OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/02

Health Physics

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 provided 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 6 questions concern Health Physics. The last question concerns general physics.

FOR EXAMINER'S USE

Qu.	Max.	Mark
1	13	
2	15	
3	12	
4	13	
5	7	
6	10	
7	20	
TOTAL	90	

This question paper consists of 20 printed pages.

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

For Examiner's Use

Answer **all** the questions.

1 X-rays are produced in an X-ray tube when electrons, moving at high speed, are slowed down rapidly upon impact with a target.

(a) For a tube voltage of 100 kV, calculate

(i) the maximum energy in joules of the X-ray photons produced

energy = ... J [2]

(ii) the minimum wavelength of these photons.

wavelength = ... m [3]

(b) Fig. 1.1 shows the relative distribution of photon energies from the X-ray tube in **(a)**.

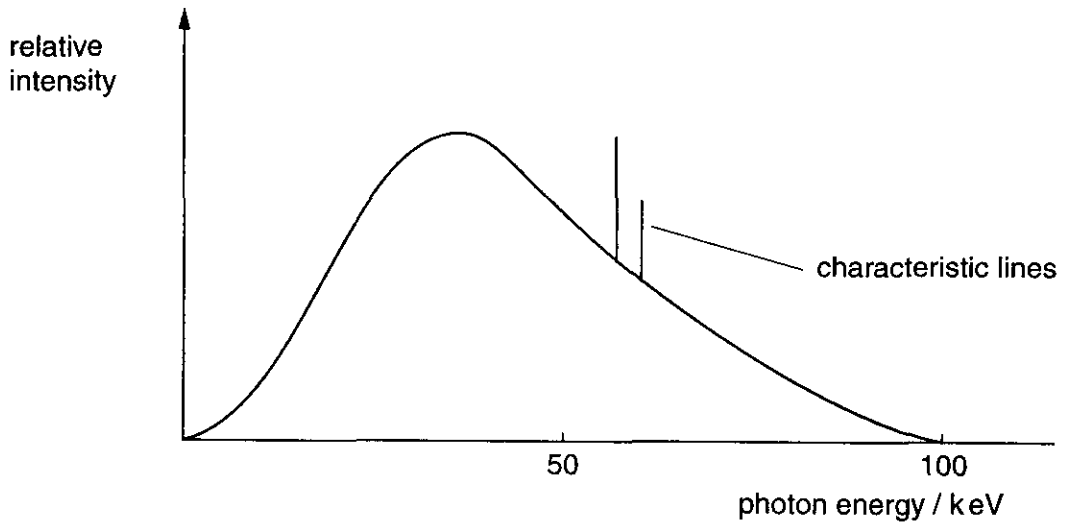

Fig. 1.1

Explain how the characteristic lines (at about 60 keV) are produced.

....

....

....

....[3]

(c) The attenuation of X-rays in matter by the photoelectric effect is related to Z^3, the cube of the atomic number. Explain the significance of this for the imaging of the digestive tract using a contrast medium such as a barium compound.

....

....

....

....[5]

[Total: 13]

2 A CT (computerised axial tomography) scan delivers energy to a person of mass 60 kg by a dose equivalent to the whole body of 10 mSv. The quality factor of the radiation is 2.

(a) **(i)** Calculate the absorbed dose. Give a suitable unit for your answer.

absorbed dose = ... unit .... [3]

(ii) Calculate the energy delivered to the whole body of this person.

energy = ... J [2]

For Examiner' Use

(b) Explain how an image is produced in a CT scan.

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....[3]

(c) Cancer may be induced if cells are exposed to ionising radiation such as X-rays. State and explain whether this effect is stochastic or non-stochastic. Explain why large doses of X-rays may be used to kill cancerous cells during therapy and how damage to the surrounding healthy cells is minimised.

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....[7]

[Total: 15]

For Examiner's Use

3 (a) The intensity level of sound at the ear of a person listening to music is 55 dB. The intensity level of the music at the ear has to be increased to 64 dB to be just detectable as an aircraft passes overhead.

