## Newton's laws of motion questions

**Q1.** A car of mass 1300 kg is stopped by a constant horizontal braking force of 6.2 kN.

(a) Show that the deceleration of the car is about 5 m $s^{-2}$.

**(3)**

(b) The initial speed of the car is 27 m $s^{-1}$.
Calculate the distance travelled by the car as it decelerates to rest.

distance travelled _____ m

**(3)**

**(Total 6 marks)**

**Q2.** The Thrust SSC car raised the world land speed record in 1997. The mass of the car was $1.0 \times 10^4$ kg. A 12 s run by the car may be considered in two stages of constant acceleration. Stage one was from 0 to 4.0 s and stage two 4.0 s to 12 s.

(a) In stage one the car accelerates from rest to 44 m $s^{-1}$ in 4.0 s. Calculate the acceleration produced and the force required to accelerate the car.

(b) In stage two the car continued to accelerate so that it reached 280 m $s^{-1}$ in a further 8.0 s. Calculate the acceleration of the car during stage two.

_____

_____

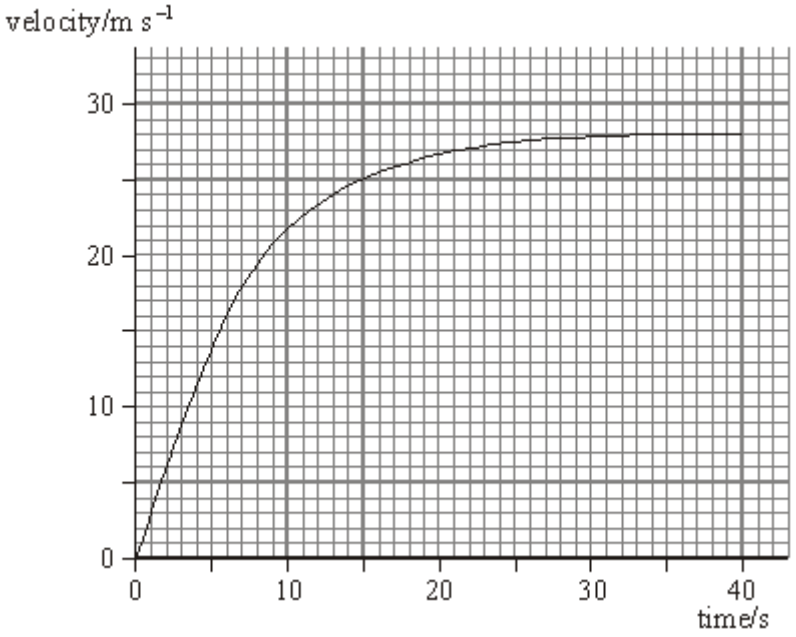
(c) Calculate the distance travelled by the car from rest to reach a speed of 280 m $s^{-1}$.

_____

_____

**(Total 6 marks)**

**Q3.** The figure below shows how the velocity of a motor car increases with time as it accelerates from rest along a straight horizontal road.




(a) The acceleration is approximately constant for the first five seconds of the motion. Show that, over the first five seconds of the motion, the acceleration is approximately 2.7 m $s^{-2}$.

**(3)**

(b) Throughout the motion shown in the figure above there is a constant driving force of 2.0 kN acting on the car.

(i) Calculate the mass of the car and its contents

mass _____

(ii) What is the magnitude of the resistive force acting on the car after 40 s?

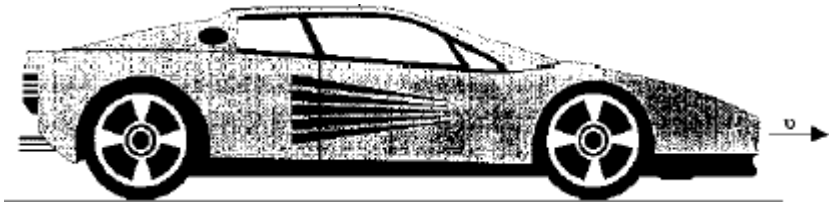
resistive force _____

**(3)**

(c) Find the distance travelled by the car during the first 40 s of the motion.

distance _____ **(3) (Total 9 marks)**

**Q4.** The diagram shows a car travelling at a constant velocity along a horizontal road.




(a) (i) Draw and label arrows on the diagram representing the forces acting on the car.

