NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

PHYSICS 8867/01

Paper 1 Multiple Choice

25 September 2018

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **14** printed pages.

Data

speed of light in free space	c	$= 3.00 \times 10^{8}$ m s^{-1}
elementary charge	e	$= 1.60 \times 10^{-19}$ C
unified atomic mass constant	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton	m_p	$= 1.67 \times 10^{-27}$ kg
the Avogadro constant	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
gravitational constant	G	$= 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
resistors in series	R	$= R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$

1 Which of the following statements is not always true?

A The total mass of two 1 kg masses is 2 kg.

B The total charge of a +1 C charge and a –1 C charge is zero.

C The resultant of two 1 N forces is 2 N.

D The total energy of 1 J of kinetic energy and 1 J of potential energy is 2 J.

2 The following are the results obtained by two students P and Q in the determination of the mass of an object.

Student P	1.05 kg	0.96 kg	1.01 kg	0.97 kg
Student Q	1.08 kg	1.07 kg	1.08 kg	1.06 kg

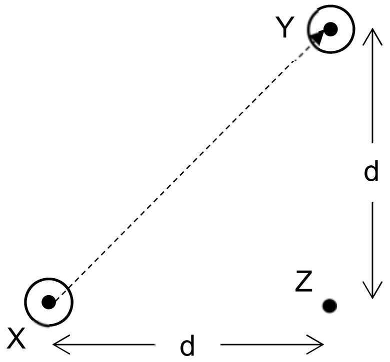
Which of the following most appropriately describes the results obtained by students P and Q?

	more accurate	more precise
A	Q	*cannot be determined*
B	P	Q
C	Q	P
D	*cannot be determined*	Q

3 Capacitance is defined as the ratio of charge stored in a capacitor to the potential difference across it. The S.I. unit for capacitance is the farad (F). Which of the following is not equivalent to F?

A $C\ V^{-1}$ **B** $C^2\ J^{-1}$ **C** $J\ V^{-2}$ **D** $A^2\ kg^{-1}\ m^{-2}$

4 A long wire that is carrying a constant current directed out of the page is moved from point X to point Y, as shown below.



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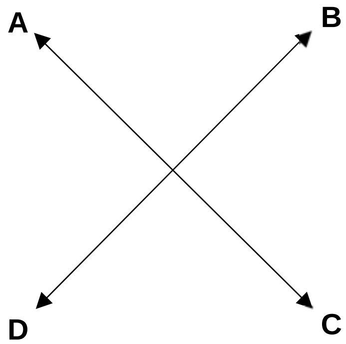
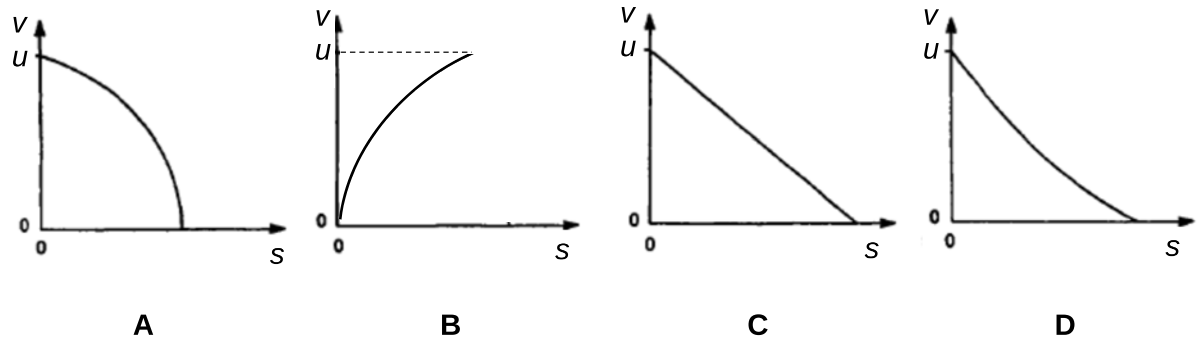


5 A train initially at rest accelerates at a constant rate of 1.4 m s^{-2} for 10 s and then slows down at a constant rate of 0.20 m s^{-2} until it comes to a rest. The total distance travelled by the train is

