Past-paper walk-through

Non-uniform motion ▪ 3.2

eXercise

Questions in this set

- 9702/11 N25 Q8 ▪ 1 mark
- 9702/12 N25 Q11 ▪ 1 mark
- 9702/21 N25 Q2 ▪ 12 marks
- 9702/11 J25 Q20 ▪ 1 mark
- 9702/12 J25 Q12 ▪ 1 mark
- 9702/13 J25 Q8 ▪ 1 mark
- 9702/14 J25 Q8 ▪ 1 mark
- 9702/23 J25 Q3 ▪ 8 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 8

9702/11 N25 ▪ Q8 ▪ 1 mark

A sphere falls from rest through the air. The graph shows the variation with time of the sphere's velocity.

Which diagram shows the forces acting on the sphere when it is at the velocity corresponding to point P on the graph? **[1]**

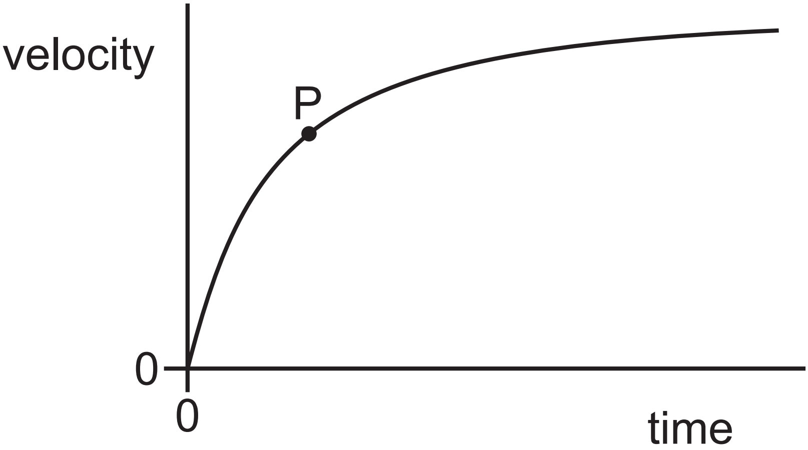
A air resistance and weight of equal magnitude

B weight only

C air resistance of smaller magnitude than weight

D air resistance of greater magnitude than weight

Question 8



Solution 8

A air resistance and weight of equal magnitude

B weight only

C air resistance of smaller magnitude than weight ✓

D air resistance of greater magnitude than weight

Why

- At P the curve is still rising, so the sphere is still accelerating downwards.
- That needs a downward resultant, so the weight must be larger than the air resistance.
- C is the only diagram with both forces present and the weight arrow the longer one; A is terminal velocity and B the instant of release.

Question 11

9702/12 N25 ▪ Q11 ▪ 1 mark

A skydiver is falling at constant velocity. She then opens her parachute. The graph shows the variation with time of her velocity.
Which statements about the motion of the skydiver are correct?

1. The magnitude of the acceleration is maximum at time t_2.
2. The magnitude of the drag force at time t_1 equals the magnitude of the drag force at time t_3.
3. The magnitude of the drag force is maximum at time t_1.

Question 11

[1]

