P14. N13/P1/11

The motor M in a crane is used to lift a total mass of 1400 kg through a height of 2.0 m at a constant speed of 1.6 m s^{-1}. The motor is 20% efficient.



What is the minimum power to motor M?

A 11 kW **B** 22 kW **C** 110 kW **D** 140 kW

Numerical Answers to Exercise Questions

2a)	75 J	6b)	0.37 m s^{-1}	7a)	24.4 m s^{-1}	b)	10.3 m s^{-1}
8a)	2.5 J	b)	1.6 m s^{-1}	9)	9.5 m s^{-1}		