A 80 m **B** 220 m **C** 560 m **D** 1120 m

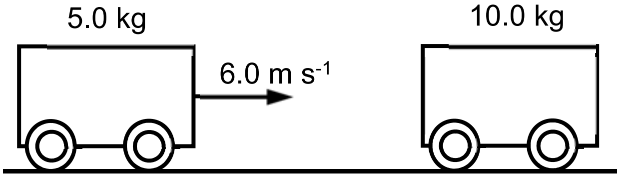
6 A falling stone strikes some soft ground at speed *u* and suffers a constant deceleration until it stops. Which one of the following graphs best represents the variation of the stone's speed, *v*, with distance, *s*, measured downwards, from the surface of the ground?



7 A pigeon is flying horizontally with a speed of 15 m s^{-1} and at an altitude of 12 m above the ground when it drops a seed. Neglecting air resistance and assuming that the pigeon does not change its course, speed or altitude, how far from the pigeon is the seed when it hits the ground?

A 12 m **B** 23 m **C** 26 m **D** 37 m

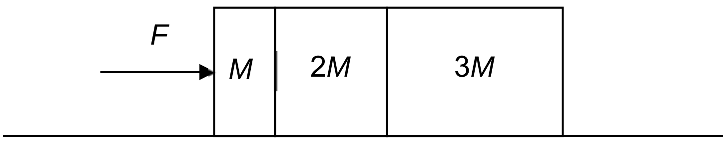
8 A trolley of mass 5.0 kg travelling at a speed of 6.0 m s^{-1} collides head-on and locks together with another trolley of mass 10.0 kg which is initially at rest. The collision lasts for 0.20 s.



What is the total kinetic energy of the two trolleys after the collision and the average force acting on each trolley during this collision?

	Total kinetic energy after the collision / J	Average force on each trolley / N
A	30	150
B	75	150
C	30	100
D	75	100

9 Three blocks with masses *M*, 2*M* and 3*M* are pushed along a rough surface by a horizontal force *F* as shown.



The frictional force between a block and the rough surface is directly proportional to the weight of the block. Given that the frictional force between the block with mass *M* and the rough surface is *f*, what is the magnitude of the force mass 3*M* exerts on mass 2*M*?

A $\frac{F}{2}$

B $\frac{F}{2}+3f$

C $\frac{F}{3}+f$

D $\frac{F}{3}+3f$

10 A man of mass *M* is standing on a weighing scale in an elevator. The motion of the elevator undergoes several stages of motions as described below.

Stage of motion of elevator	**Weighing scale reading**
Moving downward with increasing speed	N_1
Moving downward with constant speed	N_2
Moving downward with decreasing speed	N_3

Which of the following is correct?

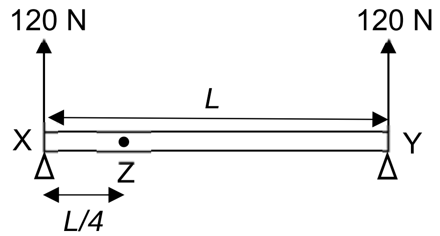
A $N_1 = N_2 = N_3$

B $N_1 = N_3 < N_2$

C $N_1 < N_2 < N_3$

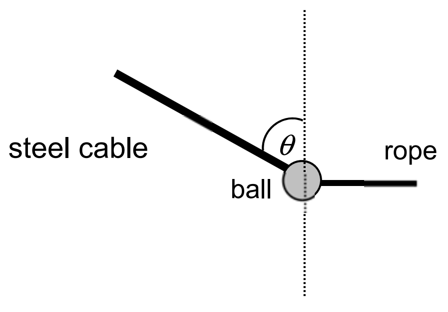
D $N_3 < N_2 < N_1$

11 A uniform plank of length *L* is supported by initially equal forces of 120 N at X and Y. If the force at X is now moved to Z such that the plank is kept horizontal, what is the magnitude of the force at Y?



