TOPIC 3 Dynamics

1 An astronaut's boots weigh 100 N on Earth where the acceleration of free fall is 10 m/s^2.

How much will they weigh on Mars where the acceleration of free fall is 4 m/s^2.

A 25 N
B 40 N
C 100 N
D 250 N
E 400 N J90/I/3

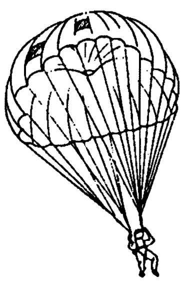
2 When a force is applied to a body, several effects are possible.

Which of the following effects could **not** occur?

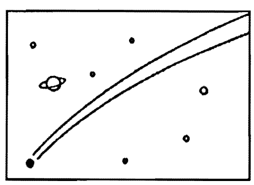
A The body speeds up.
B The body rotates.
C The body changes direction.
D The pressure on the body increases.
E The mass of the body decreases. J90/I/5

3 The diagrams show some effects which are all due to the same physical property.

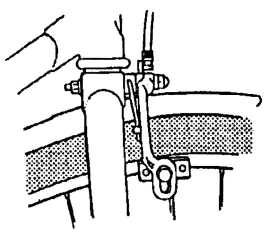
a parachutist falling through the air



a meteor glowing as it falls through the atmosphere



brakes slowing down a bicycle



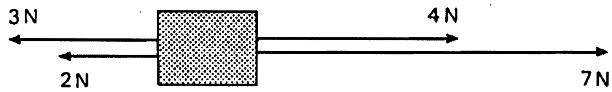
What is this physical property?

A density
B friction
C heat
D mass
E weight N91/I/6

4 Which expression can be used to calculate force?

A force = frequency × wavelength
B force = mass × acceleration
C force = power ÷ time
D force = pressure ÷ area
E force = work × distance N91/I/7

5 The diagram shows four forces acting on a block.



What is the resultant force?

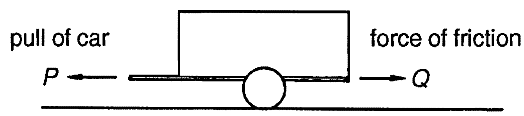
A zero
B 5 N to left
C 6 N to right
D 11 N to right
E 16 N to left N91/I/8

6 A known force is applied to an object on a horizontal, frictionless surface.

What property of the object must be known in order to calculate its acceleration?

A density
B mass
C surface area
D volume
E weight J92/I/5

7 The diagram shows the horizontal forces acting on a trailer as it is pulled along a level road by a car. No other horizontal forces act on the trailer.

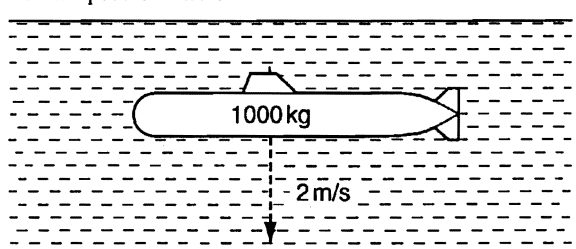


Which values of P and Q will cause the trailer to move with constant velocity?

	P	Q
A	50 N	100 N
B	50 N	200 N
C	100 N	50 N
D	100 N	100 N
E	100 N	200 N

N93/I/6

8 A small submarine of mass 1000 kg sinks in water with a uniform speed of 2 m/s.



What is the resultant force exerted on the submarine as it sinks?

A 0 N
B 500 N downwards
C 2000 N downwards
D 10 000 N downwards J94/I/6

9 When a block of wood of mass 2 kg was pushed along the horizontal flat surface of a bench, the friction force measured was 4 N.