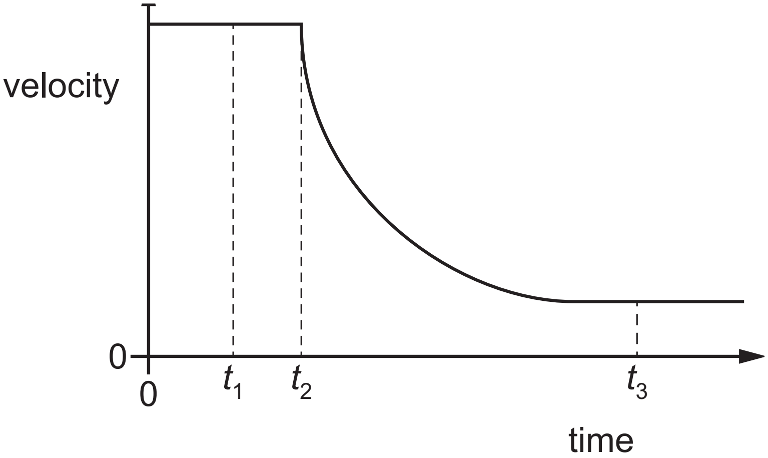
A 1 and 2

B 1 and 3

C 2 only

D 3 only

Question 11



Solution 11

A 1 and 2 ✓

B 1 and 3

C 2 only

D 3 only

Why

- At t_1 and t_3 she is at terminal velocity, so the drag equals her weight at both – statement 2 holds.
- The graph is steepest just after the parachute opens, so the acceleration peaks at t_2 – statement 1 holds.
- The drag is largest at t_2, not t_1, so statement 3 fails.

Question 2

9702/21 N25 ▪ Q2 ▪ 12 marks

(a)(i) Define pressure. **[1]**

(a)(ii) Explain how hydrostatic pressure results in an upthrust force acting on a solid object immersed in a liquid. **[2]**

(b)(i) On Fig. 2.1, draw labelled arrows from the ball to show the directions of the three forces that act on the ball as it falls. **[3]**

(b)(ii) Determine the SI base units of η. **[2]**

(c)(i) Show that the upthrust force acting on the ball is 2.8×10^{-3} N. **[1]**

(c)(ii) Determine the terminal speed v of the ball. **[3]**

Solution 2

(a)(i)

Mark scheme

- (normal) force per (unit cross-sectional) area **B1**

Solution 2

(a)(ii)

Mark scheme

- (due to difference in depth there is a) difference in pressure between top and bottom (of ball) **B1**
- (due to pressure difference, upwards) force on bottom of ball is greater
- (than downwards force on top of ball, so resultant force is upwards) **B1**

Solution 2

(b)(i) Worked steps

Three forces, and only three — do not add a "reaction".

- **Weight**, vertically downwards.
- **Upthrust**, vertically upwards (the liquid pushes harder on the bottom than the top).
- **Viscous drag**, vertically upwards — it opposes the motion, and the ball is falling.

Solution 2

Label each arrow with its name.

Mark scheme

- arrow vertically downwards labelled ‘weight’ **B1**
- arrow vertically upwards labelled ‘upthrust’ **B1**
- arrow vertically upwards labelled ‘(viscous) drag’ **B1**

Solution 2

(b)(ii) Worked steps

Get the base units of the drag force first, then divide them out.

- Force in base units: $\mathrm{N} = \mathrm{kg\ m\ s^{-2}}$.
- Rearranging $D = 6\pi\eta rv$ gives $\eta = \dfrac{D}{6\pi rv}$; the 6π is a pure number.
- Units: $\dfrac{\mathrm{kg\ m\ s^{-2}}}{\mathrm{m} \times \mathrm{m\ s^{-1}}}$
- η has base units $\mathrm{kg\ m^{-1}\ s^{-1}}$

Solution 2

Mark scheme

- SI base units of D: kg m s–2 **C1**
- base units of η: kg m s–2 / (m $\times$ m s–1)
- $=$ kg m–1 s–1 **A1**

Solution 2

(c)(i) Worked steps

Upthrust is the weight of liquid displaced, and the ball is a sphere.

- $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(4.2 \times 10^{-3})^3 = 3.10 \times 10^{-7}$ m^3
- $U = \rho_{\text{liquid}} V g = 920 \times 3.10 \times 10^{-7} \times 9.81$
- $U = 2.8 \times 10^{-3}$ N, as required.

Solution 2

Mark scheme

- upthrust $= 920 \times (4 \;/\; 3) \times \pi \times (4.2 \times 10–3)3 \times 9.81 = 2.8 \times 10–3$ (N) A1

Solution 2

(c)(ii) Worked steps

At terminal speed the ball stops accelerating, so the three forces balance.

