Mr Cowen's answers

THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
PHYSICS A 2821
Forces and Motion

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator
- Protractor
- Ruler (cm/mm)

Thursday 21 May 2009
Afternoon

Duration: 1 hour

Candidate Forename	Cowen	Candidate Surname	Physics
Centre Number		Candidate Number	

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **60**.
- 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.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	6	
2	6	
3	7	
4	12	
5	7	
6	7	
7	8	
8	7	
TOTAL	60	

Turn over

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,	$= 10 \lg\left(\frac{I}{I_0}\right)$

Answer **all** the questions.

1 **(a)** State the difference between a vector and a scalar quantity.

Vector has magnitude and direction, scalar has magnitude only. ✓ [1]

(b) In the following list underline **all** the scalar quantities.

displacement <u>kinetic energy</u> <u>mass</u> <u>power</u> velocity weight [1]

(c) Fig. 1.1 shows a climber on a vertical rock face supported by a rope. The climber is in equilibrium.

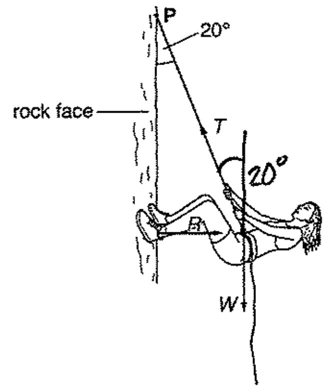


Fig. 1.1

The weight of the climber and her equipment is 650 N. The rope is attached to the climber and fixed to a point **P** where it makes an angle of 20° to the vertical. The contact force R acts on the climber at right angles to the rock face.

(i) Use a vector triangle or resolve forces to calculate

1 the tension T in the rope

$$W = T\cos 20^\circ$$

$$T = \frac{W}{\cos 20^\circ} = \frac{650}{\cos 20^\circ} = 692\ N$$

$T =$ 692 ~~N~~ N

2 the contact force R.

$$R = T\sin 20$$

$$R = 692\sin 20$$

$$R = 237N$$

$R =$ 237 N [3]

(ii) The climber moves down the rock face and the angle the rope makes with the vertical decreases. Explain why the magnitude of the tension decreases.

$T \propto \frac{1}{\cos\theta}$ As θ decreases, $\cos\theta$ increases and $\frac{1}{\cos\theta}$ decrease. [1]

∴ Smaller angle will reduce tension.

[Total: 6]

2 Fig. 2.1 shows a skier during a speed skiing competition. Speed skiing is skiing downhill in a straight line as fast as possible.

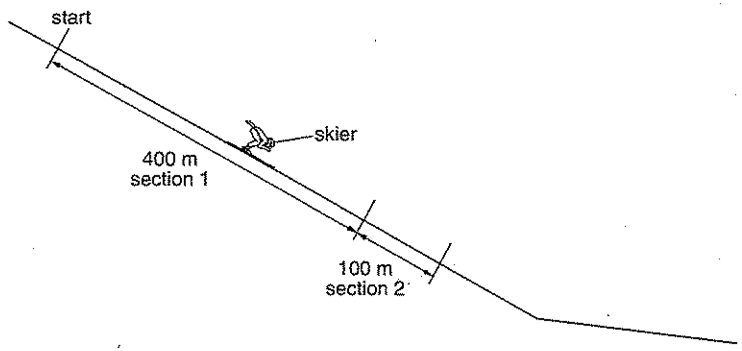


Fig. 2.1

In section 1 the skier started from rest and travelled at constant acceleration of 3.90 m s^{-2} for a distance of 400 m. Section 2 is 100 m long and this is where the skier is timed for the competition. The time recorded was 1.82 s.

(a) Calculate

(i) the time taken for section 1

$u = 0,\ a = 3.90,\ t = ?,\ s = 400 \qquad s = \cancel{ut} + \frac{1}{2}at^2$

$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 400}{3.90}} = 14.3s$$

time = 14.3 s [2]

(ii) the speed of the skier at the end of section 1

$v = ? \qquad v^2 = u^2 + 2as$

$$v = \sqrt{u^2 + 2as} = \sqrt{0 + 2 \times 3.9 \times 400} = 55.9\ ms^{-1}$$

speed = 55.9 m s^{-1} [1]

(iii) the average speed for section 2.

$$V = \frac{s}{t} = \frac{100}{1.82} = 54.9\ ms^{-1}$$

average speed = 54.9 m s^{-1} [1]

(b) Explain two methods the skier could adopt to increase the average speed for section 2.