Calculate the factor by which the intensity of the music at the ear changes during this increase in volume.

factor = ... [5]

(b) (i) On Fig. 3.1, sketch a graph to show how the minimum detectable intensity varies with the frequency of sound for a person with normal hearing. Care should be taken with the end points of your line. Label your graph C. [5]

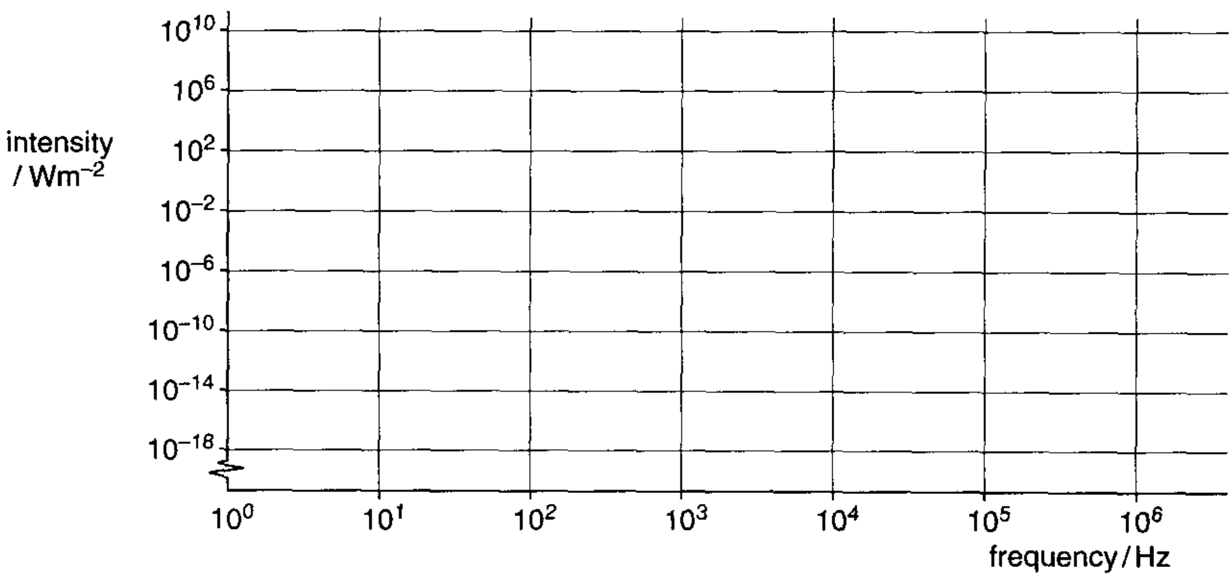

Fig. 3.1

(ii) On Fig. 3.1, sketch a second graph to suggest how the minimum detectable intensity might vary across the audible frequency range for a worker exposed to a continuous noise of intensity at the ear of 10^{-8} W m^{-2}. Label this graph D. [2]

[Total: 12]

[Turn over

4 The fovea is the point on the retina where the image of an object that the viewer is observing is formed. The fovea contains only cones which are responsible for *photopic vision. Scotopic vision* is provided by rods, the proportion of which increases as the distance from the fovea increases.

(a) Explain the terms *scotopic* and *photopic* vision.

scotopic vision ....

....

photopic vision ....

....
[4]

(b) Fig. 4.1 describes the response of rods and cones to variation in light intensity.