- Upwards = downwards: $U + D = W$, so $D = W - U$.
- $W = 2.4 \times 10^{-3} \times 9.81 = 2.35 \times 10^{-2}$ N, so
  $D = 2.35 \times 10^{-2} - 2.8 \times 10^{-3} = 2.07 \times 10^{-2}$ N.
- $D = 6\pi\eta rv$, so $v = \dfrac{D}{6\pi\eta r} = \dfrac{2.07 \times 10^{-2}}{6\pi \times 4.7 \times 4.2 \times 10^{-3}}$
- $v = 0.056$ m s^{-1}

Solution 2

Mark scheme

- weight $=$ drag $+$ upthrust **C1**
- $(2.4 \times 10–3 \times 9.81) = (2.8 \times 10–3) + (6\pi \times 4.7 \times 4.2 \times 10–3 \times v)$ **C1**
- $v = 0.056$ m s–1 **A1**

Question 20

9702/11 J25 ▪ Q20 ▪ 1 mark

A parachutist is falling at constant (terminal) velocity.

Which statement is **not** correct? **[1]**

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.

Solution 20

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.

Why

- At terminal velocity the speed is constant, so the parachutist's kinetic energy does not change.
- All the lost gravitational potential energy goes into the air – moving it and warming it.
- B is therefore the statement that is not correct.

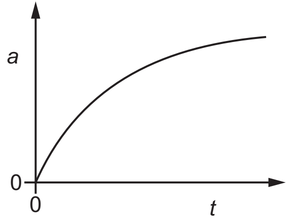
Question 12

9702/12 J25 ▪ Q12 ▪ 1 mark

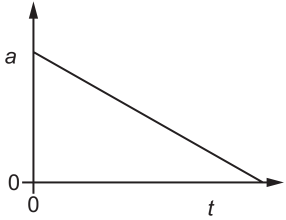
12 A stone is released from rest and falls a long distance in air.

Which graph could show the variation with time t of the acceleration a of the stone?

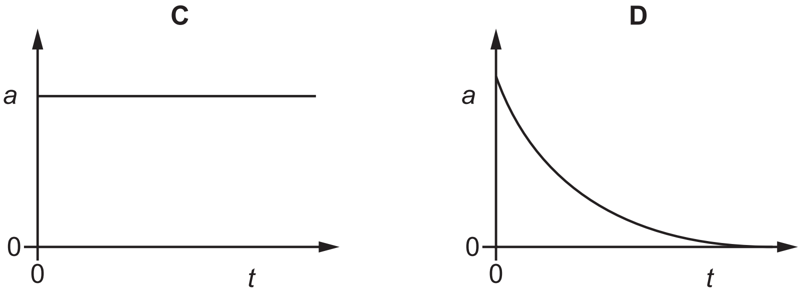
A



B



Question 12



Solution 12

Answer: **D**

Why

- The stone starts with only its weight acting, so the acceleration begins at g.
- As it speeds up the drag grows, so the resultant force – and the acceleration – falls.
- At terminal velocity the acceleration is zero, so the graph starts at g and decays towards zero.

Question 8

9702/13 J25 ▪ Q8 ▪ 1 mark

8 Two spheres are released from rest at equal heights above the ground.

Both spheres reach terminal velocity.

One sphere has a larger density than the other sphere.

Both spheres have equal volumes.

Which statement is correct while both spheres are at terminal velocity?

A The drag forces on the spheres are equal.

B The resultant forces on the spheres are equal.

Question 8

C The velocities of the spheres are equal.

D The weights of the spheres are equal.

Solution 8

Answer: **B**

Why

- At terminal velocity the forces on each sphere balance, so each resultant force is zero.
- Zero equals zero, which is precisely why B is the correct statement.
- The denser sphere weighs more, so it needs more drag and falls faster – A, C and D all fail.

Question 8

9702/14 J25 ▪ Q8 ▪ 1 mark

8 A skydiver is falling vertically with terminal velocity when their parachute opens fully.

Which statement describes the motion of the skydiver for the first few seconds after the parachute opens fully?

A falling with non-uniform acceleration and increasing speed

B falling with non-uniform acceleration and decreasing speed

C falling with uniform acceleration and increasing speed

D falling with uniform acceleration and decreasing speed

Solution 8

Answer: **B**

Why

- Opening the parachute makes the drag far larger than the weight, so the resultant acts upwards.
- The skydiver therefore slows down.
- As the speed falls the drag falls with it, so the deceleration is not uniform.

