OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary GCE

PHYSICS A 2821

Forces and Motion

Wednesday **6 JUNE 2001** 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 will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	14	
2	12	
3	11	
4	8	
5	10	
6	10	
7	11	
8	10	
QWC	4	
Total	90	

This question paper consists of 15 printed pages and 1 blank page.

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,	$p = \frac{1}{3}\frac{Nm}{V} \langle c^2 \rangle$
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,	$= 10 \lg \left(\frac{I}{I_0} \right)$

For Examiner's Use

Answer **all** questions.

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

(ii) Distinguish between speed and velocity.

....

.... [2]

(b) Use the equations given below, which represent uniformly accelerated motion in a straight line, to obtain an expression for v in terms of u, a and s only.

$v = u + at$

$s = (u + v)t/2$

[2]

(c) Fig. 1.1 shows a ball kicked from the top of a cliff with a horizontal velocity of $5.6\,\mathrm{m\,s^{-1}}$. Air resistance can be neglected.

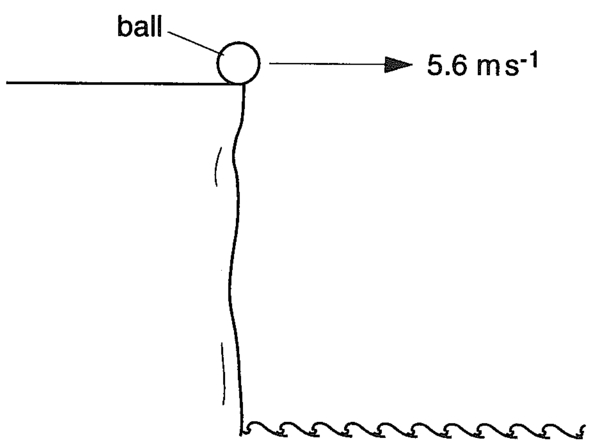

Fig. 1.1

(i) Show that after 0.90 s the vertical component of the velocity is $8.8\,\mathrm{m\,s^{-1}}$.

[2]

For Examiner's Use

(ii) Use a vector triangle to determine the resultant velocity of the ball after 0.90 s.

resultant velocity: magnitude = ... $m\,s^{-1}$

angle to the horizontal = ... ° [4]

(iii) Calculate

1. the vertical distance the ball falls in 0.90 s,
2. the horizontal distance the ball travels in this time.

1. vertical distance = ... m

2. horizontal distance = ... m [3]

2 Fig. 2.1 shows a trolley of mass 0.80 kg, on a bench surface, connected to a mass M by a string. The mass M is released and the trolley moves along the surface. Fig. 2.2 shows the variation of the velocity v of the trolley with time t for the motion from A to B.

