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9702/21

October/November 2011

1 hour

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

DO **NOT** WRITE IN ANY BARCODES.

You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [] at the end of each question or part question.

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This document consists of **15** printed pages and **1** blank page.

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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
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 constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
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.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
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,	$W = \frac{1}{2} QV$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

For
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Use

- 1 (a) Define *density*.

.....
..... [1]

- (b) Explain how the difference in the densities of solids, liquids and gases may be related to the spacing of their molecules.

.....
.....
.....
..... [2]

- (c) A paving slab has a mass of 68 kg and dimensions 50 mm × 600 mm × 900 mm.

- (i) Calculate the density, in kg m^{-3} , of the material from which the paving slab is made.

density = ... kg m^{-3} [2]

- (ii) Calculate the maximum pressure a slab could exert on the ground when resting on one of its surfaces.

pressure = ... Pa [3]

- 2 (a) Define the *torque* of a couple.

.....
 [2]

- (b) A uniform rod of length 1.5 m and weight 2.4 N is shown in Fig. 2.1.

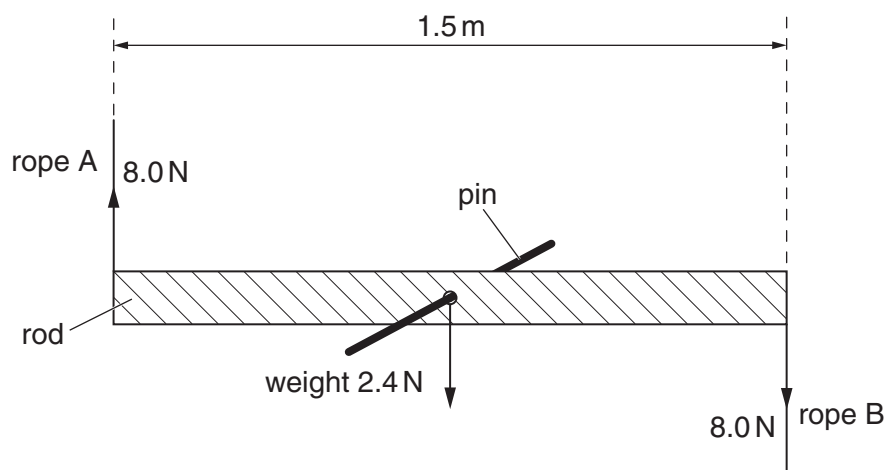


Fig. 2.1

The rod is supported on a pin passing through a hole in its centre. Ropes A and B provide equal and opposite forces of 8.0 N.

- (i) Calculate the torque on the rod produced by ropes A and B.

torque = ... Nm [1]

- (ii) Discuss, briefly, whether the rod is in equilibrium.

.....

 [2]

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- (c) The rod in (b) is removed from the pin and supported by ropes A and B, as shown in Fig. 2.2.

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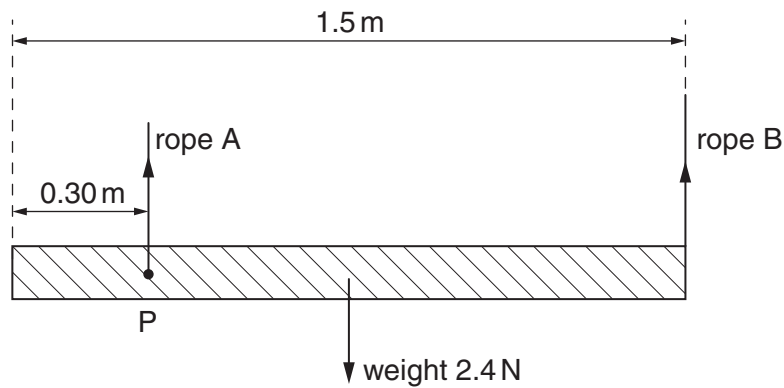


Fig. 2.2

Rope A is now at point P 0.30 m from one end of the rod and rope B is at the other end.

- (i) Calculate the tension in rope B.

tension in B = ... N [2]

- (ii) Calculate the tension in rope A.

tension in A = ... N [1]

- 3 A ball is thrown against a vertical wall. The path of the ball is shown in Fig. 3.1.

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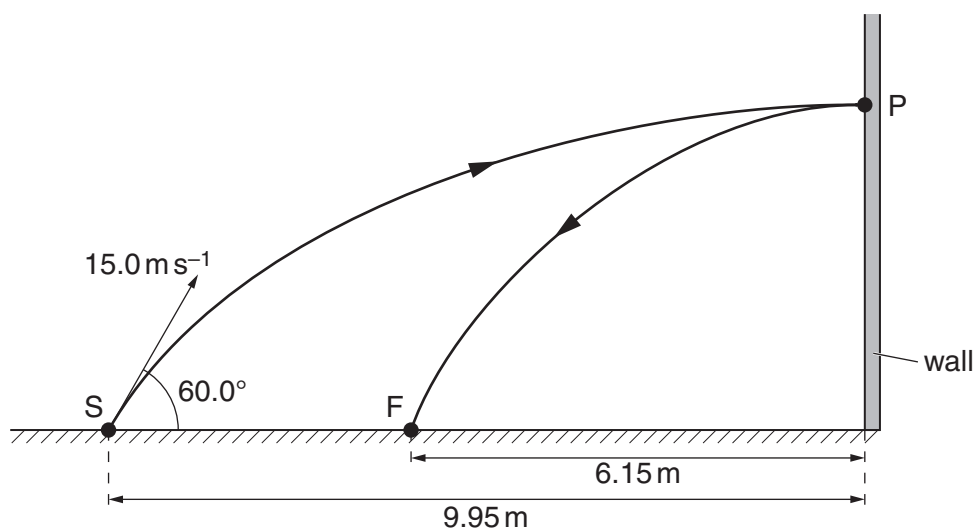


Fig. 3.1 (not to scale)

The ball is thrown from S with an initial velocity of 15.0 ms^{-1} at 60.0° to the horizontal. Assume that air resistance is negligible.