Question 3

9702/23 J25 ▪ Q3 ▪ 8 marks

3 A car of mass 1500 kg is travelling along a straight horizontal road at constant velocity *v*. The car is subject to a total resistive force *F*, as shown in Fig. 3.1.

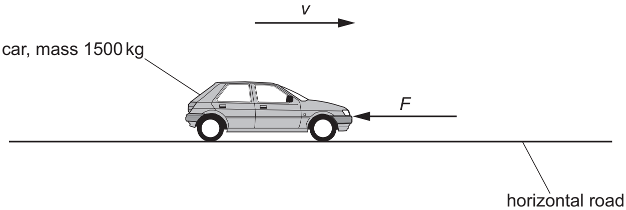


Fig. 3.1

(a) Show that the power *P* developed by the engine in overcoming the total resistive force is given by the equation

Question 3

given by the equation

$$P = Fv\,.$$

Question 3

[2]

(b) The car now moves up a slope at a constant speed of $30\,\mathrm{m\,s^{-1}}$.
The slope is at an angle to the horizontal of 6.0°, as shown in Fig. 3.2.

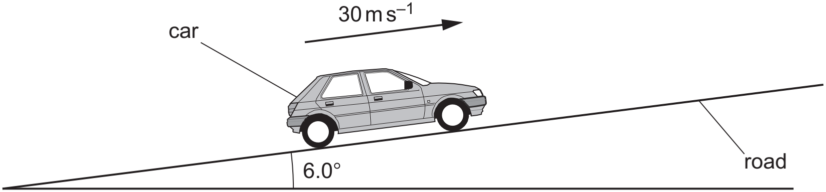


Fig. 3.2

The total resistive force acting on the car is 1600 N.

(i) Show that the increase in gravitational potential energy of the car in a time of 1.0 s is

Question 3

(i) Show that the increase in gravitational potential energy of the car in a time of 1.0 s is

Question 3

46 000 J.

[2]

(ii) Use the information in **(b)(i)** to determine the power developed by the engine to move the car up the slope.

Question 3

Question 3

Question 3

(c) The car picks up a passenger and then continues up the slope at the same speed as in **(b)**.

State and explain the effect, if any, that the passenger has on:

(i) the air resistance acting on the car

Question 3

(ii) the power developed by the engine.

Question 3

[Total: 8]

Solution 3

(a)

Mark scheme

- $W = Fd$
- $P = Fd\,/\,t = Fv$ or $P = Fvt\,/\,t = Fv$

Solution 3

(b)(i)

Worked steps

In one second the car travels 30 m **along** the slope, so it climbs the vertical component of that distance.

- Height gained $= 30\sin 6.0^\circ = 3.14$ m
- $\Delta E_\mathrm{P} = mg\Delta h = 1500 \times 9.81 \times 3.14$
- $\Delta E_\mathrm{P} = 4.6 \times 10^4$ J

Mark scheme

- (Δ)E(P) $=$ mg(Δ)h
- increase of gravitational potential energy of car in 1.0 s
- $=$ 1500 $\times$ 9.81 $\times$ 30 $\times$ sin 6.0 $=$ 46 000 J
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Solution 3

(b)(ii) Worked steps

The speed is constant, so the engine does two jobs at once: it lifts the car and it works against resistance.

- Power against resistive forces $= Fv = 1600 \times 30 = 4.8 \times 10^4$ W
- Power going into potential energy $= 4.6 \times 10^4$ W (from part (b)(i), which is per second)
- Total $= 4.8 \times 10^4 + 4.6 \times 10^4$
- $P = 9.4 \times 10^4$ W

Solution 3

Mark scheme

- (Power to overcome total resistive forces)
- $= 1600 \times 30$
- $= 48\,000$ W
- power $= 48\,000 + 46\,000$
- $= 9.4 \times 104$ W

Solution 3

(c)(i)

Mark scheme

- Air resistance is the same, as the speed is the same

(c)(ii)

Mark scheme

- Mass / weight has increased so (power will) increase