OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A **2825/05**

Telecommunications

Friday **31 JANUARY 2003** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first five questions concern Telecommunications. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	14	
2	17	
3	14	
4	16	
5	9	
6	20	
TOTAL	90	

This question paper consists of 19 printed pages and 1 blank page.

SP (NH/CG) S29234/6

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
refractive index,	$n = \frac{1}{\sin C}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \frac{3H_0^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg\left(\frac{I}{I_0}\right)$

[Turn over

For Examiner's Use

Answer **all** the questions.

1 An AM radio station begins operating each day by switching on the carrier and thus broadcasting silence for a few moments. Then a single-frequency pilot tone is broadcast for a few minutes after which the station broadcasts music. The power spectra of each of these three situations are shown in Fig. 1.1 although they are not in order.

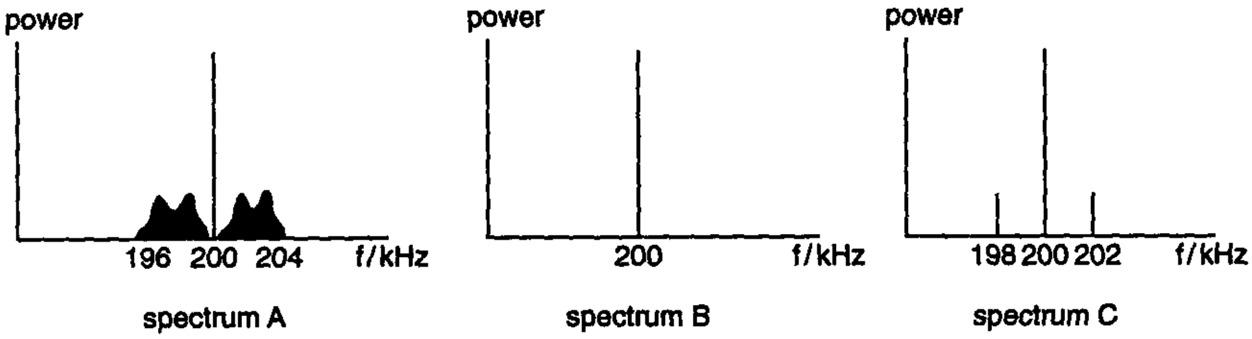


Fig. 1.1

(a) Using Fig. 1.1, state and explain which power spectrum corresponds to

1. silence

....

....[2]

2. pilot tone

....

....[2]

3. music.

....

....[2]

For Examiner's Use

(b) Using data from Fig. 1.1, state or calculate

(i) the transmission frequency of the station

frequency = ... kHz [1]

(ii) the frequency of the pilot tone

frequency = ... kHz [1]

(iii) the bandwidth of the radio station

bandwidth = ... kHz [1]

(iv) the waveband in which the station operates

waveband = ... [1]

(v) the maximum number of similar stations which could share this waveband.

number = ... [2]

(c) Explain why the station uses AM rather than FM in this waveband.

....

....[2]

[Total: 14]

For Examiner's Use

2 (a) Fig. 2.1 shows an op-amp set up as an amplifier.

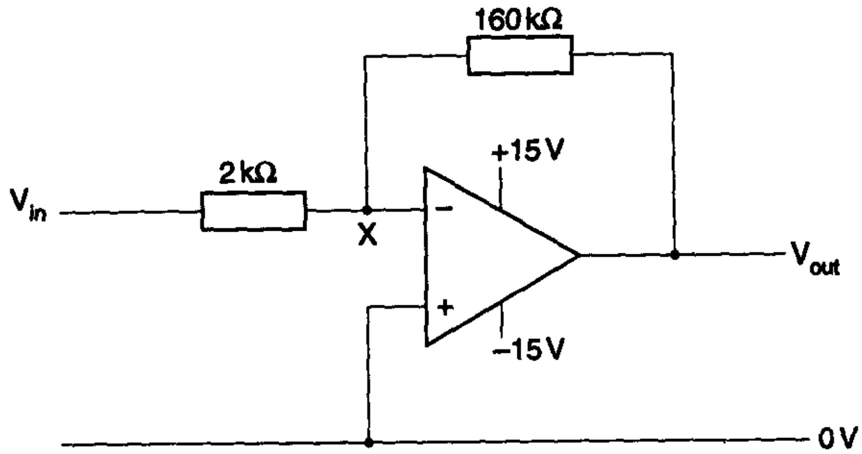


Fig. 2.1

The input voltage is V_{in} = 40 mV.