(ii) Referring to Newton's Laws of motion, explain why the car is travelling at constant velocity.

_____

_____

_____

_____

**(5)**

(b) The car has an effective power output of 18 kW and is travelling at a constant velocity of 10 m $s^{-1}$. Show that the total resistive force acting is 1800 N.

_____

_____

_____

**(1)**

(c) The total resistive force consists of two components. One of these is a constant frictional force of 250 N and the other is the force of air resistance, which is proportional to the square of the car's speed.

Calculate

(i) the force of air resistance when the car is travelling at 10 m $s^{-1}$,

_____

_____

(ii) the force of air resistance when the car is travelling at 20 m $s^{-1}$,

_____

_____

(iii) the effective output power of the car required to maintain a constant speed of 20 m $s^{-1}$ in a horizontal road.

_____

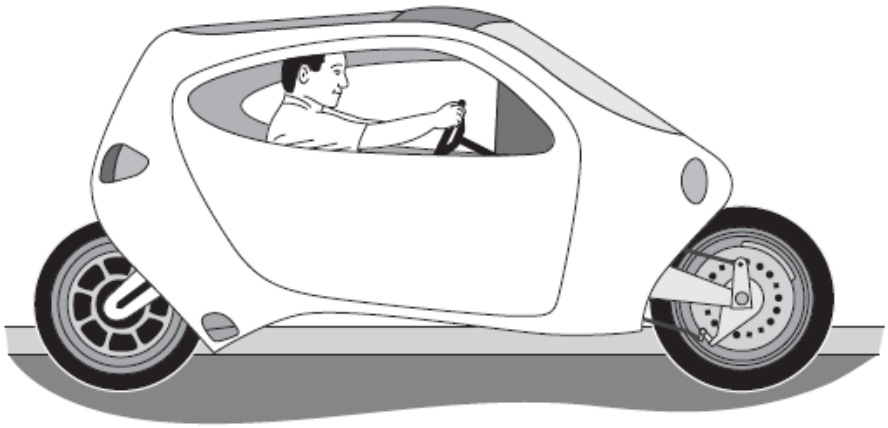
_____

_____

**(4)**

**(Total 10 marks)**

**Q5.** The diagram below shows an electric two-wheeled vehicle and driver.



(a) The vehicle accelerates horizontally from rest to 27.8 m $s^{-1}$ in a time of 4.6 s. The mass of the vehicle is 360 kg and the rider has a mass of 82 kg.

(i) Calculate the average acceleration during the 4.6 s time interval.
Give your answer to an appropriate number of significant figures.

acceleration = _____ m $s^{-2}$

**(2)**

(ii) Calculate the average horizontal resultant force on the vehicle while it is accelerating.

resultant force = _____ N

**(2)**

(b) State and explain how the horizontal forward force on the vehicle has to change for **constant** acceleration to be maintained from 0 to 27.8 m $s^{-1}$.

_____

_____

_____

_____

_____

_____

_____

_____

**(3)**

(c) The electric motors drive both wheels of the vehicle.

Add labelled force arrows to the diagram to show the horizontal forces acting on the vehicle when it is moving at a constant speed.

**(2)**

(d) The vehicle now accelerates to a constant speed of 55 m $s^{-1}$. The useful power output of the motors is 22 kW at this speed.

Calculate the horizontal resistive force acting on the vehicle.

horizontal resistive force = _____ N

**(2)**

**(Total 11 marks)**

**Q1.** (a) a force/1300 (condone power of ten error)

C1

6200 ÷ 1300

C1

4.77 (m s$^{-2}$)

A1

3

(b) use of suitable kinematic equation

C1

eg distance = 27$^2$/(2 × 4.8) correct sub

C1

76/76.4 m/72.9 from *a* = 5/75.9 from *a* = 4.8

A1

3

**[6]**

**Q2.**

(a) $a = \frac{44}{4.0}$ = 11 ms$^{-2}$ **(1)**

$F = ma$ = 1.1 × 10$^5$ N **(1)**

(b) $\Delta v$ = 236 m s$^{-1}$

$a = \frac{236}{8.0}$ = 29.5 m s$^{-2}$ **(1)**

(c) $s_{one} = v_{av} \times t = \left(\frac{44 + 0}{2}\right)$ × 4.0 = 88 m **(1)**

