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9702/22

May/June 2020

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

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[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

- 1 (a) Define *velocity*.

.....
 [1]

- (b) The drag force F_D acting on a car moving with speed v along a straight horizontal road is given by

$$F_D = v^2 Ak$$

where k is a constant and A is the cross-sectional area of the car.

Determine the SI base units of k .

SI base units [2]

- (c) The value of k , in SI base units, for the car in (b) is 0.24. The cross-sectional area A of the car is 5.1 m^2 .

The car is travelling with a constant speed along a straight road and the output power of the engine is $4.8 \times 10^4 \text{ W}$. Assume that the output power of the engine is equal to the rate at which the drag force F_D is doing work against the car.

Determine the speed of the car.

speed = ms^{-1} [3]

[Total: 6]

- 2 (a) Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

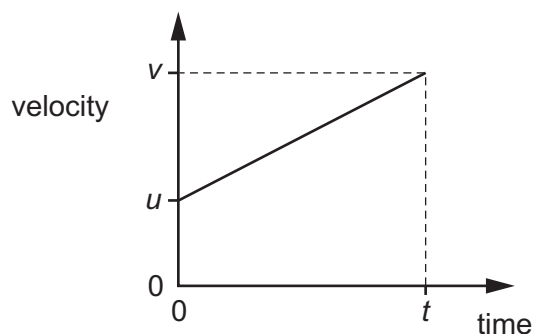


Fig. 2.1

- (i) Determine an expression, in terms of u , v and t , for the area under the graph.

area = [1]

- (ii) State the name of the quantity represented by the area under the graph.

..... [1]

- (b) A ball is kicked with a velocity of 15 m s^{-1} at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

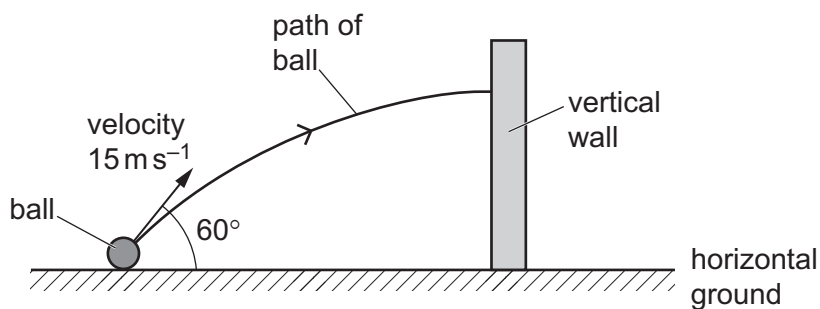


Fig. 2.2 (not to scale)

Assume that air resistance is negligible.

- (i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = s [3]

- (ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

.....
 [1]

- (iii) Show that the ball strikes the wall with a horizontal velocity of 7.5 m s^{-1} .

[1]

- (c) The mass of the ball in (b) is 0.40 kg . It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of 4.3 m s^{-1} .

- (i) Use the information from (b)(iii) to calculate the change in momentum of the ball due to the collision.

change in momentum = kg m s^{-1} [2]

- (ii) Calculate the magnitude of the average force exerted on the ball by the wall.

average force = N [1]

[Total: 10]

- 3 (a) Explain what is meant by *work done*.

.....
 [1]

- (b) A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of 23 m s^{-1} .

- (i) Calculate, for the ball falling from the top of the building to the ground:

1. the decrease in gravitational potential energy

decrease in gravitational potential energy = J [2]

2. the increase in kinetic energy.

increase in kinetic energy = J [2]

- (ii) Use your answers in (b)(i) to determine the average resistive force acting on the ball as it falls from the top of the building to the ground.

average resistive force = N [2]

- (c) The ball in (b) is dropped at time $t = 0$ and hits the ground at time $t = T$. The acceleration of free fall is g .

On Fig. 3.1, sketch a line to show the variation of the acceleration a of the ball with time t from time $t = 0$ to $t = T$.