- (a) For the ball at S, calculate

- (i) its horizontal component of velocity,

horizontal component of velocity = ... ms^{-1} [1]

- (ii) its vertical component of velocity.

vertical component of velocity = ... ms^{-1} [1]

- (b) The horizontal distance from S to the wall is 9.95 m. The ball hits the wall at P with a velocity that is at right angles to the wall. The ball rebounds to a point F that is 6.15 m from the wall.

Using your answers in (a),

- (i) calculate the vertical height gained by the ball when it travels from S to P,

height = ... m [1]

- (ii) show that the time taken for the ball to travel from S to P is 1.33 s,

[1]

- (iii) show that the velocity of the ball immediately after rebounding from the wall is about 4.6 m s^{-1} .

[1]

- (c) The mass of the ball is $60 \times 10^{-3} \text{ kg}$.

- (i) Calculate the change in momentum of the ball as it rebounds from the wall.

change in momentum = ... N s [2]

- (ii) State and explain whether the collision is elastic or inelastic.

.....

 [1]

- 4 (a) Distinguish between *gravitational potential energy* and *electric potential energy*.

For
Examiner's
Use

.....

 [2]

- (b) A body of mass m moves vertically through a distance h near the Earth's surface. Use the defining equation for work done to derive an expression for the gravitational potential energy change of the body.

[2]

- (c) Water flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

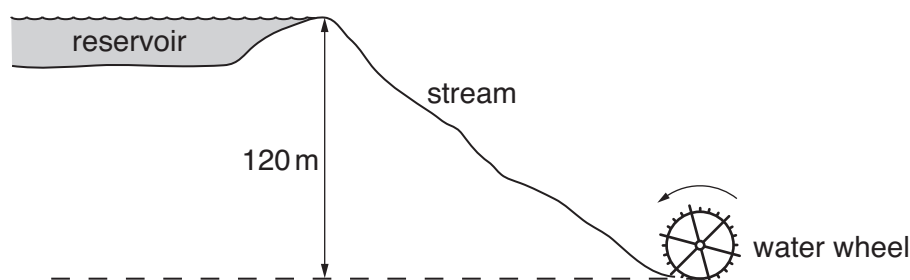


Fig. 4.1

As the water falls through a vertical height of 120 m, gravitational potential energy is converted to different forms of energy, including kinetic energy of the water. At the water wheel, the kinetic energy of the water is only 10% of its gravitational potential energy at the reservoir.

- (i) Show that the speed of the water as it reaches the wheel is 15 m s^{-1} .

[2]

- (ii) The rotating water wheel is used to produce 110 kW of electrical power. Calculate the mass of water flowing per second through the wheel, assuming that the production of electric energy from the kinetic energy of the water is 25% efficient.

*For
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Use*

mass of water per second = ... kg s^{-1} [3]

- 5 (a) Define the *ohm*.

..... [1]

- (b) Determine the SI base units of **resistivity**.

base units of resistivity = ... [3]

- (c) A cell of e.m.f. 2.0V and negligible internal resistance is connected to a variable resistor R and a metal wire, as shown in Fig. 5.1.

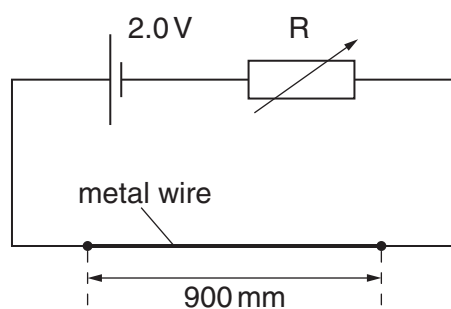


Fig. 5.1

The wire is 900mm long and has an area of cross-section of $1.3 \times 10^{-7} \text{ m}^2$. The resistance of the wire is 3.4Ω .

- (i) Calculate the resistivity of the metal wire.

resistivity = ... [2]

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- (ii) The resistance of R may be varied between 0 and $1500\ \Omega$.
Calculate the maximum potential difference (p.d.) and minimum p.d. possible across the wire.

For
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Use

maximum p.d. = ... V

minimum p.d. = ...V
[2]

- (iii) Calculate the power transformed in the wire when the potential difference across the wire is 2.0V.

power = ... W [2]

- (d) Resistance R in (c) is now replaced with a different variable resistor Q. State the power transformed in Q, for Q having

- (i) zero resistance,

power = ... W [1]

- (ii) infinite resistance.

power = ... W [1]

- 6 (a) State Hooke's law.

.....
 [1]

- (b) The variation with extension x of the force F for a spring A is shown in Fig. 6.1.