When the block was pushed along the same bench with a force of 10 N, it moved with a constant

A speed of 3 m/s.
B speed of 5 m/s.
C acceleration of 3 m/s^2.
D acceleration of 5 m/s^2. N96/I/5

10 The total weight of a gas-filled balloon is 1500 N. The balloon rises at a constant speed of 3 m/s.

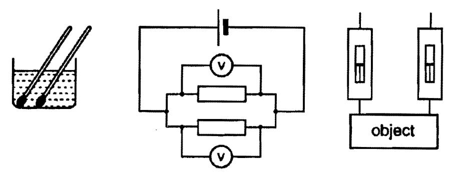
What is the resultant force acting on the balloon while it is rising?

A zero
B 500 N
C 1500 N
D 4500 N N94/I/6; J97/I/8

11 Simple experiments are performed to determine values of three quantities.

quantity	the temperature of a liquid	the e.m.f. of a cell	the weight of an object
instruments	2 thermometers	2 voltmeters	2 newton-meters

experiment



In how many of these experiments, if any, are the measured values of both instruments added together to determine the value of the quantity?

A 0
B 1
C 2
D 3 N97/I/2

12 An experiment is carried out by an astronaut on the surface of the Moon. A coin and a feather are dropped at the same instant from the same height.

Which statement is correct?

A The coin falls faster than the feather, but both take a longer time than if they were falling from the same height on Earth.

B The coin falls faster than the feather, but both take a shorter time than if they were falling from the same height on Earth.

C They fall together, taking a longer time than the coin would in falling from the same height on Earth.

D They fall together, taking a shorter time than the coin would in falling from the same height on Earth. N97/I/4

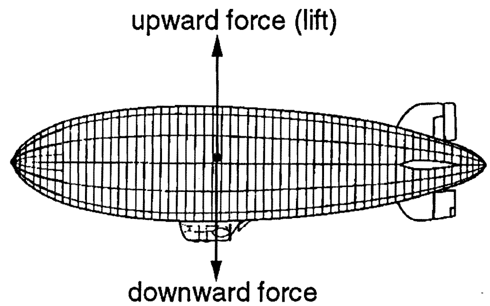
13 In which of the following is a force of friction necessary?

A when a ball is bouncing off a wall
B when a car is accelerating
C when a drum skin is vibrating
D when a rocket is taking off J98/I/39

14 Which property of a solid object **cannot** be changed by the application of a force?

A length
B mass
C shape
D speed J99/I/6

15 An airship is moving forwards at constant height.



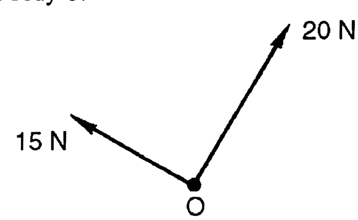
Which statement is correct?

A Gravity no longer has any effect.
B The airship now has zero mass
C The potential energy is zero.
D The upward and downward forces are balanced. J2000/I/6

16 In which direction does the frictional force always act on an object moving across a horizontal surface?

A in the direction of the gravitational force
B opposite to the direction of the gravitational force
C in the direction of motion
D opposite to the direction of motion N2000/I/6

17 The diagram below shows two horizontal forces of magnitude 15 N and 20 N, acting in perpendicular directions on a small body O.



(a) Determine the magnitude of the resultant force acting on the body.

(b) The body rests on a horizontal ice surface and friction between the body and the ice can be neglected. What is the angle between the direction of motion of the body and the direction of the 20 N force?

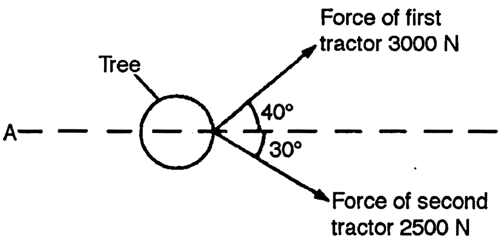
(c) The body accelerates at 4.0 m/s^2; what is its mass?

(d) The forces continue to act so that the body moves in the direction of the resultant force for 6.0 s. Calculate

(i) the velocity acquired by the body in this time,

(ii) the distance travelled in this time. J79/II/3

18 The diagram shows the horizontal forces exerted on a tree by two tractors in an attempt to pull it out of the ground.



(a) *In the space below* draw a diagram to a stated scale and use it to determine the magnitude and direction of the resultant force exerted on the tree by the two tractors.