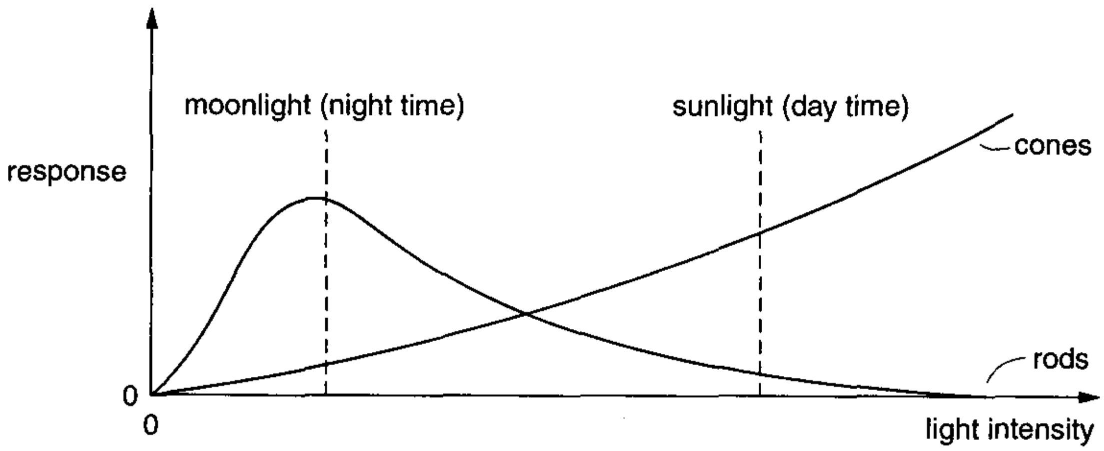

Fig. 4.1

Explain with reference to Fig. 4.1, how the vision of a person changes as the intensity falls gradually to 0 W m^{-2}.

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....[3]

For Examiner's Use

(c) Fig. 4.2 is a graph of the variation of the relative light absorption of rods and cones with wavelength.

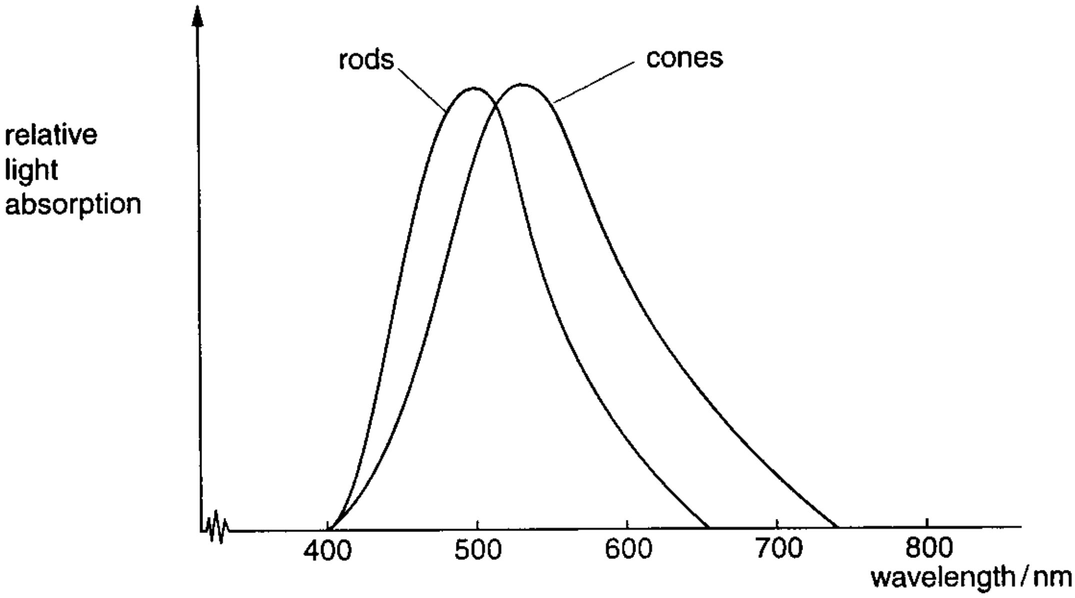

Fig. 4.2

(i) The line labelled 'cones' in Fig. 4.2 is the composite response of the red, blue and green cones. On Fig. 4.2, sketch three graphs to show the individual responses of these cones with variation in wavelength. Label these lines R, G and B respectively. [4]

(ii) Blue-green light has a wavelength around 500 nm. With reference to Fig. 4.2, suggest why the background colour for many road signs is either blue or green.

....

....