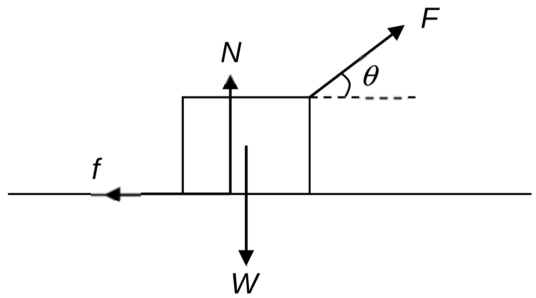
A 60 N **B** 80 N **C** 120 N **D** 160 N

12 A massive iron ball of mass 200 kg is hung from a steel cable with an angle θ to the vertical. It is held back by a horizontal rope. If the rope cannot safely tolerate a tension of more than 1000 N, what is the maximum value of θ for the steel supporting cable?



A 11° **B** 27° **C** 63° **D** 79°

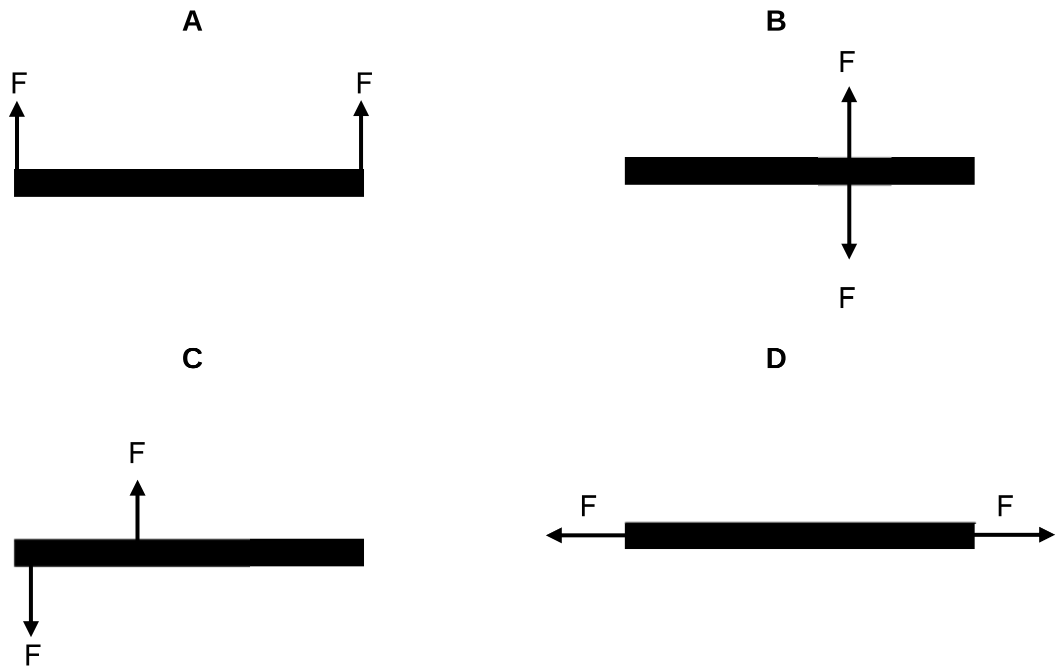
13 A box on a rough horizontal surface is *just* about to move when subjected to a force F applied at an angle θ to the horizontal as shown in the figure below.



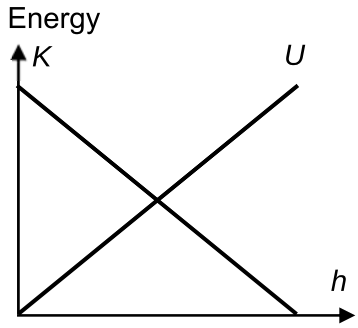
If the frictional force between the box and the surface is f, the weight of the box is W and the normal contact force is N, which of the following are the correct equations for forces considered in the vertical and horizontal directions?

	Vertical	**Horizontal**
A	$N + F\sin\theta = W$	$F\cos\theta = f$
B	$N = W$	$F\cos\theta = f$
C	$N = W$	$F\sin\theta = f$
D	$N + F\cos\theta = W$	$F\sin\theta = f$

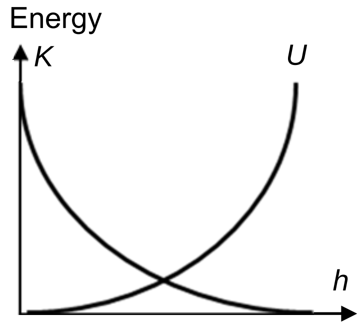
14 In which situation could the pair of forces applied to the rigid object produce a couple?