Scale used

Magnitude of resultant force exerted on tree

Angle between AB and the direction of the resultant force.

(b) Once pulled out of the ground the tree is dragged away at constant speed by a steady force. Explain why a force is necessary to maintain a constant speed.

(c) Finally the tree trunk of mass 4000 kg is dropped into a fast-moving river. Assuming the water exerts a resultant force of 1440 N on the trunk in the direction of the flow of the water, calculate the initial acceleration of the trunk in this direction. J80/II/1

19 Why is *force* referred to as a vector quantity?

Two forces acting at a point have magnitudes 5 N and 8 N. Explain why their resultant may have any magnitude between 3 N and 13 N.

Forces of 7.0 N and 11.0 N act at a point so that the angle between their lines of action is 35°. By means of a scale diagram, determine the magnitude of the resultant of these two forces.

Describe an experiment which demonstrates that the application of a force to a mass produces an acceleration.

A resultant force of 50 N acts on a mass 4.0 kg. Calculate the acceleration produced. J81/II/7

20 With the aid of a labelled diagram, describe an experiment which could be used to find a value of g, the acceleration of free fall. Indicate clearly how you would work out the result.

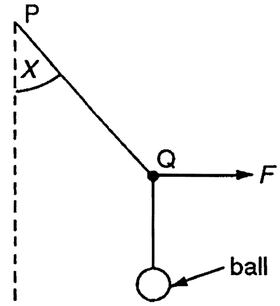
The diagram shows a ball of mass 6 kg hanging from a string that is pulled to one side by a horizontal force F of 50 N.

By taking the weight of 1 kg as 10 N, draw a scale diagram to find

(a) the resultant of F and the weight of the ball,

(b) the tension in the string PQ to maintain the string as shown,

(c) the value of angle X.



The string holding the ball breaks so that the ball falls vertically to the ground in 1.5 s.

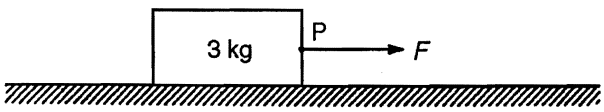
Calculate

(i) the speed with which the ball hits the grounds,

(ii) the distance fallen.

[Take g as 10 m/s^2.] N83/II/7

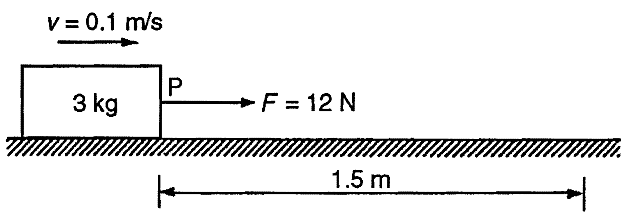
21 *(a)* The diagram shows a mass of 3 kg resting on a horizontal surface. A force F, steadily increasing from zero, is applied at P in the direction shown and eventually the mass starts to move.



Explain what prevents the mass moving until the force reaches a particular value.

(b) The diagram shows the same mass moving at a *steady speed* of 0.1 m/s when the applied force F is 12 N.

(i) Draw in the other horizontal force which is acting on the mass and indicate its line of action and magnitude.



(ii) Calculate the work done in moving the mass 1.5 m along the surface.