....[2]

[Total: 13]

[Turn over

For Examiner's Use

5 Fig. 5.1 shows a schematic diagram of the forces acting on an arm when the arm is supporting a weight of 120 N. The arm has a weight of 20 N which acts at a point 15 cm from the fulcrum **F**. The weight of the 120 N acts through a point 33 cm from the fulcrum. The biceps act with effort **E** to support the arm at a distance of 2 cm from the fulcrum. The reaction **R**, due to the bone, acts along a line through the fulcrum.

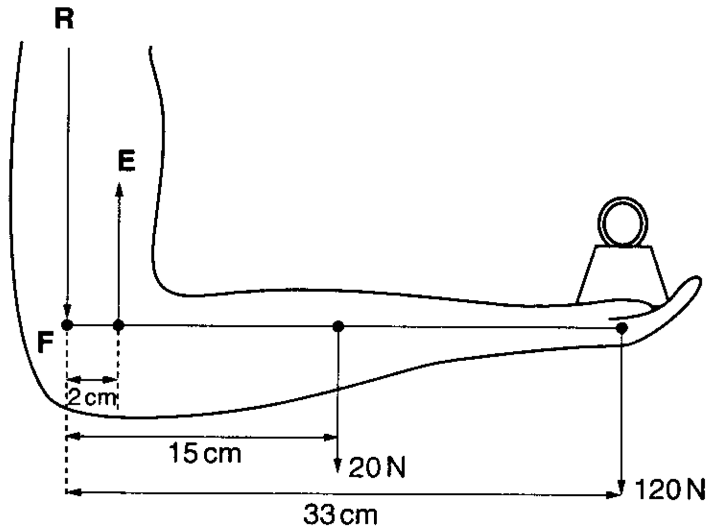

Fig. 5.1

(a) Show that the effort **E**, required to maintain the arm in the position shown in Fig. 5.1, is about 2100 N.

[3]

For Examiner's Use

(b) Calculate the mechanical advantage of the lever system of the arm in Fig. 5.1.

mechanical advantage = ...[2]

(c) Fig. 5.2 shows the arm supporting the weight of 120 N in another position.

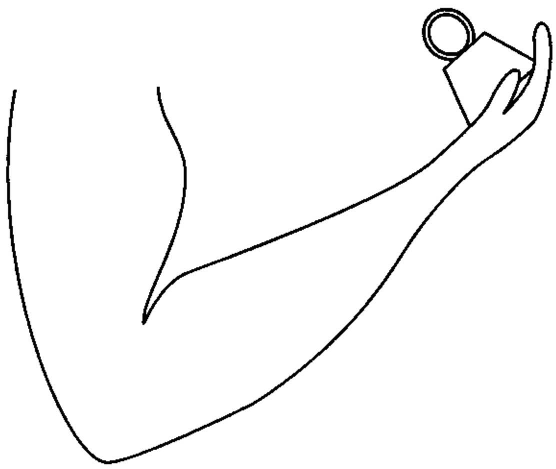

Fig. 5.2

The effort E in the biceps muscle has the same value in Fig. 5.2 as in Fig. 5.1. Explain why.

....

....[2]

[Total: 7]

For Examiner's Use

6 Fig. 6.1 is a diagram showing an ultrasound transducer in contact with skin. A bone of thickness 1.6 cm is situated 1.8 cm below the skin. **A**, **B** and **C** are the boundaries air-skin, soft tissue-bone and bone-soft tissue respectively.

the speed of sound in soft tissue is $1.5 \times 10^3\,\text{m s}^{-1}$
the speed of sound in bone is $4.0 \times 10^3\,\text{m s}^{-1}$

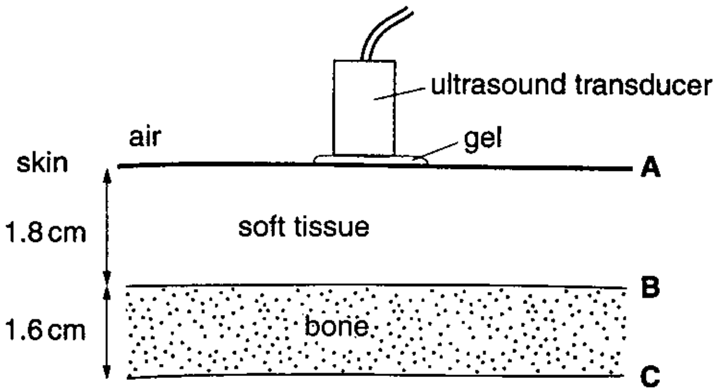

Fig. 6.1

(a) Calculate the time taken for an ultrasound pulse to travel from

(i) boundary **A** to boundary **B**

time = ... s [2]