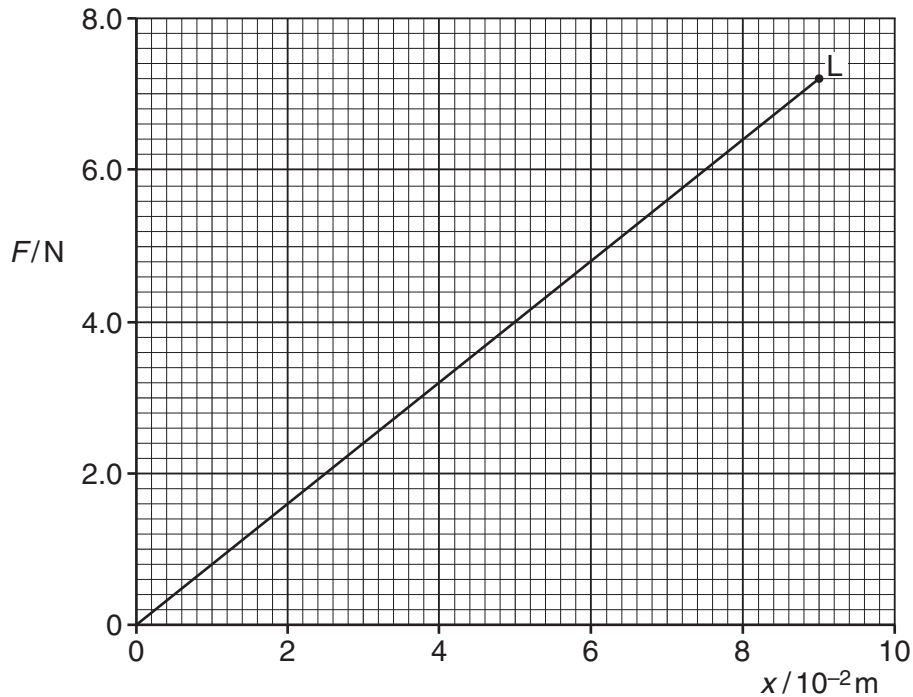


Fig. 6.1

The point L on the graph is the elastic limit of the spring.

- (i) Describe the meaning of *elastic limit*.

.....

 [1]

- (ii) Calculate the spring constant k_A for spring A.

$$k_A = \dots\dots\dots \text{Nm}^{-1} [1]$$

- (iii) Calculate the work done in extending the spring with a force of 6.4 N.

work done = ... J [2]

- (c) A second spring B of spring constant $2k_A$ is now joined to spring A, as shown in Fig. 6.2.

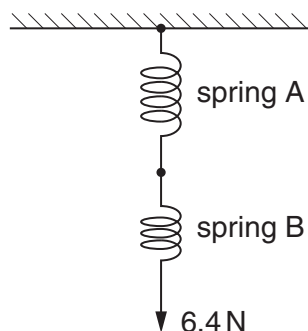


Fig. 6.2

A force of 6.4 N extends the combination of springs.

For the combination of springs, calculate

- (i) the total extension,

extension = ... m [1]

- (ii) the spring constant.

spring constant = ... Nm^{-1} [1]

- 7 (a) Two isotopes of the element uranium are $^{235}_{92}\text{U}$ and $^{238}_{92}\text{U}$.

Explain the term *isotope*.

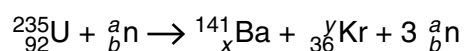
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 [2]

- (b) (i) In a nuclear reaction, proton number and neutron number are conserved. Other than proton number and neutron number, state a quantity that is conserved in a nuclear reaction.

..... [1]

- (ii) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.



State the values of a , b , x and y .

$a =$

$b =$

$x =$

$y =$

[3]

- (c) When the nucleus of $^{238}_{92}\text{U}$ absorbs a neutron, the nucleus decays, emitting an α -particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the α -particle.

proton number = ...

nucleon number = ...

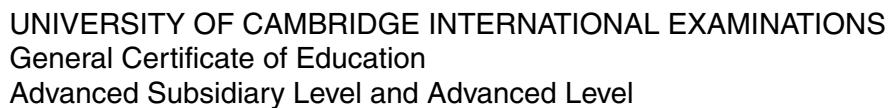
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9702/22

October/November 2011

1 hour

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

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- 1 The variation with time t of the displacement s for a car is shown in Fig. 1.1.

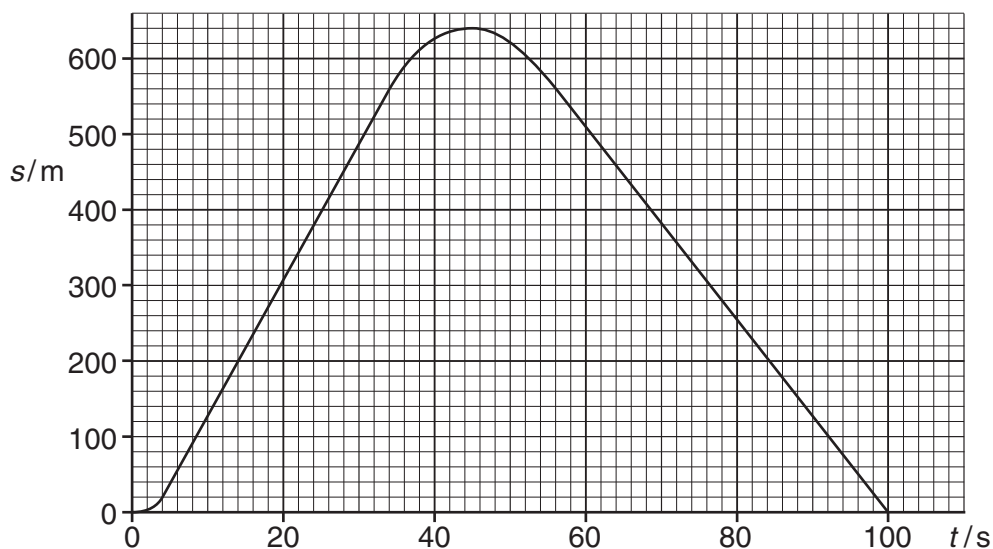


Fig. 1.1

- (a) Determine the magnitude of the average velocity between the times 5.0 s and 35.0 s.

average velocity = ... ms^{-1} [2]

- (b) On Fig. 1.2, sketch the variation with time t of the velocity v for the car.