(c) Force F is now increased to 18 N and acts for 0.2 s. Assuming that all other forces remain constant, calculate

(i) the acceleration produced,

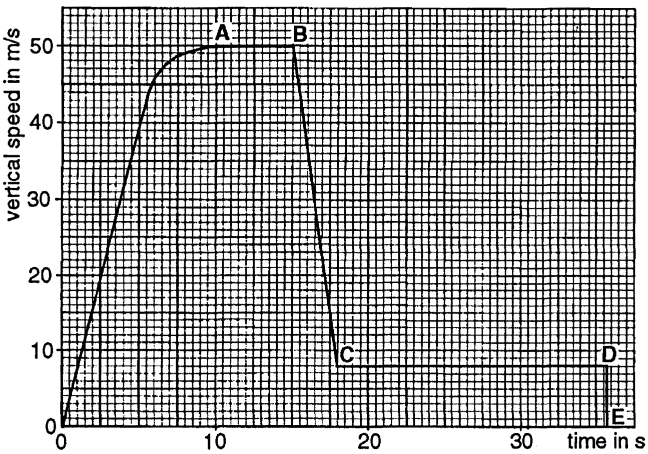
(ii) the highest speed reached. N83/II/1

22 The graph below shows how the vertical speed of a parachutist falling from an aircraft varies with time until he reaches the ground.

(a) Calculate

(i) the average speed of the parachutist during the first five seconds.

(ii) the acceleration of the parachutist during this period.



(b) During the period AB, the speed of the parachutist is steady even though his parachute has not opened. Why is this?

(c) The parachute opens at B. Given that the mass of the parachutist is 120 kg, calculate the average force slowing him down during the period BC. J84/II/1

23 A metal box, attached to a small parachute, is dropped from a helicopter.

(a) Explain in terms of the forces acting, why

(i) its velocity increased immediately after being dropped,

(ii) it reached a uniform velocity after a short time.

(b) The total force opposing the motion of the box and parachute at a particular instant during its fall is 30 N. The combined mass of the box and parachute is 5.0 kg. Calculate the resultant downward force on the box and parachute. (g = 10 N/kg)

Briefly describe the motion of the box and parachute at this time.

(c) At the end of this fall the parachute is caught on a tall tree. The box is then cut loose and falls from rest to the ground. The time of fall is 2.4 s.

Calculate

(i) the velocity with which the box strikes the ground,

(ii) the average velocity during its fall,

(iii) the distance fallen. (g = 10 m/s^2) N85/II/I/1

24 In a laboratory experiment a small trolley was accelerated from rest by applying a small force to it. The distance travelled by the trolley was measured as 1.1 m in a time of 0.55 s. Calculate its average speed.

During this movement, the trolley was uniformly accelerating from rest. Calculate its speed after 0.55 s and its acceleration during this period.

The mass of the trolley is 1.2 kg. What is the force producing this acceleration?

N86/II/7

25 Explain what is meant by *speed* and *velocity*. Illustrate the difference between them by quoting an example.

A loaded lorry has a mass of 9000 kg. The graph below shows how the speed of the lorry varied with time during part of a journey.

(a) From A to B the lorry was accelerating along a flat, straight road. Use the graph to calculate

(i) the acceleration during the first 4.0 s,

(ii) the force necessary to cause this acceleration,

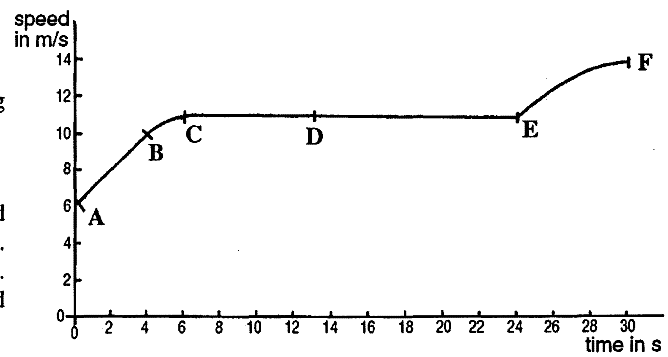
(iii) the distance travelled during the first 4.0 s.

(c) From D to E the lorry travelled up a straight hill of constant gradient; from E to F it travelled along a section of flat road. The force transmitted from the engine to the wheels was constant throughout DF.

Explain, in terms of the other forces acting on the lorry, why

(i) the acceleration was zero from D to E,

(ii) the speed began to increase after E.