$s_{two} = v_{av} \times t = \left(\frac{280 + 44}{2}\right)$ × 8.0 **(1)** = 1296 (m) **(1)**

total distance = 1384 m **(1)**

**[6]**

**Q3.**

(a) clear statement that gradient = acceleration *accept* $\Delta v/\Delta t$

or statement of v = u + at

B1

suitable values taken from graph

M1

3

i.e. (5.0, 13.5 – 0.5) (4.0, 11 – 0.5) (3.0, 8 – 0.5)

acceleration = 2.7 – 0.1 (m $s^{-2}$)

A1

(b) (i) *use of* m = F/a

C1

mass = 740 kg

*accept 741 kg*
*or answer consistent with part (a)*

A1

3

(ii) resistive force = 2.0 kN

c.a.o.

B1

(c) clear attempt to count squares/estimate area *(37 – 2 $cm^2$)*

C1

scale factor 1 $cm^2$:25 m

C1

3

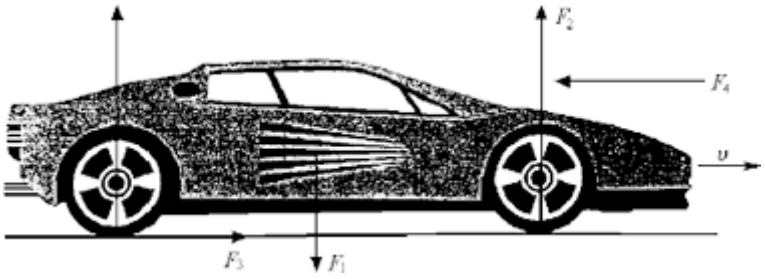
distance = 925 – 50 m

rA1

**[9]**

**Q4.**

(a) (i)




$F_1$ weight / *mg* **(1)**
$F_2$ reaction or normal contact force **(1)**
$F_3$ driving force **(1)**
$F_4$ friction or air resistance **(1)**

(ii) zero acceleration **(1)**
zero resultant force **(1)**

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part.

**(max 5)**

(b) ($P = Fv$ gives) $18 \times 10^3 = F \times 10$ **(1)** (and $F = 1.8 \times 10^3$ N)

**(1)**

(c) (i) $1800 - 250 = 1.6 \times 10^3$ N **(1)** ($1.55 \times 10^3$ N)

(ii) force = $4 \times 1.55 \times 10^3 = 6.2 \times 10^3$ N **(1)**
(allow e.c.f. from (i))

(iii) total force = 6200 + 250(N) **(1)** (= $6.45 \times 10^3$ (N))
($P = Fv$ gives) $P = 6.45 \times 10^3 \times 20 = 1.3 \times 10^5$ W **(1)** ($1.29 \times 10^5$ W)
(allow e.c.f. for value of total force) **(4)** **[10]**

**Q5.** (a) (i) *( a =(v-u) / t )*
= 27.8 (−0) / 4.6 = 6.04 ✓
= <u>6.0</u> ($ms^{-1}$) ✓

*no need to see working for the mark*
*2 sig fig mark stands alone*

**2**

(ii) ( *F = ma* )
= (360 + 82) × 6.0(4) ✓ (allow CE from (i))
= 2700 (N) ✓ (2670 N or 2652 N)

*F = 442 × (i)*

*1 mark may be gained if mass of rider is ignored giving answer 2200N from 2175N*

**2**

(b) (forward force would have to) increase ✓
air resistance / drag increases (with speed) ✓

driving / forward force must be greater than resistive / drag force ✓

*no mark for wind resistance*

(so that) resistant / net force stayed the same / otherwise the resistant / net force would decrease ✓

**4max3**

(c) horizontal force arrows on both wheels towards the right starting where tyre meets road or on the axle labelled driving force or equivalent ✓

*ignore the actual lengths of any arrows*

*ignore any arrows simply labelled 'friction'*

a horizontal arrow to the left starting anywhere on the vehicle labelled drag / air resistance