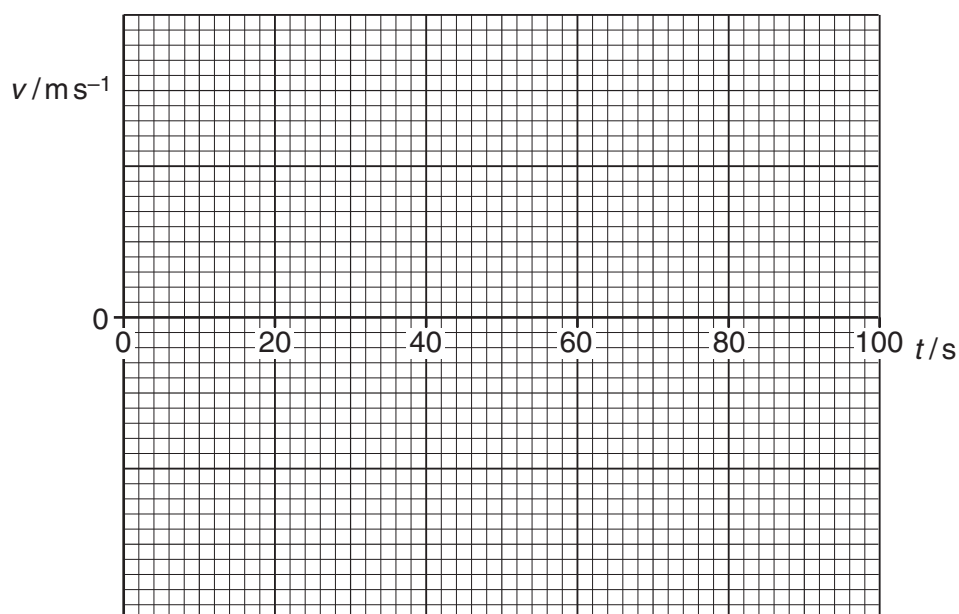


Fig. 1.2

[4]

2 (a) Define

(i) *force*,

.....
[1]

(ii) *work done*.

.....
[1]

(b) A force F acts on a mass m along a straight line for a distance s . The acceleration of the mass is a and the speed changes from an initial speed u to a final speed v .

(i) State the work W done by F .

[1]

(ii) Use your answer in (i) and an equation of motion to show that kinetic energy of a mass can be given by the expression

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

[3]

(c) A resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of 15 m s^{-1} to a final speed of 30 m s^{-1} .

(i) Calculate the distance moved by the car during this acceleration.

distance = ... m [2]

(ii) The same force is used to change the speed of the car from 30 m s^{-1} to 45 m s^{-1} . Explain why the distance moved is not the same as that calculated in (i).

.....

[1]

3 (a) Define

(i) *stress*,

.....
[1]

(ii) *strain*.

.....
[1]

(b) Explain the term *elastic limit*.

.....
[1]

(c) Explain the term *ultimate tensile stress*.

.....

[2]

(d) (i) A **ductile** material in the form of a wire is stretched up to its breaking point. On Fig. 3.1, sketch the variation with extension x of the stretching force F .



Fig. 3.1

[2]

- (ii) On Fig. 3.2, sketch the variation with x of F for a **brittle** material up to its breaking point.

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Use



Fig. 3.2

[1]

- (e) (i) Explain the features of the graphs in (d) that show the characteristics of ductile and brittle materials.

.....

.....

.....

.....

.....[2]

- (ii) The force F is removed from the materials in (d) just before the breaking point is reached. Describe the subsequent change in the extension for

1. the ductile material,

.....

.....[1]

2. the brittle material.

.....

.....[1]

- 4 (a) Define *electric field strength*.

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.....
..... [1]

- (b) Two horizontal metal plates are 20 mm apart in a vacuum. A potential difference of 1.5 kV is applied across the plates, as shown in Fig. 4.1.

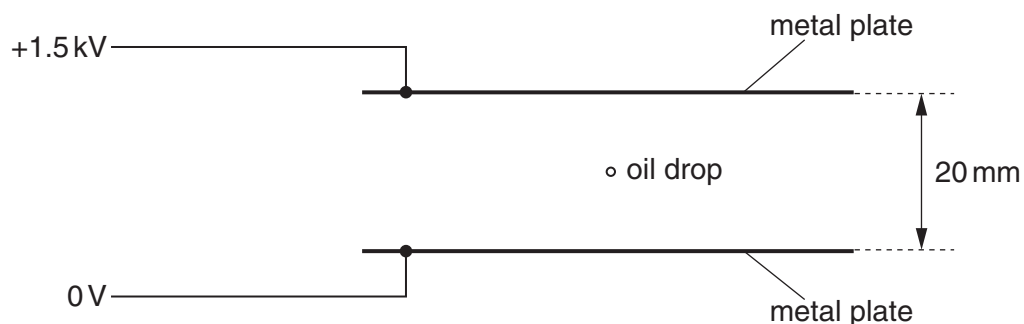


Fig. 4.1

A charged oil drop of mass $5.0 \times 10^{-15} \text{ kg}$ is held stationary by the electric field.