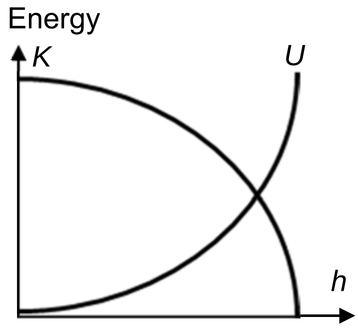
15 A ball is projected vertically upwards. At a height h, the kinetic energy of the ball is K and its potential energy is U. Taking air resistance to be negligible, which graph correctly shows the variations of K and U with h?



A



B



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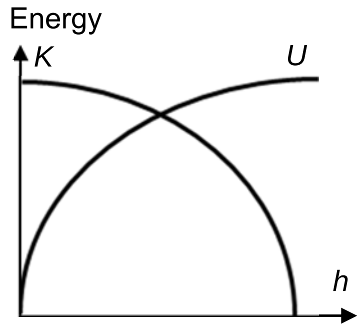


D

16 The engine of a car has maximum output power of 54 kW. The air resistance acting on the car when it is moving with speed v is cv^2, where c is 2.0 kg m^{-1}. What is the maximum speed that can be achieved by the car on level road?

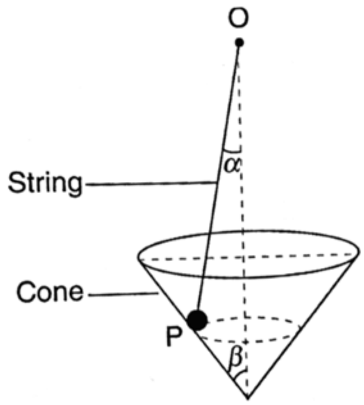
A 3.0 m s^{-1} **B** 5.0 m s^{-1} **C** 30 m s^{-1} **D** 160 m s^{-1}

17 A wire is stretched elastically by a force of 200 N, causing an extension of 4.00 mm. The force is then steadily increased to 250 N such that the wire still behaves elastically.

How much extra work is done in producing the additional extension?

A 0.225 J **B** 0.250 J **C** 225 J **D** 250 J

18 A pendulum bob at the end of the string which is fixed at O moves in a horizontal circle on the inside of a cone as shown.



If the tension in the string is T and the normal contact force by the cone is R, which of the following gives the centripetal force on the bob?

A $T \sin \alpha + R \cos \beta$

B $T \sin \alpha - R \cos \beta$

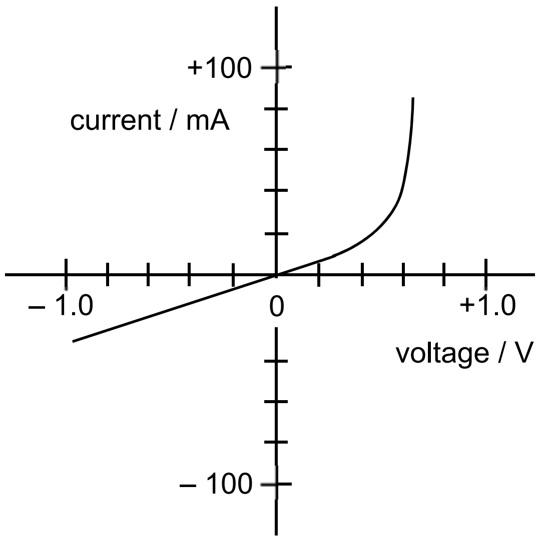
C $T \cos \alpha + R \sin \beta$

D $T \cos \alpha - R \sin \beta$

19 A geostationary satellite orbits at an altitude of 35800 km above the surface of the Earth. Given that the radius of the Earth is 6400 km, what are its angular speed and centripetal acceleration?