Lubricate skis to reduce friction.
Adopt a smaller posture to reduce air resistance.

[2]

[Total: 6]

3 Fig. 3.1 shows a stair lift that takes a woman up a flight of stairs.

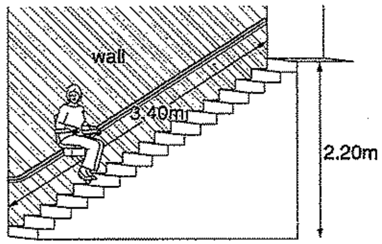


Fig. 3.1

The total weight of the woman and the chair is 930 N. The height gained is 2.20 m and the distance travelled by the woman is 3.40 m.

(a) Calculate the gain in gravitational potential energy of the woman and the chair.

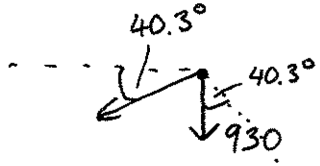
$E_p = mgh = 930 \times 2.20$
$= 2046\ J$

potential energy = 2046 J [2]

(b) Define *power*.

~~Rate at~~ Power $= \frac{\text{Energy}}{\text{Time}}$ [1]

(c) The lift travels up a slope at an angle of 40.3° to the horizontal in a time of 42.0 s. Calculate



(i) the component of the weight of the woman and chair down the slope

$W_{par} = 930 \sin 40.3 = 602\ N$

component = 602 N [1]

(ii) the power required to lift the woman and chair to the top of the stairs.

$P = \frac{Fs}{t} = \frac{602 \times 3.4}{42} = 48.7\ W$

or $P = \frac{E_p}{t} = \frac{2046}{42} =$

power = 48.7 unit W [3]

[Total: 7]

4 In this question, two marks are available for the quality of written communication.

(a) Fig. 4.1 shows a graph of the velocity v against time t for a moving object.

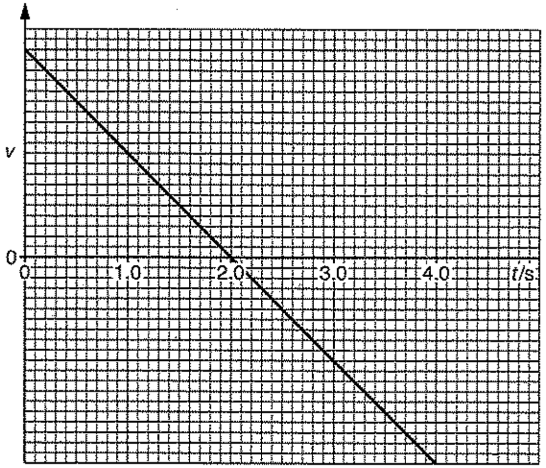


Fig. 4.1

Use the graph to describe and explain how the velocity and acceleration of the object change with time. Use the values on the time axis as reference for your description.

The object is initially decelerating at a constant rate. At 2 seconds the object is momentarily stationary, before it begins to accelerate at the same ~~at~~ steady rate, causing motion in the opposite direction at an increasing velocity [3]

Gradient = acceleration

(b) Fig. 4.2 shows the displacement s against time t for a second object.

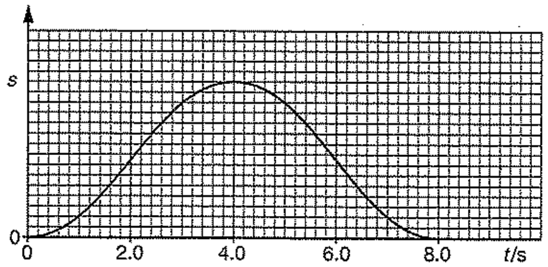


Fig. 4.2

(i) Use the graph to describe and explain how the velocity for this object changes with time. Use the time values on the graph as a reference for your description.

For the first two seconds, the velocity is increasing, then between 2s and 4s the velocity decreases until the object is stationary momentarily at 4 seconds. Between 4s and 6s the ~~ball~~ object accelerates, before decelerating to zero between 6s and 8s. Velocity reverses direction at $t = 4.0$s

Gradient = velocity

[5]

(ii) Sketch on Fig. 4.3 a possible shape for variation of the velocity v against time t for this object.