(i) State the voltage at X.

voltage = ... V [1]

(ii) Calculate the current in the 2 kΩ resistor.

current = ... A [2]

(iii) State and explain the current in the 160 kΩ resistor.

current = ... A

....

....[2]

For Examiner's Use

(iv) Calculate the output voltage V_{out}.

V_{out} = ... V [2]

(v) Calculate the maximum input voltage before saturation occurs. Show your working.

max V_{in} = ... V [2]

(b) Fig. 2.2 shows another amplifier circuit made from three op-amps, each powered from ±15 V supply rails.

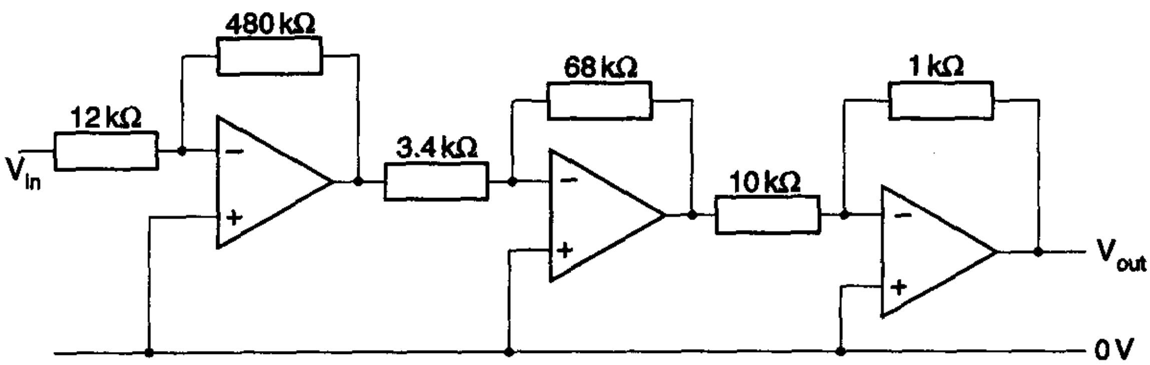


Fig. 2.2

Show that the overall voltage gain of the circuit of Fig. 2.2 is –80.

[3]

[Turn over

(c) The overall voltage gain for the two circuits in Figs. 2.1 and 2.2 is the same. State and explain the similarities or differences in the overall behaviour of these two circuits in terms of

(i) the phase of the output relative to the input

....

....[1]

(ii) the input resistance

....

....[1]

(iii) the overall bandwidth

....

....[1]

(iv) the maximum input voltage before saturation occurs.

....

....[2]

[Total: 17]

BLANK PAGE

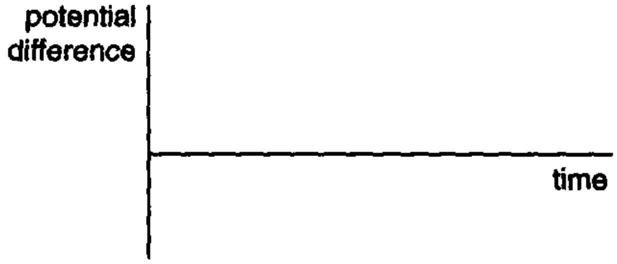
Turn to page 10 for Question 3.

[Turn over

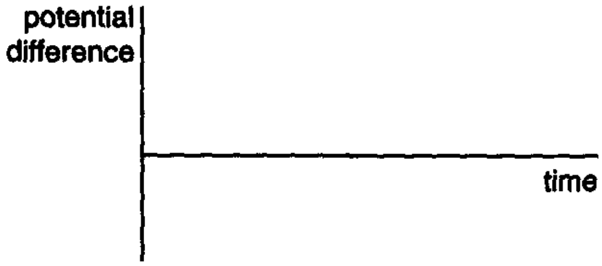
For Examiner's Use

3 The telephone industry uses pulse code modulation to process and transmit analogue voice signals. Describe pulse code modulation using the following sequence.