- (i) On Fig. 4.1, draw lines to represent the electric field between the plates. [2]
(ii) Calculate the electric field strength between the plates.

electric field strength = ... V m^{-1} [1]

- (iii) Calculate the charge on the drop.

charge = ... C [4]

- (iv) The potential of the upper plate is increased. Describe and explain the subsequent motion of the drop.

.....
.....
..... [2]

- 5 A potentiometer circuit that is used as a means of comparing potential differences is shown in Fig. 5.1.

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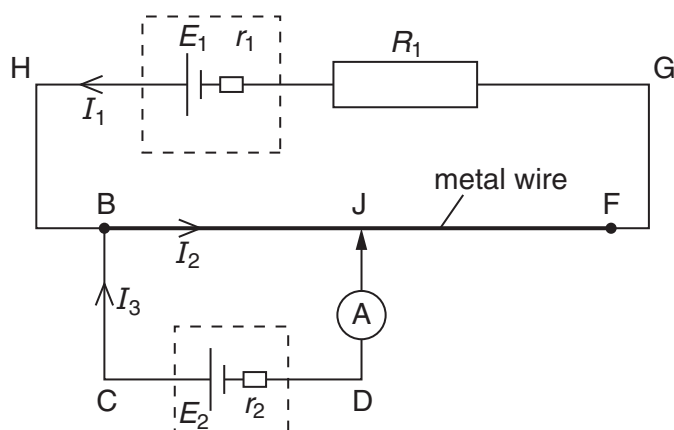


Fig. 5.1

A cell of e.m.f. E_1 and internal resistance r_1 is connected in series with a resistor of resistance R_1 and a uniform metal wire of total resistance R_2 . A second cell of e.m.f. E_2 and internal resistance r_2 is connected in series with a sensitive ammeter and is then connected across the wire at BJ. The connection at J is halfway along the wire. The current directions are shown on Fig. 5.1.

- (a) Use Kirchhoff's laws to obtain the relation

- (i) between the currents I_1 , I_2 and I_3 ,

.....[1]

- (ii) between E_1 , R_1 , R_2 , r_1 , I_1 and I_2 in loop HBJFGH,

.....[1]

- (iii) between E_1 , E_2 , r_1 , r_2 , R_1 , R_2 , I_1 and I_3 in the loop HBCDJFGH.

.....[2]

- (b) The connection at J is moved along the wire. Explain why the reading on the ammeter changes.

.....

[2]

- 6 (a) State the *principle of superposition*.

.....

.....

.....[2]

- (b) An arrangement that can be used to determine the speed of sound in air is shown in Fig. 6.1.

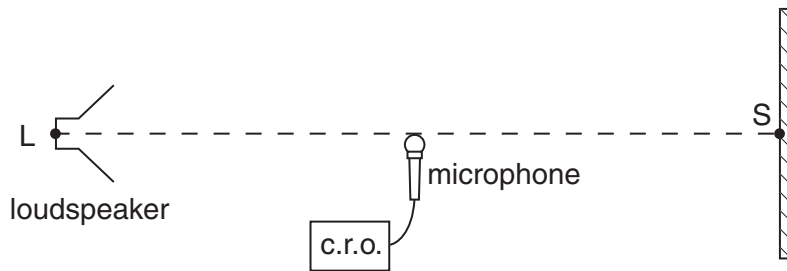


Fig. 6.1

Sound waves of constant frequency are emitted from the loudspeaker L and are reflected from a point S on a hard surface.

The loudspeaker is moved away from S until a stationary wave is produced.

Explain how sound waves from L give rise to a stationary wave between L and S.

.....

.....

.....[2]

- (c) A microphone connected to a cathode ray oscilloscope (c.r.o.) is positioned between L and S as shown in Fig. 6.1. The trace obtained on the c.r.o. is shown in Fig. 6.2.

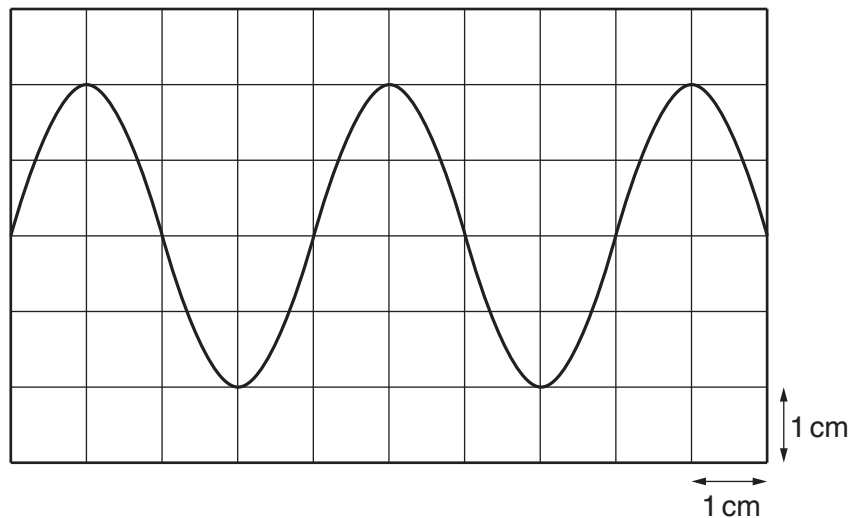


Fig. 6.2

The time-base setting on the c.r.o. is 0.10 ms cm^{-1} .