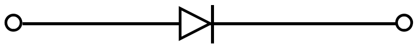
	angular speed / rad s^{-1}	centripetal acceleration / m s^{-2}
A	7.27×10^{-5}	1.89×10^{-1}
B	7.27×10^{-5}	2.23×10^{-1}
C	1.75×10^{-3}	1.09×10^{2}
D	4.36×10^{-3}	8.03×10^{2}

20 A student is given a sealed box containing a concealed electrical circuit. The student plots the current-voltage characteristics below.

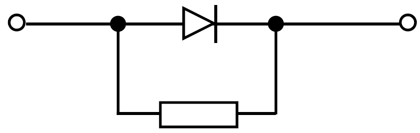


Which circuit is most likely to be enclosed within the box?

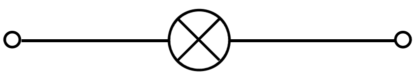
A



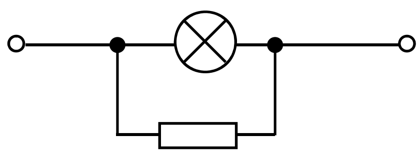
B



C



D



21 The terminal p.d. of a battery is observed to change when the battery supplies a current to an external resistor.

Which pair of quantities are needed to calculate the change in p.d.?

A the battery's e.m.f. and its internal resistance

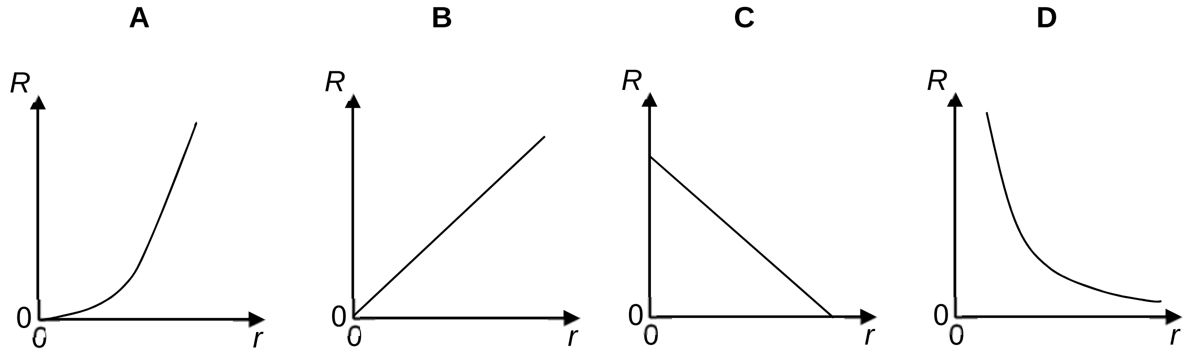
B the battery's e.m.f. and the current

C the current and the external resistance

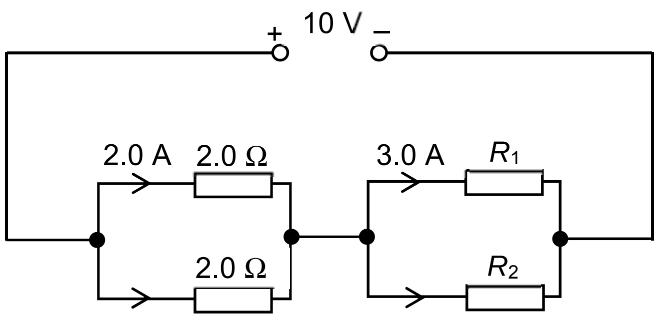
D the current and the internal resistance of the battery

22 A number of wires of the same material have the same length but different radii.

Which graph shows the variation with radius r of resistance R of the wires?



23 A circuit containing four resistors is connected across a 10 V supply as shown.



What are the resistances R_1 and R_2?