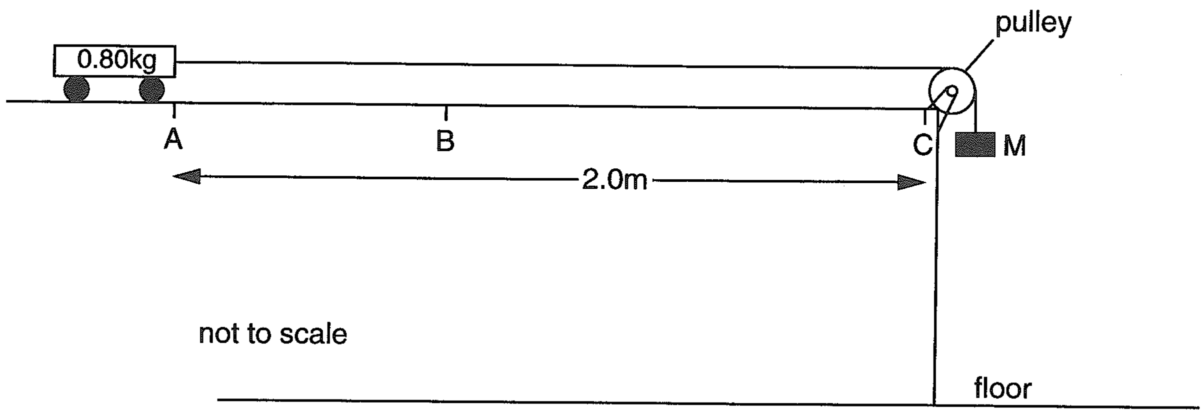

Fig. 2.1

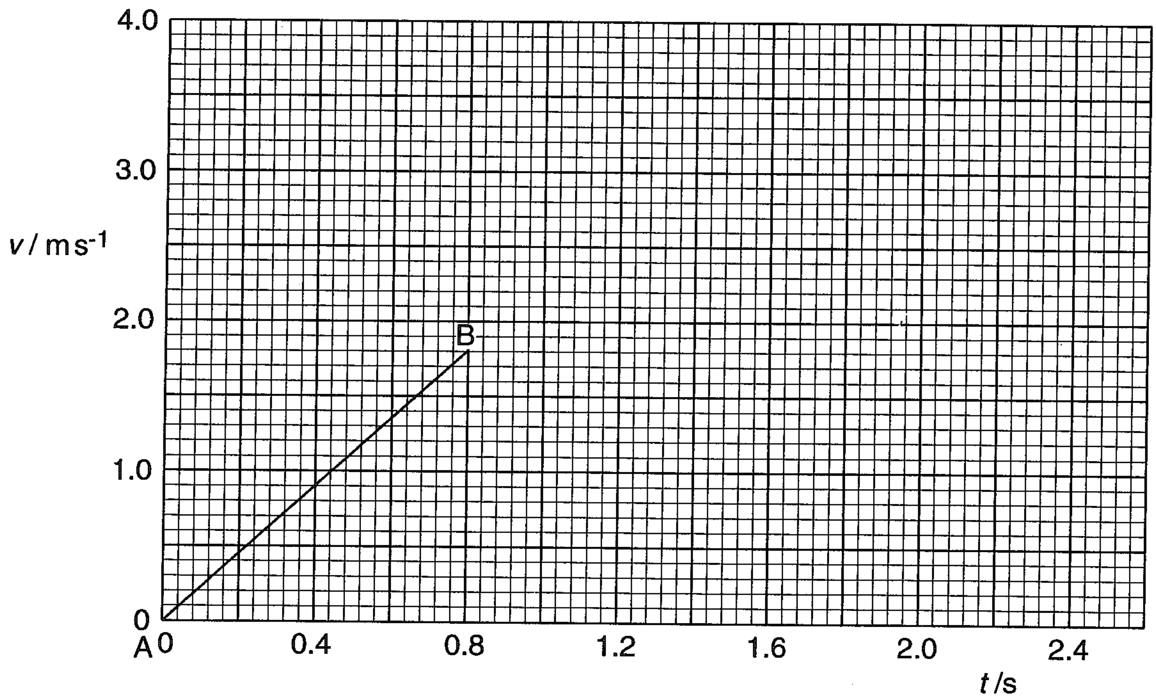

Fig. 2.2

(a) **(i)** Calculate the acceleration of the trolley between A and B.

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

(ii) Calculate the resultant force acting on the trolley between A and B.

force = ... N [2]

For Examiner's Use

(iii) Show that the distance from A to B is 0.72 m.

[2]

(b) When the trolley reaches B the mass M has just reached the floor.

(i) Ignoring any resistive forces, calculate the time it takes the trolley to travel from B to C.

time for B to C = ... s [3]

(ii) On Fig. 2.2, complete the graph for the trolley moving from B and coming to rest at the pulley at C. [3]

3 (a) Use the relation between force, mass and acceleration to express the newton in terms of the SI units of mass, length and time.

....

....[1]

(b) Fig. 3.1 shows a garden roller, of mass 80 kg, being pulled with a force of 250 N at an angle of 30° to the horizontal. The roller moves at a constant velocity.