(a) The telephone signal from the home to the local exchange is an analogue signal. The local exchange transmits the call as a digital signal. Explain what is meant by an analogue signal and a digital signal. Illustrate your answer with typical sketch graphs.



analogue



digital

....

....

....

....[6]

For Examiner's Use

(b) Explain the process by which the analogue signal is converted to a digital signal suitable for transmission.

....

....

....

....

....[3]

(c) At the receiving exchange, explain how the digital signal is processed to allow it to be passed to the receiving telephone.

....

....

....

....

....[3]

(d) Explain **two** advantages to the telephone industry of using pulse code modulation.

....

....

....

....

....

....[2]

[Total: 14]

4 Fig. 4.1 represents a 4.0 km straight length of step-index multimode optic fibre.

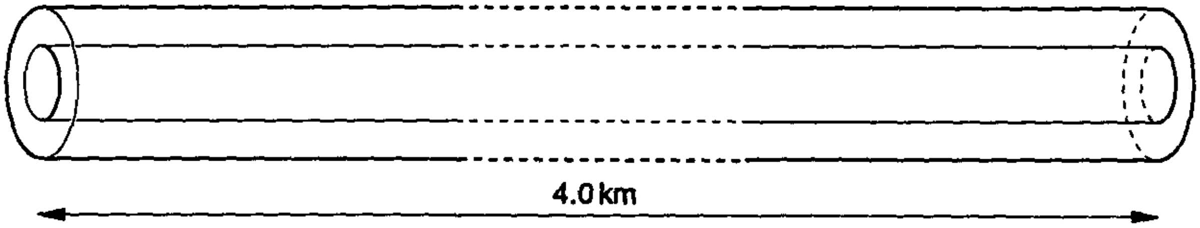


Fig. 4.1

(a) How does the refractive index of the core glass differ from that of the cladding glass? Explain why this difference is necessary.

....

....

....[2]

(b) The refractive index of the core glass is 1.5. Calculate the speed of light in the core. Give a suitable unit for your answer.

speed = ... unit .... [2]

(c) The length of the fibre is 4.0 km. Calculate the shortest time a ray of light could take to pass through the core.

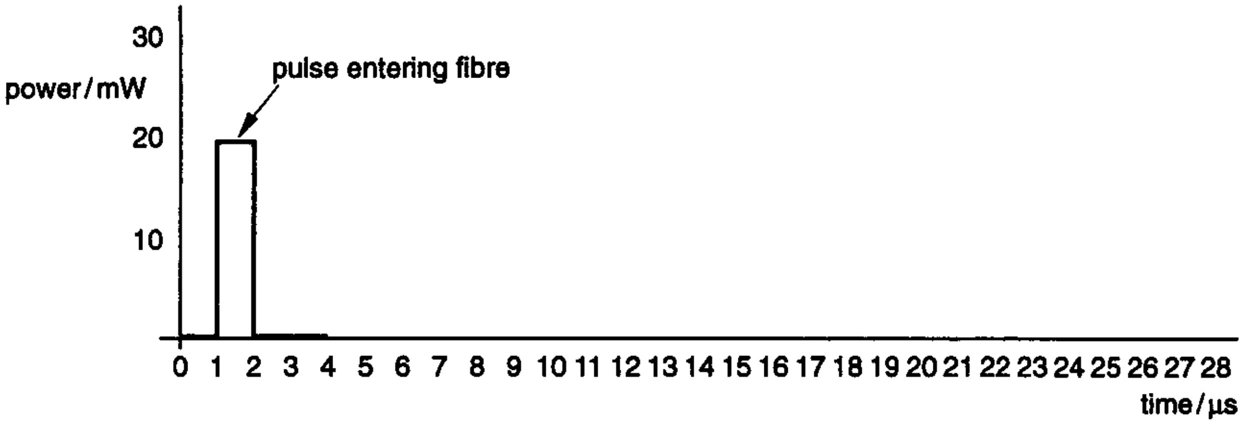
time = ... μs [2]

(d) The critical angle at the core-cladding boundary is 65.4°. Show that the longest time a ray of light could take to travel down the core is 22 μs.