- (i) Calculate the frequency of the sound wave.

frequency = ... Hz [2]

- (ii) The microphone is now moved towards S along the line LS. When the microphone is moved 6.7 cm, the trace seen on the c.r.o. varies from a maximum amplitude to a minimum and then back to a maximum.

1. Use the properties of stationary waves to explain these changes in amplitude.

.....
.....
.....[1]

2. Calculate the speed of sound.

speed of sound = ... ms^{-1} [3]

Please turn over for Question 7.

7 (a) State the experimental observations that show radioactive decay is

(i) spontaneous,

.....
[1]

(ii) random.

.....
[1]

(b) On Fig. 7.1, complete the charge and mass of α -particles, β -particles and γ -radiation. Give example speeds of α -particles and γ -radiation emitted by a laboratory source.

	α -particle	β -particle	γ -radiation
charge			0
mass	4u		
speed		up to 0.99c	

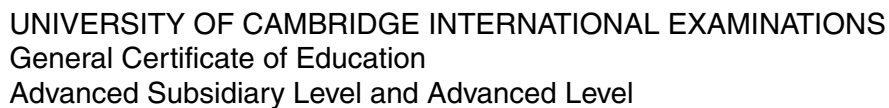
Fig. 7.1

[3]

(c) Explain the process by which α -particles lose energy when they pass through air.

.....

[2]



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9702/23

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velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
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,	$W = \frac{1}{2} QV$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

For
Examiner's
Use

- 1 (a) Distinguish between scalars and vectors.

.....
 [1]

- (b) Underline **all** the vector quantities in the list below.

acceleration kinetic energy momentum power weight [2]

- (c) A force of 7.5 N acts at 40° to the horizontal, as shown in Fig. 1.1.

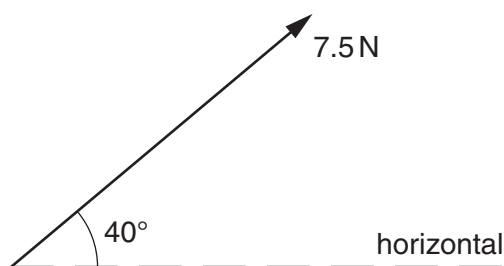


Fig. 1.1

Calculate the component of the force that acts

- (i) horizontally,

horizontal component = ... N [1]

- (ii) vertically.

vertical component = ... N [1]

- (d) Two strings support a load of weight 7.5 N, as shown in Fig. 1.2.

For
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Use

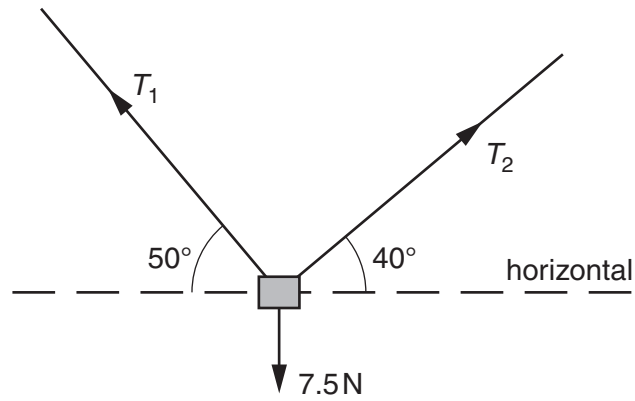


Fig. 1.2

One string has a tension T_1 and is at an angle 50° to the horizontal. The other string has a tension T_2 and is at an angle 40° to the horizontal. The object is in equilibrium. Determine the values of T_1 and T_2 by using a vector triangle or by resolving forces.

$$T_1 = \dots\dots\dots \text{ N}$$

$$T_2 = \dots\dots\dots \text{ N}$$

[4]

- 2 The variation with time t of velocity v of a car is shown in Fig. 2.1.