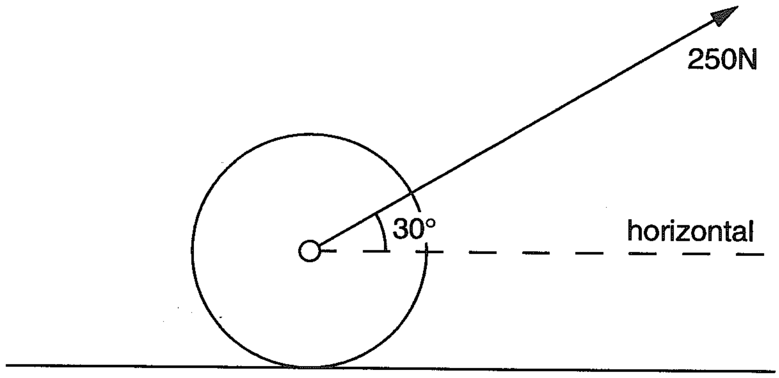

Fig. 3.1

(i) Calculate the weight of the roller.

weight = ... N [1]

(ii) Calculate the magnitude of the horizontal component of the force pulling the roller.

horizontal force = ... N [2]

(iii) Calculate the magnitude of the vertical force exerted by the roller on the ground.

vertical force = ... N [3]

For Examiner's Use

(c) **(i)** Explain how the roller in **(b)** is able to travel at a constant velocity when being pulled by a force of 250 N.

....

....

....

....[2]

(ii) The roller is now pushed with a force of 250 N at 30° to the horizontal. State and explain the change that occurs to the force exerted on the ground by the roller. A numerical answer is not required.

....

....

....

....[2]

For Examiner's Use

4 (a) (i) Explain the concept of work and relate it to power.

....

....

....

....[2]

(ii) Define the joule.

....

....[1]

(b) A cable car is used to carry people up a mountain. The mass of the car is 2000 kg and it carries 80 people, of average mass 60 kg. The vertical height travelled is 900 m and the time taken is 5 minutes.

(i) Calculate the gain in gravitational potential energy of the 80 people in the car.

gravitational potential energy gain = ... J [2]

(ii) Calculate the minimum power required by a motor to lift the cable car and its passengers to the top of the mountain.

power = ... unit .... [3]

For Examiner's Use

5 (a) (i) Define the moment of a force.

....[1]

(ii) State the principle of moments.

....

....[2]

(b) Fig. 5.1 shows a pillar (lying horizontally) made of two uniform sections X and Y each of cross-sectional area 3.5×10^{-2} m^2. The sections are made from two different materials. The weights of X and Y are shown acting through the centre of gravity of each section.

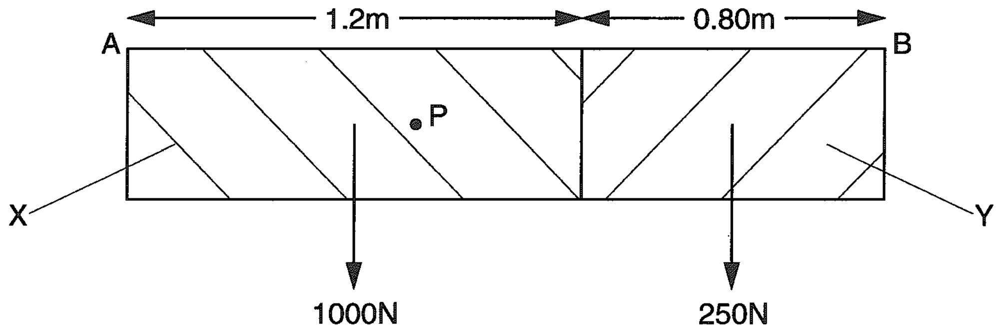

Fig. 5.1

Show that the average density of the pillar is about 1800 kg m^{-3}.

[3]

(c) The pillar in **(b)** will balance horizontally when supported vertically below the point P.

(i) Show, using the principle of moments, that the point P is 1.2 m from the end B.

[3]

(ii) State the significance of the point P.

....[1]

[Turn over

6 **(a)** State Hooke's Law.

....

....[1]

(b) A spring is compressed by applying a force. Fig. 6.1 shows the variation of the force F with compression x.