J87/II/7

26 A stunt man has one end of a thick elastic cord attached to him; the other end of the cord is firmly attached to a point on a high bridge. When the man jumps from the bridge he falls freely under gravity for 2.5 s. Take the acceleration of free fall to be 10 m/s^2 and assume that the man is initially at rest.

(a) Calculate

(i) the vertical speed the man acquires during his free fall,

(ii) the vertical distance fallen.

Suggest *one* reason why, in a real jump, the distance fallen in 2.5 s and the speed reached would be less than your calculated answers, *even though the cord was slack throughout* the 2.5 s. [3]

(b) After this time the cord begins to stretch and the man falls with continually reducing downward acceleration.

Why is this? [2]

(c) Eventually his downward acceleration becomes zero. Explain why this happens.

If the mass of the man is 80 kg, suggest a value for the tension in the cord when his downward acceleration is zero.

Without making any further calculation, describe his motion after the point where his downward acceleration has become zero. [5] N88/II/1

27 *(a)* What is meant by *acceleration*? [2]

(b) In an experiment, a trolley was pulled by a force along a straight track. The trolley started from rest and the total distance travelled was measured at regular intervals of time. The results obtained are shown.

time/s	*distance travelled*/m
0	0
1.0	0.16
2.0	0.64
3.0	1.44
4.0	2.56
5.0	4.00

(i) Explain how the results show that the trolley was accelerating.

(ii) Use the results to show that the acceleration was uniform, and calculate a value for the acceleration.

(iii) Assuming that the force accelerating the trolley was 0.80 N, find the mass of the trolley. [9]
J89/II/8

28

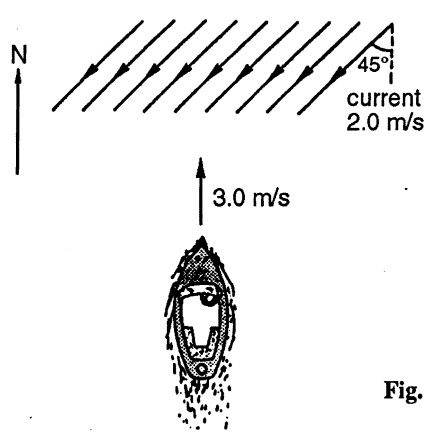


Fig. 1

29 A motor boat travels due north at a steady speed of 3.0 m/s through calm water in which there is no current. The boat then enters an area of water in which a steady current flows at 2.0 m/s in a south-west direction as shown in Fig. 1. Both the engine power and the course setting remain unchanged.

(a) Explain how the above paragraph gives information not only about the speed of the boat but also about its velocity. [1]

(b) In the space below, draw a vector diagram showing the velocity of the boat and the velocity of the current. Use the diagram to find

(i) the magnitude of the resultant velocity of the boat,

(ii) the angle between due north and the direction of travel of the boat. [5]

(c) Calculate the distance the boat now travels in 5.0 minutes. [1]

(d) The mass of the boat is 3.0×10^3 kg (3000 kg). Calculate the additional force which needs to be applied to give the boat an initial acceleration of 2.5×10^{-2} m/s^2 (0.025 m/s^2). [3]
N89/II/1

29 Figure 2 shows an arrangement for demonstrating the relationship between force and acceleration.

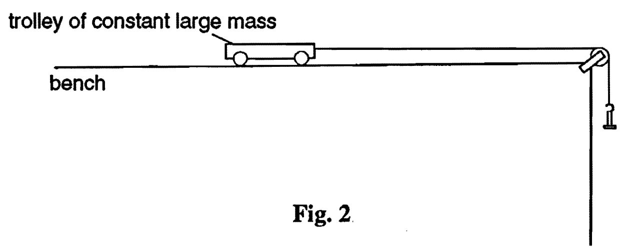


Fig. 2

(a) Draw a diagram of the trolley and, on your diagram, draw arrows to represent all the external forces acting on the trolley when it is accelerating along the bench. Label each force. [3]

(b) In one particular experiment, the mass of the trolley was kept constant. The time t for the trolley to move a distance of 1.00 m from rest was determined for various values of the pulling force F. The acceleration a was then calculated using the equation $s = \frac{1}{2}at^2$, where s = 1.00 m. The following values were obtained.