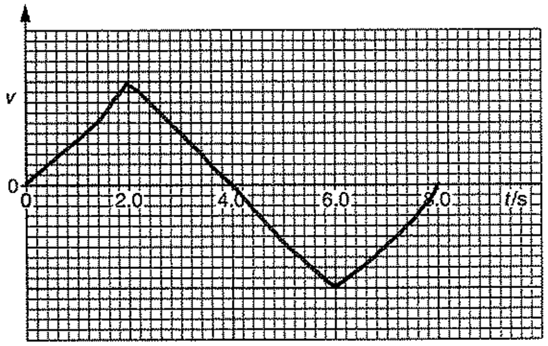


Fig. 4.3

[2]

Quality of Written Communication [2]

[Total: 12]

5 (a) Fig. 5.1 shows ropes **X** and **Y** that provide two equal and opposite forces of 120 N. These forces act vertically at the ends of a uniform horizontal rod of length 2.0 m and weight **W** of 240 N. The rod is pivoted at its centre.

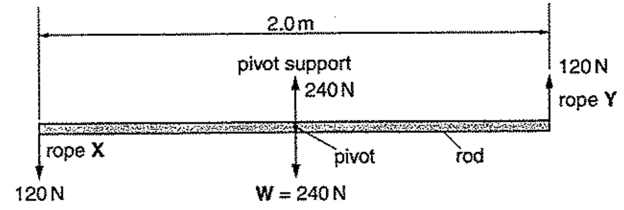


Fig. 5.1

(i) Calculate the torque on the rod.

torque = Fd = 120 × 2 = 240 Nm

torque = 240 Nm [2]

(ii) Explain why the rod is not in equilibrium.

The ~~duat~~ moments do not sum to zero.

120 + 120 ≠ 0 [1]

(b) Fig. 5.2 shows the rod taken off the pivot and supported by ropes **X** and **Y**. The tension in rope **X** and rope **Y** is 120 N.

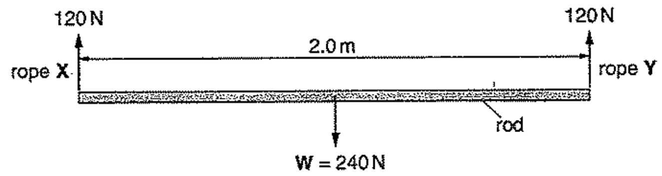


Fig. 5.2

Explain how this rod is in equilibrium.

The vertical (and horizontal) forces sum to zero and the moments sum to zero.

[1]

(c) Fig. 5.3 shows rope **X** moved, to a point **P**, 0.50 m from the end towards the centre of the rod. The tensions in the ropes change to maintain equilibrium.

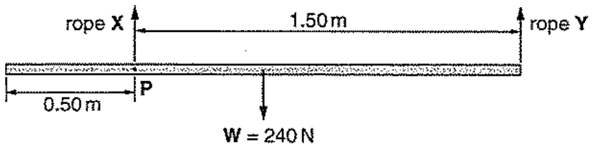


Fig. 5.3

Calculate the new tension in rope **Y** by taking moments about **P**.

$\circlearrowleft = \circlearrowright$: $240 \times 0.5 = T_Y \times 1.5$

$$T_Y = \frac{240 \times 0.5}{1.5} = 80\ \text{N}$$

tension = 80 N .... N **[3]**

[Total: 7]

6 (a) Define

(i) *stress* $\text{stress} = \dfrac{\text{force}}{\text{cross-sectional area}}$

(ii) *strain* $\text{strain} = \dfrac{\text{extension}}{\text{original length}}$ **[2]**

(b) A wire of length 1.75 m and cross-sectional area $1.96 \times 10^{-7}\ \text{m}^2$ is extended by a force of 15.0 N. The material of the wire has a Young modulus of 2.00×10^{11} Pa.

(i) Calculate the extension of the wire.

$$\text{stress} = \frac{15}{1.96 \times 10^{-7}} = 76.5\ \text{MPa}$$

$$\cancel{\text{stress}}\ \text{strain} = \frac{\text{stress}}{\text{Young M}} = \frac{76.5 \times 10^6}{2 \times 10^{11}} = 3.82 \times 10^{-4}$$

extension = strain × length
$= 3.82 \times 10^{-4} \times 1.75$

extension = 6.7×10^{-4} .... m **[3]**

(ii) A second wire made from the same material has the same volume. This wire has twice the original length and is extended by the same force. State and **explain** whether the extension of the second wire is greater, the same or less than the first wire.