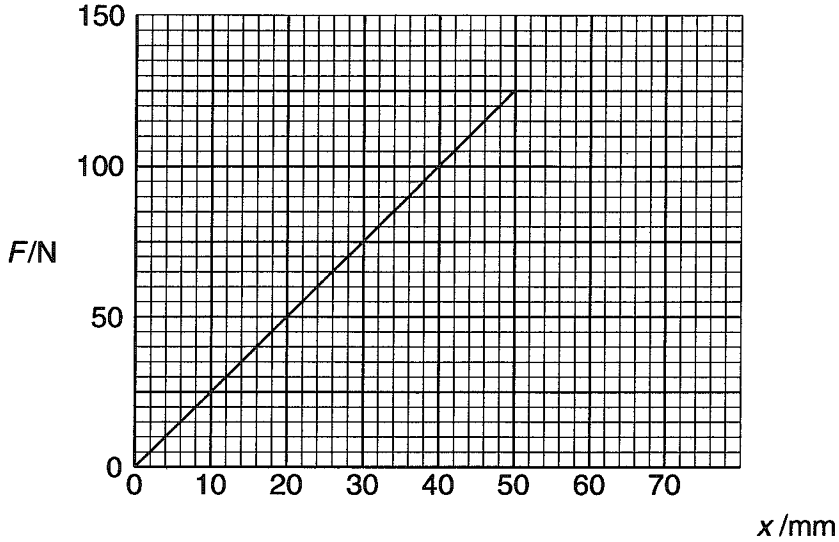

Fig. 6.1

(i) Calculate the spring constant.

spring constant = ... unit .... [2]

(ii) Show that the work done in compressing the spring by 48 mm is 2.9 J.

[2]

For Examiner's Use

(c) Fig. 6.2 shows the spring in a toy gun. The spring is used to fire a dart of mass 15 g vertically.

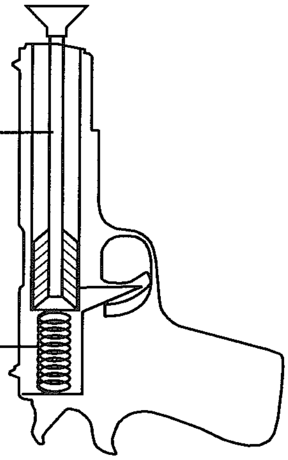

Fig. 6.2

(i) The spring is compressed by 48 mm in the gun. When the gun is fired the strain energy in the spring is converted into the kinetic energy of the dart. Calculate the speed with which the dart initially leaves the spring when the gun is fired.

speed = ... $m\,s^{-1}$ [3]

(ii) Give two reasons why the dart is unlikely to have 2.9 J of gravitational potential energy when it reaches its maximum height.

1. ....

....

2. ....

....[2]

[Turn over

For Examiner's Use

7 (a) (i) Define the Young modulus of a material.

....

....[2]

(ii) Define elastic limit.

....

....[2]

(iii) Distinguish between elastic and plastic deformation of a material.

....

....

....[2]

(b) Fig. 7.1 shows graphs of force F against extension x for three different types of material. Identify with a reason the type of material corresponding to each graph.
(In this question marks are available for the quality of written communication.)

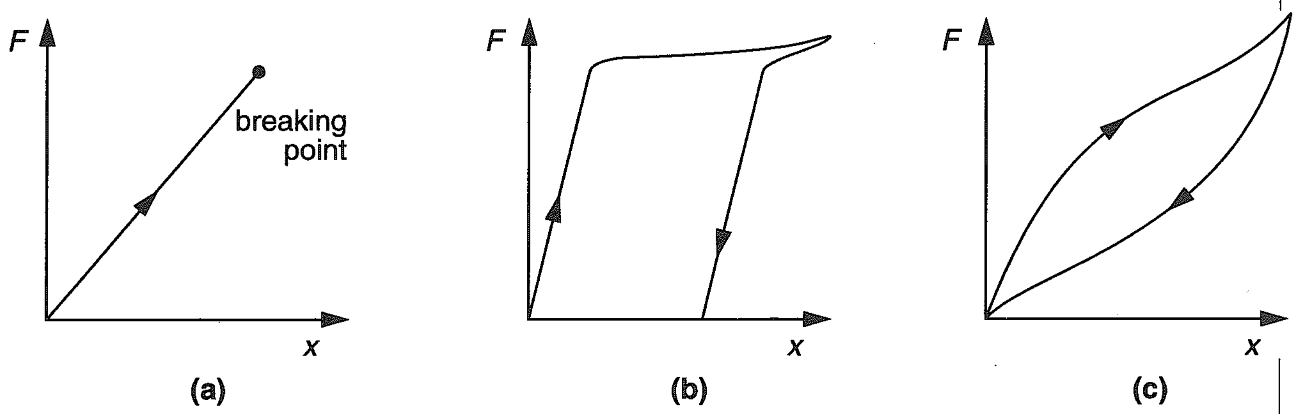

Fig. 7.1

....