	R_1	R_2
A	1.0 Ω	3.0 Ω
B	2.0 Ω	2.0 Ω
C	2.0 Ω	6.0 Ω
D	3.0 Ω	3.0 Ω

24 Which combination of 12 Ω resistors will give an overall resistance of 42 Ω?

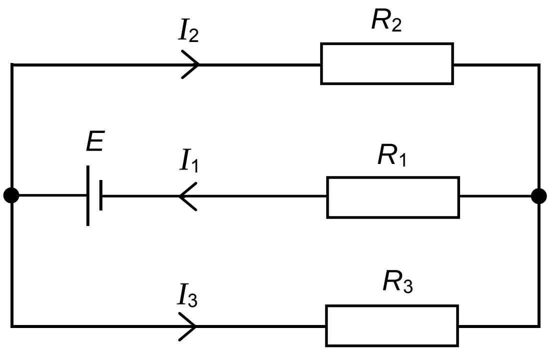
A two in series connected in series with two in parallel

B two in series connected in series with three in parallel

C three in series connected in series with two in parallel

D three in series connected in series with three in parallel

25 A cell of e.m.f. E and negligible internal resistance is connected in a circuit causing currents I_1. I_2 and I_3 in the three resistors of resistance R_1, R_2 and R_3 respectively.



Which equation relating to this circuit is correct?

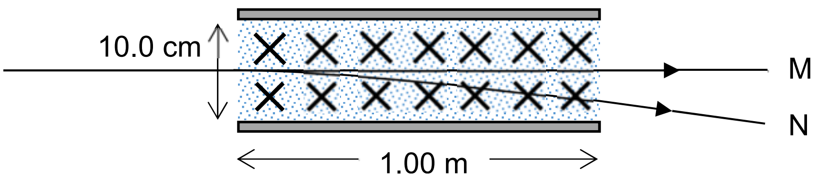
A $E + I_3R_3 = I_1R_1$

B $E - I_2R_2 = I_1R_1$

C $E + I_1R_1 = I_1R_2R_3 / (R_2 + R_3)$

D $E - I_1R_1 = I_2R_2 + I_3R_3$

26 In the region of dimensions 10.0 cm by 1.00 m between two charged plates with a p.d. of 100 V, there is a uniform magnetic field of strength 100 mT directed into the page.



M and N are the paths made by electrons of different speeds.

Which of the following correctly describes the speed of the electron that made N?

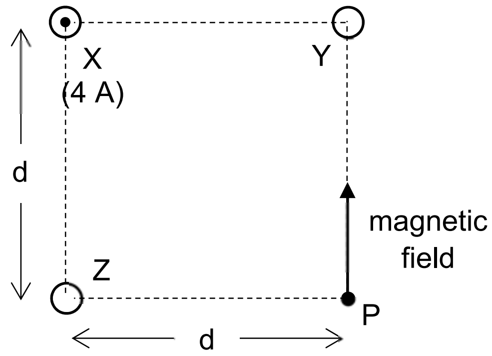
A slightly smaller than 1.00×10^4 m s^{-1}

B slightly greater than 1.00×10^4 m s^{-1}

C slightly smaller than 1.00×10^5 m s^{-1}

D slightly greater than 1.00×10^5 m s^{-1}

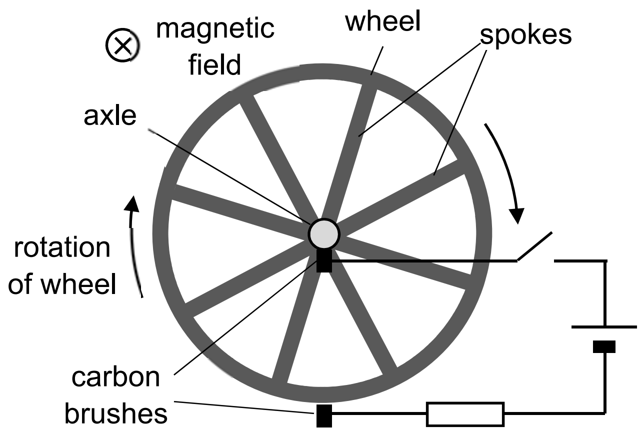
27 Three current carrying conductors X, Y and Z are arranged as shown below. The current in X is directed out of the page. The resultant magnetic field due to the three conductors at P is directed towards Y.



Which of the following correctly states the direction of the currents in Y and Z?