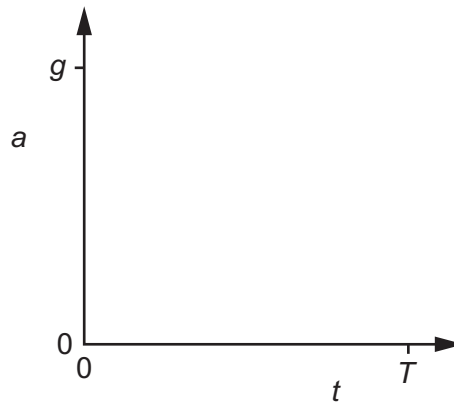


Fig. 3.1

[2]

[Total: 9]

- 4 (a) State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

.....
 [1]

- (b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

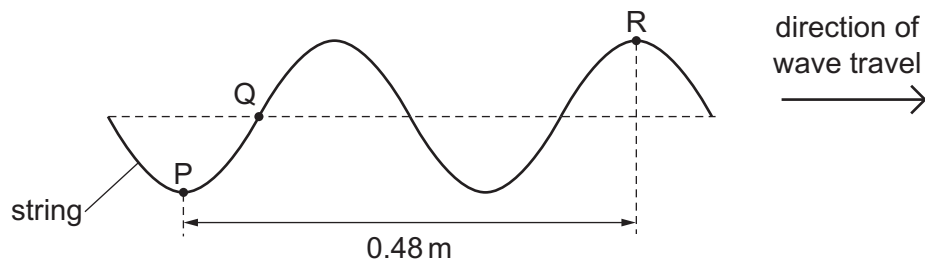


Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

- (i) Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = m [1]

- (ii) Calculate the speed of the wave.

speed = ms^{-1} [2]

- (iii) Determine the phase difference between points Q and R.

phase difference = $^{\circ}$ [1]

- (iv) Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

.....

.....

.....

..... [2]

- (c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

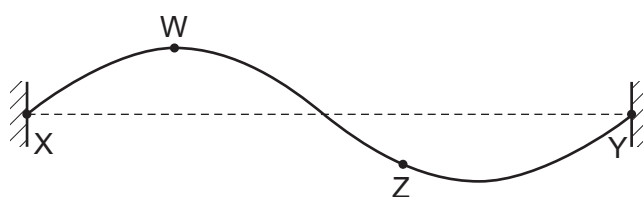


Fig. 4.2

- (i) Explain what is meant by a *node* of a stationary wave.

..... [1]

- (ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = [1]

- (iii) State the phase difference between points W and Z on the string.

phase difference =° [1]

- (iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

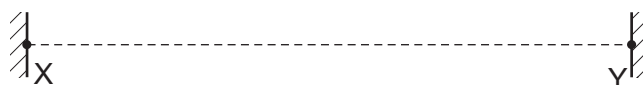


Fig. 4.3

[1]

[Total: 11]

- 5 One end of a wire is attached to a fixed point. A force F is applied to the wire to cause extension x . The variation with F of x is shown in Fig. 5.1.

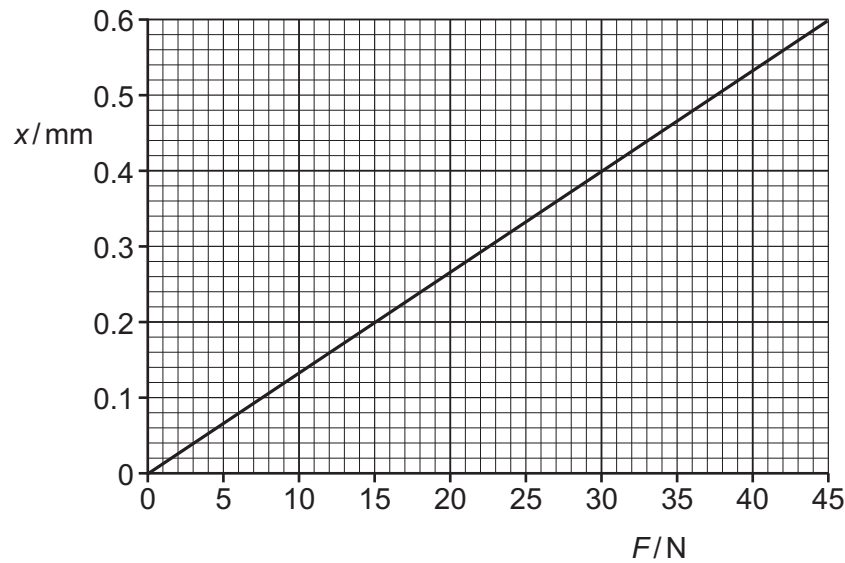


Fig. 5.1

The wire has a cross-sectional area of $4.1 \times 10^{-7} \text{ m}^2$ and is made of metal of Young modulus $1.7 \times 10^{11} \text{ Pa}$. Assume that the cross-sectional area of the wire remains constant as the wire extends.