....

....

....

....

....

....

....

....

....[5]

For Examiner's Use

(In this question marks are available for the quality of written communication.)

8 (a) Describe the physical principles of seat belts, air bags and crumple zones as design features of cars used to protect the driver from injury during a collision.

....

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....[5]

(b) Explain the term braking distance in relation to the motion of a road vehicle and discuss the factors that affect its value.

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....

....

....[5]

QWC [4]

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1. (a)(i)	distance travelled per unit time / rate of change of distance	B1
(ii)	speed has magnitude only (allow size but not quantity)	B1
	velocity has magnitude and direction	B1
	(speed is a scalar and velocity is a vector scores 1)	
	(velocity has direction but speed does not scores 1)	
(b)	$t = (v - u) / a$ or $t = 2s / (u + v)$	C1
	substitution:	
	$s = (u + v)(v - u) / 2a = ((v^2 - u^2) / 2a)$	
	$v = u + 2as / (u + v)$	B1
	hence $v^2 = u^2 + 2as$	A0
(c)(i)	$v = u + at$ $u = 0$	C1
	$= (0 +)\ 9.81 \times 0.9$	M1
	hence $v = 8.8\ (29)\ \text{m s}^{-1}$	A0
(ii)	if scale diagram used:	
	scale given	B1
	correct triangle drawn (shape)	B1
	velocity = $10.4 \pm 0.2\ \text{m s}^{-1}$	B1
	angle to the horizontal = $57 \pm 2°$	B1
	if calculated:	
	triangle drawn (shape correct but arrows not required)	B1
	algebra given	C1
	velocity = $10.45\ \text{m s}^{-1}$ (allow 10.4 or 10.5)	A1
	angle = 57.6°	A1
(iii)	vertical distance $= (8.8 \times 0.9) / 2$	C1
	$= 3.96$ m (3.97 if 8.829 is used)	A1
	(3.95 if 9.81 and 8.8 used)	
	(allow 4.0 but not 4)	
	horizontal distance $= 5.6 \times 0.9 = 5.0$ m	B1
	Total	[14]

2. (a)(i)	a = 1.8 / 0.8	C1
	= 2.25 (m s^{-2})	A1
(ii)	F = ma	
	= 0.8 x 2.25	C1
	= 1.8 (N)	A1
(iii)	area under the graph or s = (u + v) t / 2 etc	C1
	distance = (1.8 x 0.8) / 2	M1
	hence distance = 0.72 m	A0
(b)(i)	distance BC = 2 – 0.72 = 1.28 (m)	C1
	time = 1.28 / 1.8	C1
	time = 0.71 (s)	A1
(ii)	straight horizontal line of at least 2 small squares	B1
	until 1.5 (s) [note ecf from (b)(i) i.e. 0.8 + (b)(i)] within ½ square	B1
	steep line (do not consider shape) to zero speed (max of two squares)	B1
	Total	[12]
3. (a)	kg m s^{-2}	B1
(b)(i)	W = 80 x 9.81	
	= 785 (N) (allow 784 if 9.8 is used, do not allow use of g = 10)	B1
(ii)	horizontal force = 250 cos30	C1
	= 217 (N) (not 216 but allow 216.5)	A1
(iii)	vertical component = 250sin30 = (125)	C1
	force exerted on the ground = 785 – 125	C1
	= 660 (N) (allow 659 using 9.8)	A1
	(allow one mark for an answer of 125)	
(c)(i)	for constant velocity resultant force is zero / in equilibrium	B1
	other forces must act against / resistive / friction / opposite to the pulling force	B1
(ii)	greater force exerted on the ground	B1
	vertical component acts downwards	B1
	(allow 2 for calculated value of 910/909)	
	Total	[11]