F/N	0.40	0.80	1.20	1.60	2.00
a/(m/s^2)	0.08	0.22	0.43	0.57	0.74

(i) Plot a graph of *F/N* (*y*-axis) against *a*/(m/s^2) (*x*-axis); start your axes at the point *F/N* = 0, *a*/(m/s^2) = 0. Draw the best straight line through your points.

(ii) Determine the gradient of your graph.

(iii) Use your graph to determine the value of F when the acceleration is 0.

(iv) Use your answer to *(a)* to explain why a pulling force is needed to give zero acceleration. [10]

(c) State and explain the effect on the gradient of the graph if the mass of the trolley were to be doubled. [2]
N95/II/9

30 *(a)* A small steel ball, dropped from rest, takes 0.50 s to fall through a vertical distance of 1.25 m. Determine

(i) the average speed of the ball,

(ii) the actual speed of the ball when it has fallen through a vertical distance of 1.25 m, assuming that the acceleration is constant,

(iii) the value of that acceleration. [4]

(b) An object dropped from an aircraft flying horizontally takes 20 s to reach a constant vertical speed of 100 m/s.

(i) In the space below, using labelled and scaled axes, sketch a graph to show the variation of the object's vertical speed with time over the first 25 s of the fall; label this graph 'T'.

(ii) On the same axes, sketch a graph of the variation of speed of any object falling freely (i.e. neglecting air resistance) from rest to a speed of 100 m/s; label this graph 'F'. The acceleration of free fall is 10 m/s^2. [4] J96/II/1

31 Fig. 3.1 shows a trolley **P** on a horizontal bench. Fig. 3.2 shows an identical trolley **Q** on the same bench but which is loaded with steel bars. A horizontal force of 10 N acting for a time of 0.2 s is applied to each trolley in turn.

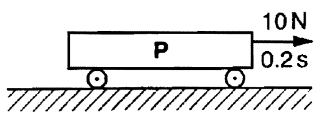


Fig. 3.1

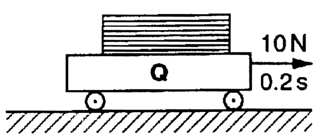


Fig. 3.2

(a) After 0.2 s, trolley **P** moves to the right with a speed of 5 m/s but trolley **Q** moves to the right with a speed of 1 m/s. Explain why these speeds are different. [2]

(b) Trolley **P** is now turned over so that it is resting on its top surface, as shown in Fig. 3.3.

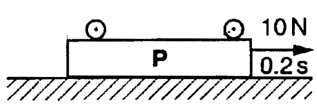


Fig. 3.3

Explain why a force of 10 N acting for 0.2 s now results in a very small speed and why that speed rapidly reduces to 0. [1]

(c) The mass of trolley **P** is 0.40 kg. Determine the weight of trolley **P** when the trolley is near

(i) the surface of the Earth,

(ii) the surface of the Moon,

given that the acceleration of free fall is 10 m/s^2 at the surface of the Earth and 1.6 m/s^2 at the surface of the Moon. [3] J96/II/2

32 *(a)* Table 1 below shows the variation with time *t* of the distance s travelled by an aircraft as it starts moving along a runway.

Table 1

t/s	0	1	2	3	4	5
s/m	0	1	6	17	37	67

State, giving your reasons,

(i) whether the speed of the aircraft is increasing, decreasing or remaining constant,

(ii) whether the acceleration of the aircraft is increasing, decreasing or remaining constant. [4]

(b) A parachutist falls from an aircraft which is flying horizontally. The parachute opens some time after the start of the fall.

(i) State why the initial vertical acceleration of the parachutist is approximately 10 m/s^2.