*no mark for wind resistance, resistance or friction force*

*the base of an arrow is where the force is applied*

**2**

(d) ( $F = P / v$ )

= 22 000 / 55 ✓ Condone 22 / 55 for this mark

= 400 ✓ (N)

**2**

**[11]**

## Q6.

(a) (i) 1000(N) AND 6000(N) seen

*Independent marks*

**OR**

$F = \sqrt{(1000)^2 + (6000)^2}$ ✓ allow incorrect values seen

= **6083** (N) ( = 6100) ✓ More than 2 sf seen

*Allow full credit for appropriate scale drawing*

*Ignore rounding errors in 3rd sig fig.*

**2**

(ii) tanϴ = 1000 / 6000 or correct use of sin or cos ✓

ϴ = 9.5 (9.46°) ✓

Allow range 9.4 − 10.4

*Use of cos yields 10.4*

*Allow use of 6100*

*Some working required for 2 marks.*

*Max 1 mark for correct calculation of vertical angle (range 79.6 − 80.6) some working must be seen*

**2**

(iii) ($m = W/g$ = ) 6500 / 9.81 ( = 662.6 kg) ✓

($a = F / m$ = 6083 / 662.6)

= 9.2 ($ms^{-2}$) ✓ (9.180)

*Use of weight rather than mass gets zero*

*Correct answer on its own gets 2 marks*

*Penalise use of g=10 in this question part only (max 1)*

**2**

(b) (i) = 6500 × 600 ✓ (662.6 × 9.81 × 600)
= 3 900 000 ✓ (J)

*Look out for W x g x h which gives 39000000 (gets zero)*
*Correct answer on its own gets 2 marks*
***Do not allow use of 1/2 mv² (= 39 000)***

**2**

(ii) (E= Pt =) 320 000 ×; 55 (= 17 600 k J )
**OR** P= 1(b)(i) / 55 (7.09 × $10^4$) ✓
3.9 / 17.6 OR 70.9 / 320 OR = 0.22(16) ✓ ecf from first line

*Some valid working required for 3 marks*

conversion to a percentage (= 22 %) ✓

*Look out for physics error: Power / time (320/55) then use of inverted efficiency equation yielding correct answer*
*Do not allow percentages >= 100% for third mark*

**3**

**[11]**

## Q7.

(a) *GPE* to *KE* to *GPE* ✓

no energy lost (from system) / no <u>work done</u> against resistive forces ✓

initial *GPE* = final (*GPE*) / initial (*GPE*) = final *GPE*

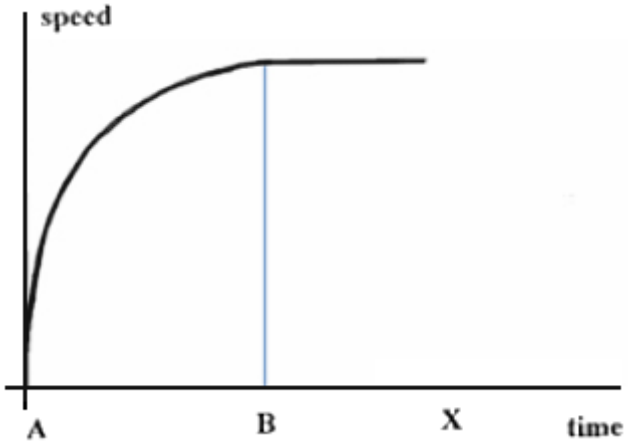
**OR** *h* = *GPE* /*mg* and these are all constant so *h* is the same ✓

**3**

(b) Initial curve with decreasing gradient and reaching constant maximum speed before X and maintaining constant speed up to X ✓

B labelled in correct place ✓

B labelled in correct place **AND** constant speed maintained for remainder of candidates graph and line is straight ✓




**3**

(c) (first law) ball travels in a <u>straight line</u> at a constant speed / constant <u>velocity</u> / (maintains) <u>uniform</u> / <u>no change in</u> motion / zero acceleration ✓

there is no (external) **unbalanced / resultant** <u>force</u> acting on it ✓ **2** **[8]**