4.	(a)(i)	work: product of force and distance moved in the direction of the force	B1
		power: rate of doing work / work done per unit time (allow power or work as the subject)	B1
	(ii)	joule: work done when (a force of) one newton moves (its point of application) one metre (in the direction of the force)	B1
	(b)(i)	g.p.e. = mgh	C1
		60 x 80 x 9.81 x 900 42379200 (allow use of 9.8 and answer of 42336000) (J) (42 MJ)	A1
	(ii)	total energy input = 6800 x 9.81 x 900 or 42379200 + 2000 x 9.81 x 900	C1
		power = 60037200 / (5 x 60) or (42379200 + 17658000) / (5 x 60)	C1
		= 200124 W (200kW) (199920 using 9.8)	A1
		unit penalty	-1
		Total	[8]
5.	(a)(i)	moment: force x perpendicular distance to the pivot / axis / point	B1
	(ii)	for equilibrium / balanced the sum of the clockwise moments about a pivot is equal to the sum of anticlockwise moments (about the same pivot/axis/point) (clockwise moments equal the anticlockwise moments scores one only)	B2
	(b)(i)	total mass = (1000 + 250) / 9.81 = (127.42) or (127.55 if 9.8 used) (allow one mark for the individual masses being calculated)	C1
		volume = 2 x 3.5 x 10^{-2} = (7.0 x 10^{-2})	C1
		density = mass / volume = 127.42 / (7.0 x 10^{-2})	M1
		hence density = 1820 (kgm^{-3}) (1822 using 9.8)	A0
	(c)(i)	moments about P (or other named and suitable point)	B1
		1000 x 0.2 = 200 or equivalent moment	C1
		equals 250 x 0.8 = 200 or equivalent moment	C1
		hence P is 0.4 + 0.8 = 1.2 m from B	A0
	(ii)	P is the centre of gravity / mass (of the whole pillar) (Allow the point where the total weight acts)	B1
		Total	[10]

6. (a)	force / load if proportional to extension		B1
(b)(i)	force constant = 100 / (40 x 10^{-3}) or equivalent		C1
	= 2500 N m^{-1} / kg s^{-2} (2.5 N mm^{-1})		A1
		unit penalty	-1
(ii)	work done = area under graph / (force x extension) / 2		C1
	= (120 x 48 x 10^{-3}) / 2		M1
	= 2.88 (2.9 to 2sf) (J)		A0
(c)(i)	k.e = ½ mv^2		C1
	v^2 = (2.9 x 2) / 0.015		C1
	v = 19.7 (ms^{-1}) (19.6 if 2.88 J is used)		A1
(ii)	(energy lost due to) friction in the gun		B1
	air resistance		B1
	(allow energy loss if type identified and place given)		
	(allow recoil of the gun)		
		Total	[10]
7. (a)(i)	Young modulus = tensile stress / tensile strain		B2
	(stress / strain scores 1, with definitions of stress and strain scores 2)		
(ii)	elastic limit: maximum force / load / stress / strain / extension which can be applied to an object and it will regain its original length when the force / load stress is removed		B2
(iii)	elastic returns to original length when load is removed		B1
	plastic returns some deformation (when load is removed)		B1
	penalise 'when load is removed' once only in (ii) and (iii)		
(b)	a. brittle substance / glass / cast iron / perspex		B1
	b. ductile substance / metal / polythene		B1
	c. polymeric substance / rubber / elastic		B1
	extends uniformly and then breaks for a		B1
	plastic behaviour for b		B1
	elastic but energy stored in the material when load removed for c / elastic but not uniform		B1
		max 5 marks	
		Total	[11]

8. (a) air bags: increase time / distance of impact
reduces force / reduces deceleration
increase area of contact
reduces pressure
prevents collision with steering wheel / windscreen / dashboard
instant deflation to reduce recoil / neck injury / whiplash

crumple zones: increase time/distance
reduces force
absorbs energy

seat belt: restraining force to prevent collision with steering wheel/ windscreen/dashboard
area of belt made large to reduce pressure

(collision with the steering wheel/windscreen scores once only if no explanation is given)
5 marks (must include all three items for maximum of five to be scored) B5

(b) braking distance:
distance vehicle travels after the brakes have been applied (until it stops) B1

road surface	B1
tread of tyres needed when the road is wet	B1
friction between the road and tyre	B1
speed of vehicle	B1
proportional to v^2	B1

(one point given B1, amplification of why and how it affects the braking distance B1) This done twice for the four marks max 4 points

Total [10]
QWC [4]