(ii) State and explain what happens to the vertical speed of the parachutist after the parachute opens. [4]
J97/II/1

33 A hovercraft moves on a cushion of air which is trapped underneath it, as shown in Fig. 4.1. The trapped air reduces friction.

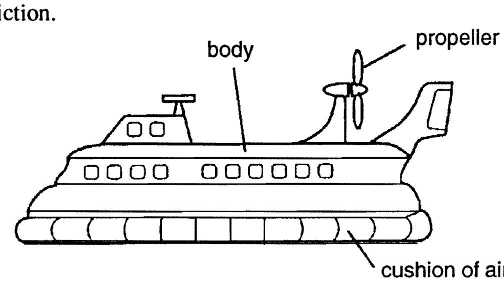


Fig. 4.1

(a) The hovercraft starts from rest and, as it starts, the propeller produces a forward force *F* of 22 000 N. The mass of the hovercraft is 25 000 kg.

Calculate the initial acceleration of the hovercraft. You may assume there is no friction. [3]

(b) Some time later, the hovercraft reaches a steady speed, even though the force *F* is unchanged. Suggest, in terms of the forces acting on the hovercraft, why the speed is now constant. [2]

(c) When the hovercraft is travelling at a speed of 16 m/s, the force F is switched into reverse and the hovercraft gradually slows down. Fig. 4.2 shows a graph of the variation of speed with time.

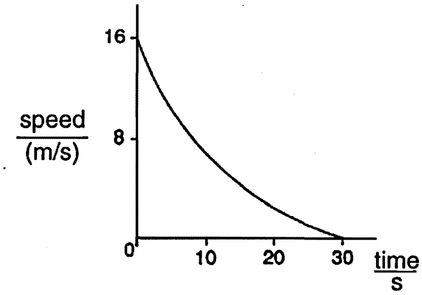


Fig. 4.2

State how the graph shows that the acceleration is not constant. [1]

N98/II/1

34 Fig. 5 shows a car moving along a horizontal road.

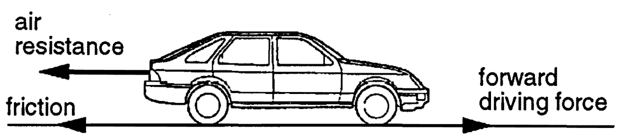


Fig. 5

The car has mass 800 kg. At one point in its motion, when the combined forces of air resistance and friction acting backwards are 400 N, its acceleration is 1.4 m/s^2.

(a) Calculate the forward driving force required to accelerate the car.

forward driving force = ... [3]

(b) With the engine working at constant full power, the car's acceleration decreases as it goes faster.

Explain why this is so. [2]

J99/II/8

ANSWERS

1. **B**	2. **E**	3. **B**	4. **B**	5. **C**
6. **B**	7. **D**	8. **A**	9. **C**	10. **A**
11. **B**	12. **C**	13. **B**	14. **B**	15. **D**

16. **D**

17. *(a)* 25 N
(b) 37°
(d) (i) 24 m/s
(ii) 72 m

18. *(a)* 4500 N at 9° to AB

20. *(a)* 78 N *(b)* 78 N *(c)* 40°
(i) 15 m/s (ii) 11.2 m

21. *(b)* (i) 12 N (ii) 18 J
(c) (i) 2 m/s^2 (ii) 0.5 m/s

22. *(a)* (i) 19.5 m/s (ii) 7.8 m/s^2
(c) 1680 N

23 *(b)* 20 N
(c) (i) 24 m/s (ii) 12 m/s (iii) 28.8 m

25. *(a)* (i) 1 m/s^2 (ii) 9000 N (iii) 32 m

26. *(a)* (i) 25 m/s (ii) 31.25 m (c) 800 N

27. *(b)* (ii) 0.32 m/s^2 (ii) 2.5 kg

28. *(b)* (i) 2.2 m/s (ii) 41°
(c) 660 m *(d)* 75 N

31. *(c)* (i) 4 N (ii) 0.64 N

33. *(a)* 0.88 m/s^2

34. *(a)* 1520 N