(ii) boundary **B** to boundary **C**.

time = ... s [1]

For Examiner's Use

(b) Fig. 6.2 shows a cathode ray oscilloscope trace of a pulse received after its reflection from boundary **A**. The time-base setting is 4.0 μs cm^{-1}.

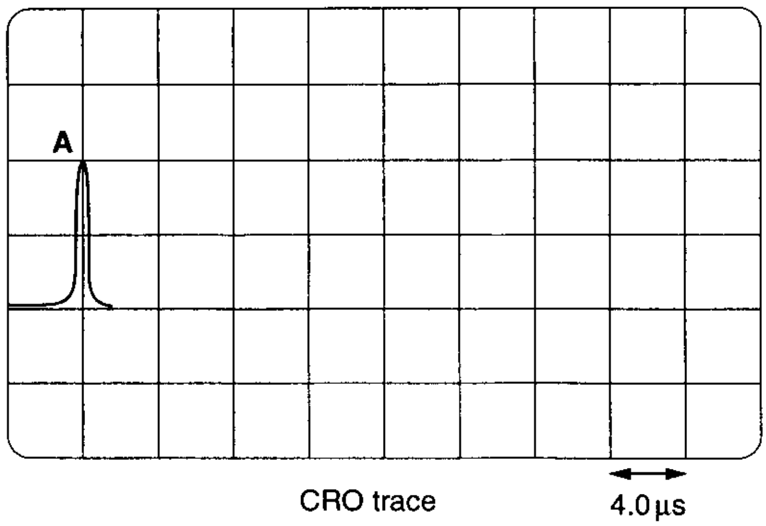

Fig. 6.2

Calculate

(i) the time interval between the reception at the transducer of an ultrasound pulse from boundary **A** and the reception of an ultrasound pulse from boundary **B**

time = ... s [1]

(ii) the number of CRO cm divisions that correspond to this time.

number .... [1]

[Turn over

For Examiner's Use

(iii) Complete Fig. 6.2 to show the reflected ultrasound pulses from boundaries **B** and **C**. Label these peaks B and C. You may assume that all of the peaks have the same height. [2]

(iv) In an experiment, a coupling gel was not used between the transducer and the skin. Explain why the peaks due to the reflections at boundaries **B** and **C** were not visible.

....

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....[3]

[Total: 10]

7 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. 7.1.

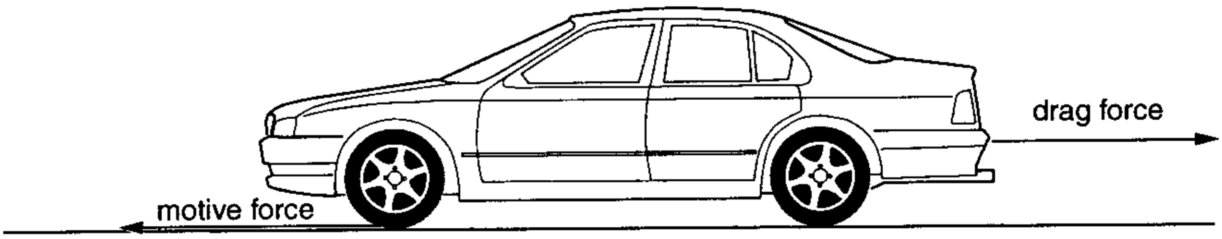

Fig. 7.1

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. 7.2 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	=	1100 kg
maximum braking force	=	9300 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.