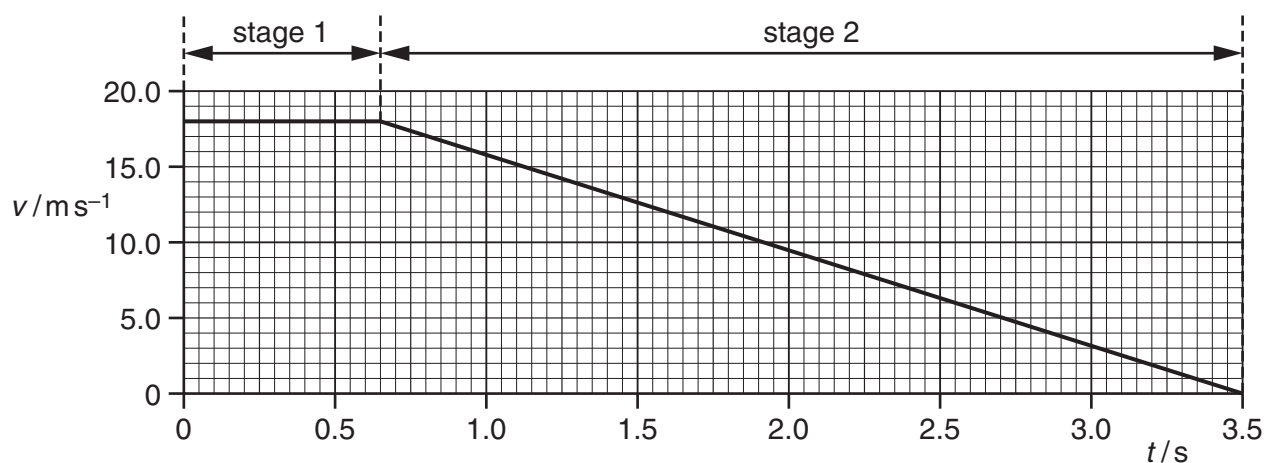


Fig. 2.1

At time $t = 0$, the driver sees an obstacle in the road. A short time later, the driver applies the brakes. The car travels in two stages, as shown in Fig. 2.1.

- (a) Use Fig. 2.1 to describe the velocity of the car in

1. stage 1,

.....
[1]

2. stage 2.

.....
[1]

- (b) (i) Calculate the distance travelled by the car from $t = 0$ to $t = 3.5$ s.

total distance = ... m [2]

- (ii) The car has a total mass of 1250 kg. Determine the total resistive force acting on the car in stage 2.

For
Examiner's
Use

force = ... N [3]

- (c) For safety reasons drivers are asked to travel at lower speeds. For each stage, describe and explain the effect on the distance travelled for the same car and driver travelling at half the initial speed shown in Fig. 2.1.

- (i) stage 1:

.....

 [1]

- (ii) stage 2:

.....

 [2]

3 (a) Define the terms

(i) *power*,

..... [1]

(ii) the *Young modulus*.

.....

.....

..... [1]

(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.

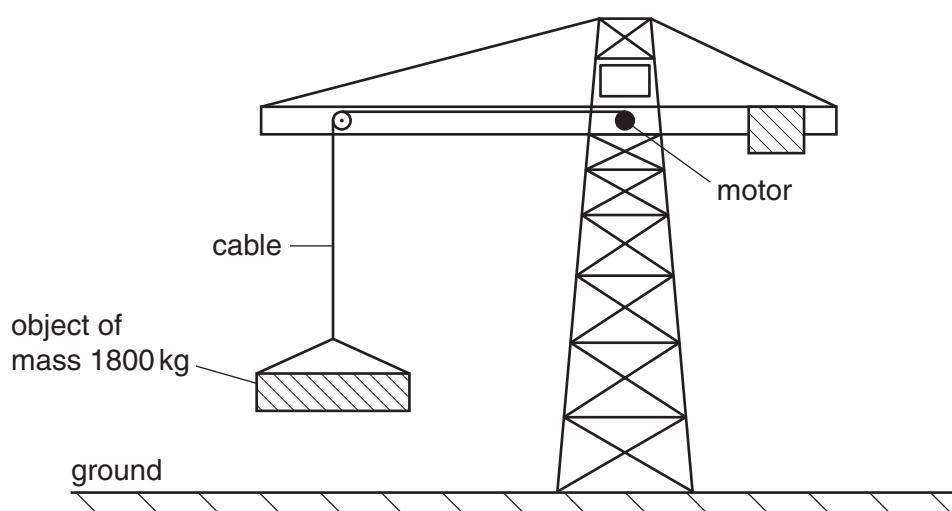


Fig. 3.1

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus 2.4×10^{11} Pa. The cross-sectional area of the cable is $1.3 \times 10^{-4} \text{ m}^2$. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

(i) 1. Use the Young Modulus of the steel to show that the tension in the cable is $3.1 \times 10^4 \text{ N}$.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

acceleration = ... ms^{-2} [3]

- (ii) The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ... N [1]

2. the gain in potential energy of the mass.

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

- (iii) The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of 0.55 m s^{-1} .

input power = ... W [3]

- 4 (a) Distinguish between *potential difference* (p.d.) and *electromotive force* (e.m.f.) in terms of energy transformations.

.....

 [2]

- (b) Two cells A and B are connected in series with a resistor R of resistance 5.5Ω , as shown in Fig. 4.1.

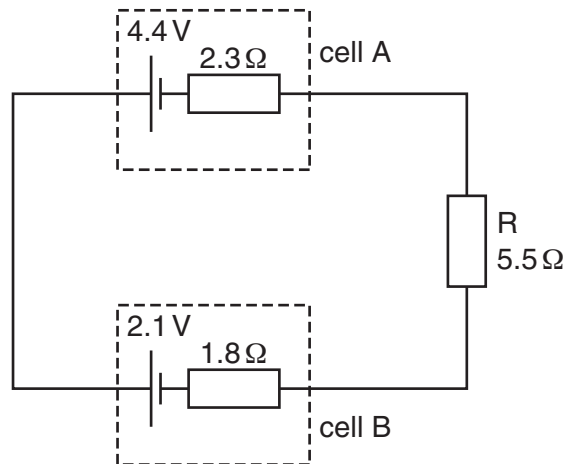


Fig. 4.1

Cell A has e.m.f. 4.4 V and internal resistance 2.3Ω . Cell B has e.m.f. 2.1 V and internal resistance 1.8Ω .

- (i) State Kirchhoff's second law.