	Y	Z
A	into page	out of page
B	out of page	out of page
C	into page	into page
D	out of page	into page

28 A copper wheel with eight spokes is placed in a uniform magnetic field that is directed into the page. The rim and axle of the wheel is connected to an electrical circuit as shown below. The wheel is initially rotating about its axle at a constant angular speed with the switch open.



What is likely to happen to the rotation of the wheel when the switch is closed?

A Rotation will slow down.

B Rotation will speed up.

C Rotation will slow down then speed up cyclically.

D Rotation will not be affected.

29 Two radioactive isotopes P and Q have half-lives of 10 minutes and 15 minutes respectively. A sample initially contains the same number of atoms of each isotope. After 30 minutes, the ratio of the number of atoms of P to the number of atoms of Q will be

A 0.25 **B** 0.50 **C** 1.0 **D** 2.0

30 Some data are provided below:

mass of proton = 1.6726×10^{-27} kg

mass of neutron = 1.6750×10^{-27} kg

mass of $^{58}_{28}\mathrm{Ni}$ nuclide = 9.6178×10^{-26} kg

What is the binding energy of $^{58}_{28}\mathrm{Ni}$?

A 9.05×10^{-28} J **B** 2.71×10^{-19} J **C** 8.13×10^{-11} J **D** 8.66×10^{-9} J

End of Paper

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1 Which of the following statements is not always true?

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B The total charge of a +1 C charge and a –1 C charge is zero.

C The resultant of two 1 N forces is 2 N.

D The total energy of 1 J of kinetic energy and 1 J of potential energy is 2 J.

Vector addition takes into consideration direction.

2 The following are the results obtained by two students P and Q in the determination of the mass of an object.

Student P	1.05 kg	0.96 kg	1.01 kg	0.97 kg
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Which of the following most appropriately describes the results obtained by students P and Q?

	more accurate	more precise
A	Q	*cannot be determined*
B	P	Q
C	Q	P
D	*cannot be determined*	Q

True value is not known.

3 Capacitance is defined as the ratio of charge stored in a capacitor to the potential difference across it. The S.I. unit for capacitance is the farad (F). Which of the following is not equivalent to F?

A $C\ V^{-1}$ **B** $C^2\ J^{-1}$ **C** $J\ V^{-2}$ **D** $A^2\ kg^{-1}\ m^{-2}$

$[C] = [Q]/[V]$ → $F = C\ V^{-1} = A\ s\ (J\ C^{-1})^{-1} = A\ s\ (kg\ m^2\ s^{-2}\ A^{-1}\ s^{-1})^{-1} = A^2\ s^4\ kg^{-1}\ m^{-2}$

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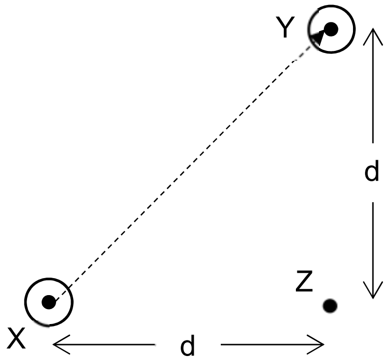

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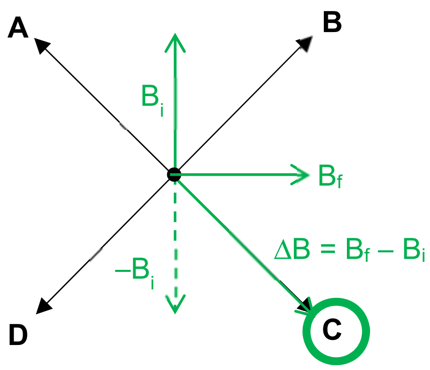