[3]

For Examiner's Use

(e) Fig. 4.2 shows a 20 mW light pulse of duration 1 μs which enters the core of the fibre of Fig. 4.1. On the same axes of Fig. 4.2, sketch the pulse emerging from the other end, allowing for the propagation delay down the fibre. You should assume there is zero attenuation in the fibre and that there is no noise on the output pulse outline.



[4]

Fig. 4.2

(f) Calculate the highest frequency of these 1 μs pulses which could enter this 4.0 km length of step-index multimode fibre and be resolved at the other end.

frequency = ... Hz [2]

(g) State the name of the effect which occurs when the input pulse frequency is greater than the limit in **(f)**.

....[1]

[Total: 16]

[Turn over

For Examiner's Use

5 Radio waves may propagate from a transmitting aerial to a receiving aerial by three different waves. For each of the waves listed below

- state the waveband in which it is the main means of propagation
- describe the means by which the wave propagates
- quote a typical maximum range for terrestrial transmissions.

Space waves

....

....

....

....[3]

Surface waves

....

....

....

....[3]

Sky waves

....

....

....

....[3]

[Total: 9]

For Examiner's Use

6 A car in motion is subject to a number of forces. In particular, it usually experiences a motive force. It also experiences a drag force which is due to the effect of both friction (rolling resistance) and air drag. These forces are illustrated in Fig. 6.1.

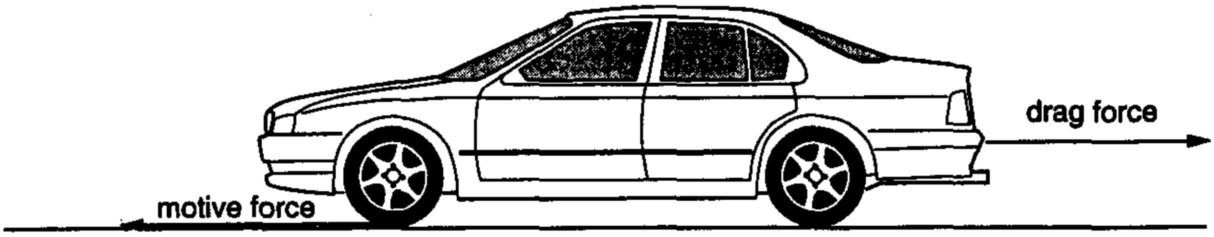


Fig. 6.1

The drag force depends on the shape and size of the car and its speed. The motive force can be varied by the driver using the accelerator pedal. Fig. 6.2 shows, for a particular car, the variation with speed of the *maximum* motive force at each speed. It also shows the variation with speed of the drag force.

Other data for this car:

mass of car	=	1 100 kg
maximum braking force	=	9 300 N
specific heat capacity of steel	=	460 J kg^{-1} K^{-1}
effective mass of brakes	=	8.0 kg

The brakes may be assumed to be made entirely of steel.