- (a) State the name of the law that describes the relationship between F and x shown in Fig. 5.1.

..... [1]

- (b) The wire has an extension of 0.48 mm.

Determine:

- (i) the stress

stress = Pa [2]

- (ii) the strain.

strain = [2]

- (c) The resistivity of the metal of the wire is $3.7 \times 10^{-7} \Omega \text{ m}$.

Determine the change in resistance of the wire when the extension x of the wire changes from $x = 0.48 \text{ mm}$ to $x = 0.60 \text{ mm}$.

change in resistance = Ω [3]

- (d) A force of greater than 45 N is now applied to the wire.

Describe how it may be checked that the elastic limit of the wire has not been exceeded.

.....

..... [1]

[Total: 9]

- 6 (a) A battery of electromotive force (e.m.f.) 7.8 V and internal resistance r is connected to a filament lamp, as shown in Fig. 6.1.

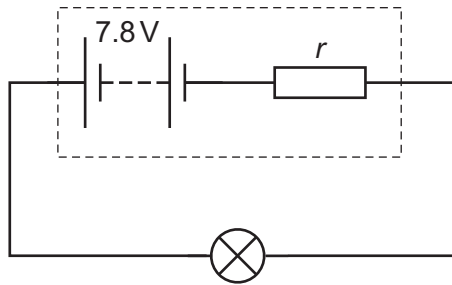


Fig. 6.1

A total charge of 750 C moves through the battery in a time interval of 1500 s . During this time the filament lamp dissipates 5.7 kJ of energy. The e.m.f. of the battery remains constant.

- (i) Explain, in terms of energy and without a calculation, why the potential difference across the lamp must be less than the e.m.f. of the battery.

.....
 [1]

- (ii) Calculate:

1. the current in the circuit

current = A [2]

2. the potential difference across the lamp

potential difference = V [2]

3. the internal resistance of the battery.

internal resistance = Ω [2]

(b) A student is provided with three resistors of resistances $90\ \Omega$, $45\ \Omega$ and $20\ \Omega$.

- (i) Sketch a circuit diagram showing how **two** of these three resistors may be connected together to give a combined resistance of $30\ \Omega$ between the terminals shown. Label the values of the resistances on your diagram.



[1]

- (ii) A potential divider circuit is produced by connecting the three resistors to a battery of e.m.f. 9.0 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 3.6 V . The circuit diagram is shown in Fig. 6.2.

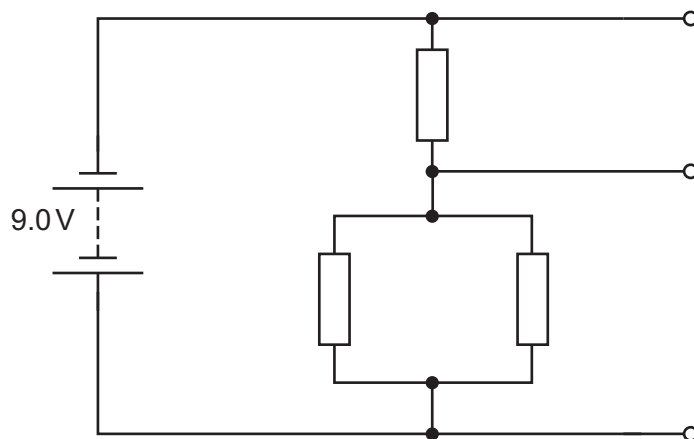


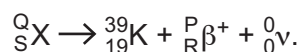
Fig. 6.2

On Fig. 6.2, label the resistances of all three resistors and the potential difference V_{OUT} .

[2]

[Total: 10]

- 7 (a) A nucleus of an element X decays by emitting a β^+ particle to produce a nucleus of potassium-39 (${}^{39}_{19}\text{K}$) and a neutrino. The decay is represented by



- (i) State the number represented by each of the following letters.

P

Q

R

S

[2]

- (ii) State the name of the interaction (force) that gives rise to β^+ decay.

..... [1]

- (b) A hadron is composed of three identical quarks and has a charge of $+2e$, where e is the elementary charge.

Determine a possible type (flavour) of the quarks.

Explain your working.

.....

..... [2]

[Total: 5]

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