For Examiner's Use

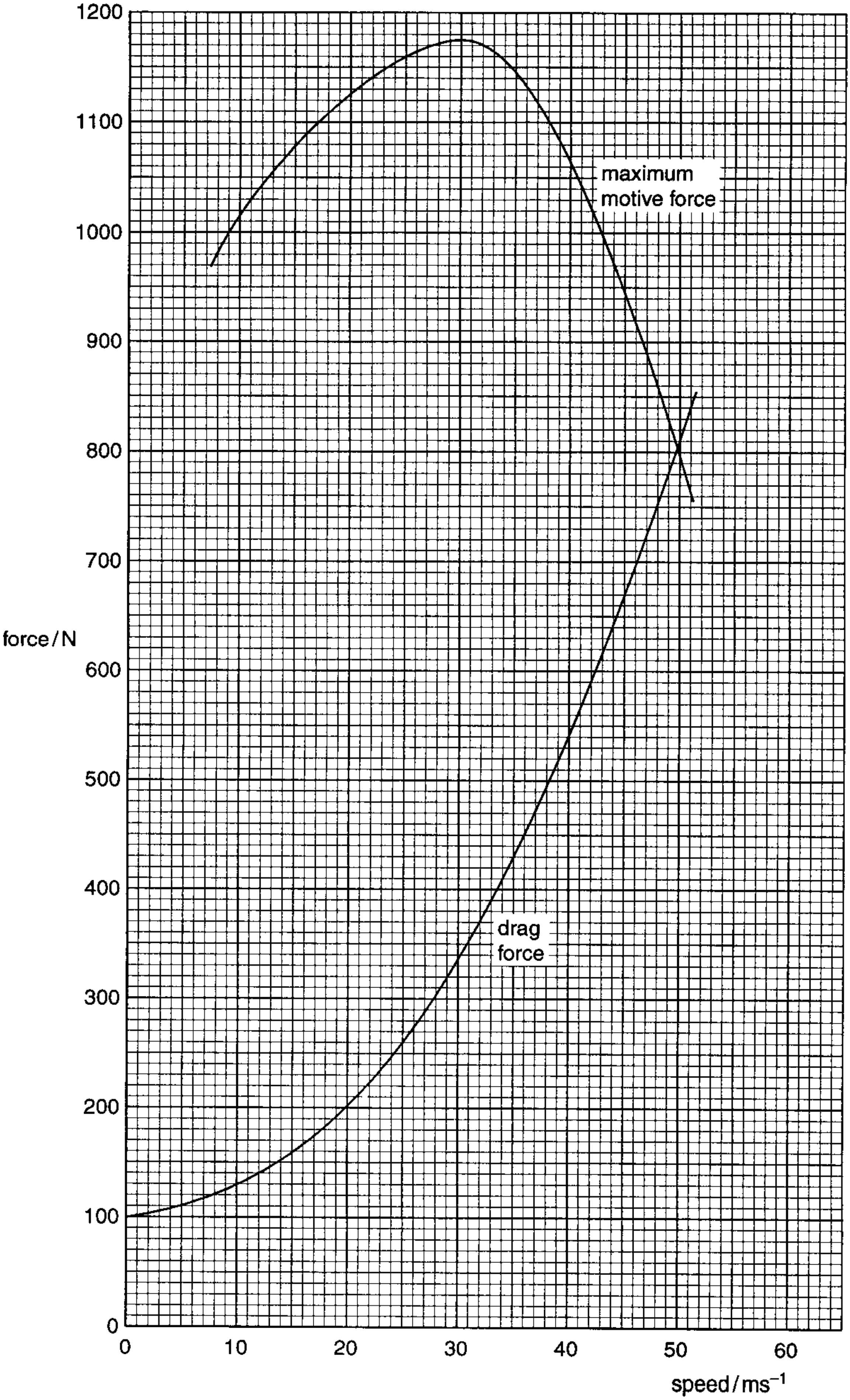

Fig. 7.2

For Examiner's Use

(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. 7.2 as appropriate.

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

....

....

....

....[2]

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

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

....

....

....[2]

For Examiner's Use

(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 2.2×10^5 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 5.3×10^5 J.

[1]

(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]