[Turn over

For Examiner's Use

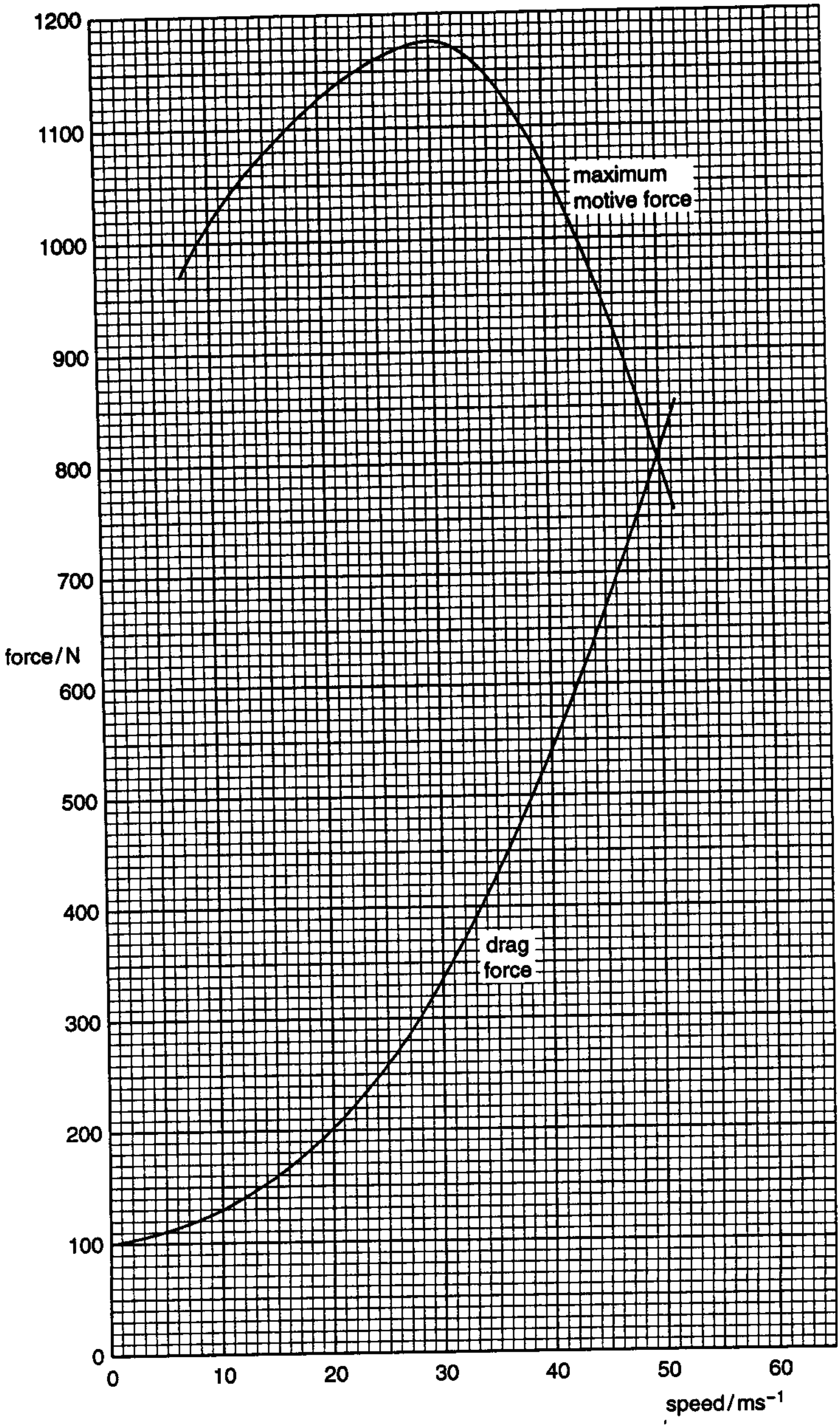


Fig. 6.2

(a) **(i)** What is the maximum motive force of this car at 10 m s^{-1}?

....

(ii) What is its drag force at 10 m s^{-1}?

.... [1]

(b) Find its maximum acceleration at 10 m s^{-1}.

acceleration = ... m s^{-2} [3]

(c) Find the speed at which its acceleration is greatest. Explain how you deduced this value, marking Fig. 6.2 as appropriate.

speed = ... m s^{-1}

....

....

....

....[2]

(d) State the maximum speed of the car. Explain your reasoning.

maximum speed = ... m s^{-1}

....

....

....[2]

(e) On a motorway, the car normally travels at constant speed. To propel the car, the motive force must do work against the drag force. Show that the work done in moving the car through 1.00 km at a constant speed of 22 m s^{-1} is 2.2 x 10^5 J.

[3]

(f) Find the work done in moving the car through 1.00 km at a constant speed of 31 m s^{-1}.

work done = ... J [1]

(g) At 22 m s^{-1}, the car travels 16.0 km for each litre of fuel used. Calculate how far it can travel using 1.00 litre of fuel at 31 m s^{-1}.

distance = ... km [2]

(h) Show that the car's kinetic energy at 31 m s^{-1} is 5.3 x 10^5 J.

[1]

For Examiner's Use

(i) The car is brought to rest from 31 m s^{-1} using its brakes, on a day when the temperature is 15 °C. Calculate the final temperature of its brakes. State any assumption you have made.

temperature = ... °C

....

....

....[3]

(j) Calculate the shortest distance within which the car can be brought to rest from 31 m s^{-1}. State any assumption you have made.

distance = ... m

....

....

....[2]

[Total: 20]