Second wire has half the area of original, but twice the length
Doubling length doubles extension. **[2]**
Halving the area doubles extension.

[Total: 7]

~~extension = strain × length~~

~~strain ∝ stress ∝ $\frac{1}{\text{area}}$~~

~~∴ extension ∝ $\frac{1}{\text{area}}$ × length~~

~~If length doubles, area halves, so extension is the same.~~

7 Fig. 7.1 shows how the force F for a spring varies with the compression x.

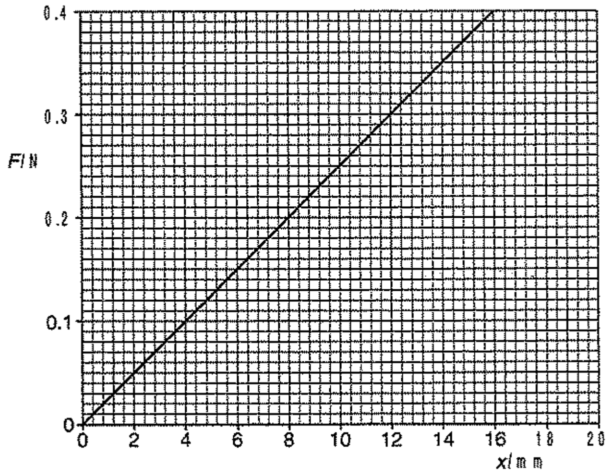


Fig. 7.1

(a) Show that the spring constant for the spring is $25\,\mathrm{N\,m^{-1}}$.

$F = kx \quad k = \frac{F}{x} = \frac{0.4-0}{16-0 \times 10^{-3}} = 25$

[1]

(b) Fig. 7.2 shows the spring being used in a buffer to stop a moving toy train.

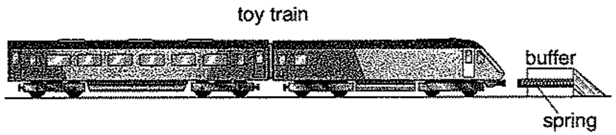


Fig. 7.2

The train of mass 0.45 kg was moving at a speed v when it hit the buffer. The train was brought to rest by the spring as it compresses 12 mm.

(i) Show that the work done compressing the spring is 1.8×10^{-3} J.

$E = \frac{1}{2}kx^2 = \frac{1}{2} \times 25 \times (12 \times 10^{-3})^2$

$= 1.8 \times 10^{-3}\ \mathrm{J}$

[2]

(ii) Calculate the speed of the train just before it hits the buffer. Assume that the work done compressing the spring is equal to the initial kinetic energy of the train.

$E_k = 1.8 \times 10^{-3} = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 1.8 \times 10^{-3}}{0.45}} = 0.089\ \mathrm{ms^{-1}}$

speed = 0.089 $\mathrm{ms^{-1}}$ [3]

(c) State and explain the effect on the compression of the spring if the speed of the train is doubled.

If the speed is doubled, the kinetic energy will be four times larger. $x \propto \sqrt{E_k}$ so the compression will double. [2]

[Total: 8]

8 (a) A car of mass 850 kg is travelling at a constant speed of $16\,\text{m s}^{-1}$ on a dry, level road when the driver reacts to a problem ahead. The car travels 12 m before the driver applies the brakes. The car then stops in a braking distance of 28 m.

(i) Calculate the average deceleration of the car when braking.

$u = 16,\ v = 0,\ s = 28,\ a = ?$

$v^2 = u^2 + 2as \qquad a = \dfrac{v^2 - u^2}{2s} = \dfrac{-16^2}{2 \times 28} = -4.57$

deceleration = 4.57 m s^{-2} [2]

(ii) Calculate the average braking force required to bring the car to rest.

$F = ma = 850 \times 4.57 = 3885\ \text{N}$

braking force = 3890 N [2]

(b) (i) Explain how the road surface enables a car to come to rest when braking.

Friction acts between tyres and road ~~so that~~ to maintain grip while the brakes slow the wheels down, providing a [2] backwards force.

(ii) Hence explain why the braking distance of a car increases if the road is wet.

The water lubricates the road and reduces friction between the tyres and road, which causes the car [1] to skid and decelerate less.

[Total: 7]

END OF QUESTION PAPER

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