.....
 [1]

- (ii) Calculate the current in the circuit.

current = ... A [2]

- (iii) On Fig. 4.1, draw an arrow to show the direction of the current in the circuit. Label this arrow *I*. [1]

(iv) Calculate

For
Examiner's
Use

1. the p.d. across resistor R,

p.d. = ... V [1]

2. the terminal p.d. across cell A,

p.d. = ... V [1]

3. the terminal p.d. across cell B.

p.d. = ... V [2]

- 5 (a) By reference to vibrations of the points on a wave and to its direction of energy transfer, distinguish between transverse waves and longitudinal waves.

.....

 [2]

- (b) Describe what is meant by a *polarised* wave.

.....

 [2]

- (c) The variation with distance x of the displacement y of a transverse wave is shown in Fig. 5.1.

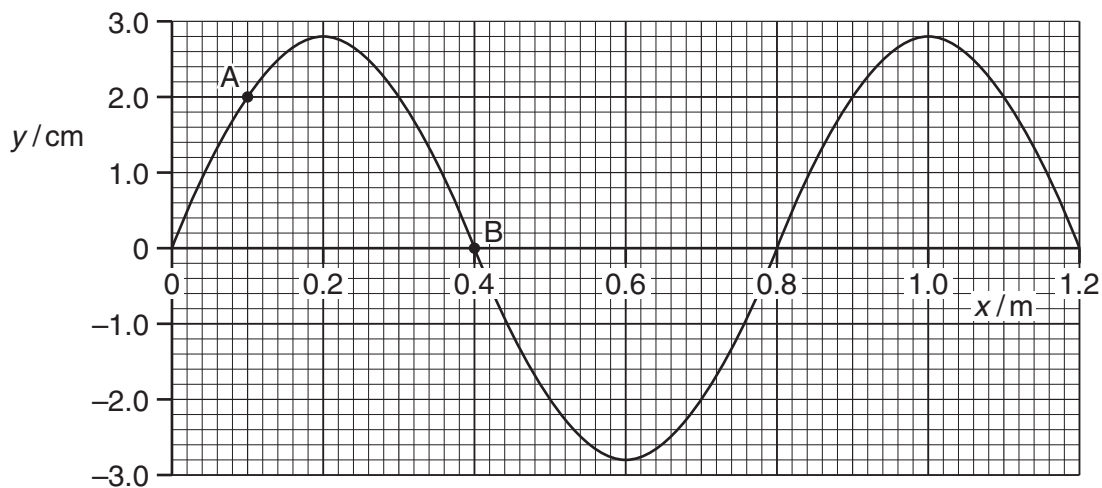


Fig. 5.1

- (i) Use Fig. 5.1 to determine

1. the amplitude of the wave,

amplitude = ... cm [1]

2. the phase difference between the points labelled A and B.

phase difference = ... [2]

- (ii) Determine the amplitude of a wave with twice the intensity of that shown in Fig. 5.1.

*For
Examiner's
Use*

amplitude = ... cm [1]

- 6 Two horizontal metal plates are separated by distance d in a vacuum. A potential difference V is applied across the plates, as shown in Fig. 6.1.

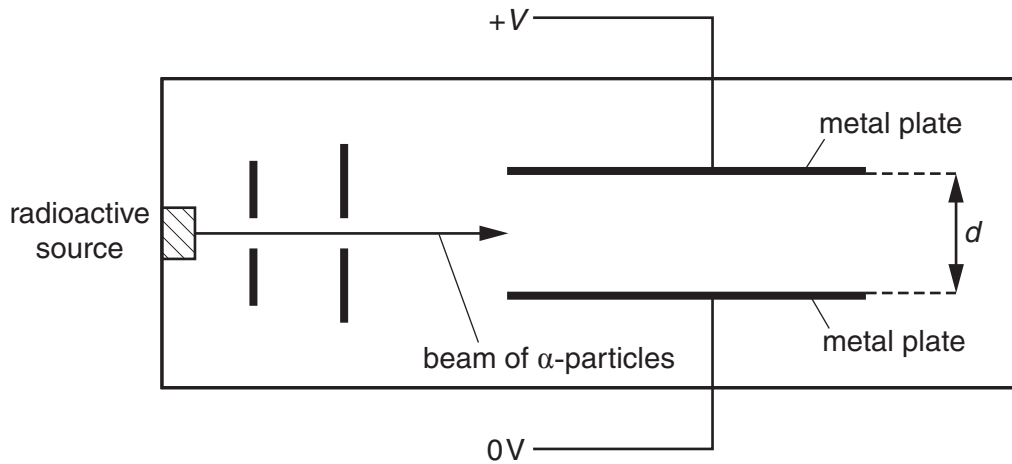


Fig. 6.1

A horizontal beam of α -particles from a radioactive source is made to pass between the plates.

- (a) State and explain the effect on the deflection of the α -particles for each of the following changes:

- (i) The magnitude of V is increased.

.....
 [1]

- (ii) The separation d of the plates is decreased.

.....
 [1]

- (b) The source of α -particles is replaced with a source of β -particles.
Compare, with a reason in each case, the effect of each of the following properties on the deflections of α - and β -particles in a uniform electric field:

(i) charge

.....

 [2]

(ii) mass

.....

 [2]

(iii) speed

.....

 [1]

- (c) The electric field gives rise to an acceleration of the α -particles and the β -particles.
Determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particles}}{\text{acceleration of the } \beta\text{-particles}} .$$

ratio = ... [3]

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