Ans: C

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A 80 m **B** 220 m **C** 560 m **D** 1120 m

$$s_1 = ut + \frac{1}{2}at^2 = \frac{1}{2}\times 1.4\times 10^2 = 70$$

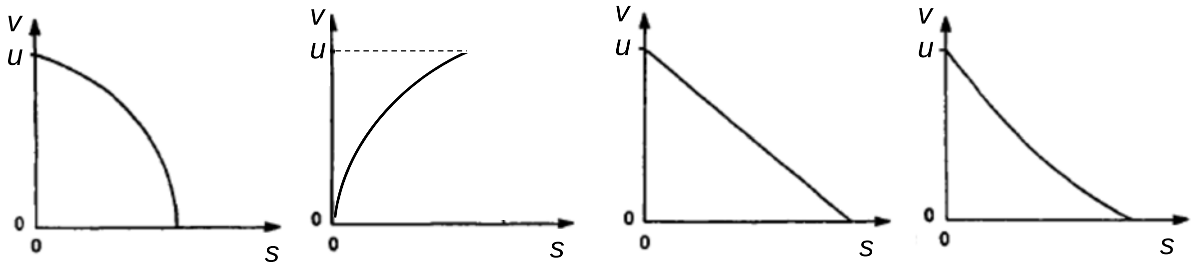
$$v = u + at = 1.4\times 10 = 14$$

$$v^2 = u^2 + 2as$$

$$s_2 = \frac{u^2}{2a} = \frac{14^2}{2\times 0.2} = 490$$

$$s = s_1 + s_2 = 70 + 490 = 560 \text{ m}$$

6 A falling stone strikes some soft ground at speed u and suffers a constant deceleration until it stops. Which one of the following graphs best represents the variation of the stone's speed, v, with distance, s, measured downwards, from the surface of the ground?



A B C D

$v^2 = u^2 + 2as$ where a is negative.

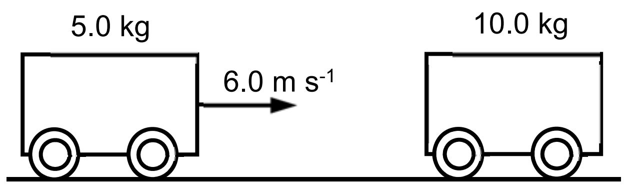
$$\frac{dv}{ds} = \frac{dv}{dt} \times \frac{dt}{ds} = \frac{a}{v}$$

As v decrease, gradient of v-s graph becomes increasingly negative.

7 A pigeon is flying horizontally with a speed of 15 m s^{-1} and at an altitude of 12 m above the ground when it drops a seed. Neglecting air resistance and assuming that the pigeon does not change its course, speed or altitude, how far from the pigeon is the seed when it hits the ground?

A 12 m **B** 23 m **C** 26 m **D** 37 m

8 A trolley of mass 5.0 kg travelling at a speed of 6.0 m s^{-1} collides head-on and locks together with another trolley of mass 10.0 kg which is initially at rest. The collision lasts for 0.20 s.

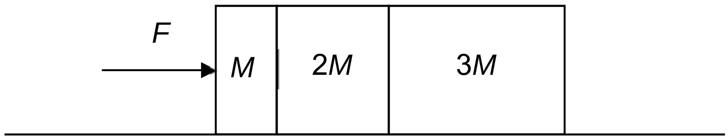


What is the total kinetic energy of the two trolleys after the collision and the average force acting on each trolley during this collision?

	Total kinetic energy after the collision / J	Average force on each trolley / N
A	30	150
B	75	150
C	30	100
D	75	100

Applying conservation of linear momentum, the speed after the collision is 2.0 m s^{-1}.
Hence, the total kinetic energy after the collision is ½ m_{total} v^2 = ½ x 15 x 2.0^2 = 30 J.
The force on either trolley is $\Delta p/\Delta t$ = 20/0.20 = 100 N.

9 Three blocks with masses *M*, 2*M* and 3*M* are pushed along a rough surface by a horizontal force *F* as shown.



The frictional force between a block and the rough surface is directly proportional to the weight of the block. Given that the frictional force between the block with mass *M* and the rough surface is *f*, what is the magnitude of the force mass 3*M* exerts on mass 2*M*?

A $\frac{F}{2}$

B $\frac{F}{2}+3f$

C $\frac{F}{3}+f$

D $\frac{F}{3}+3f$

Consider the whole system,
$F-6f=6Ma$

$$a=\frac{F-6f}{6M}$$

Let the force that 3M acts on 2M be F_1.
Consider Newton's 2nd law on 3M,
$F_1-3f=3Ma$

$$F_1=3M\left(\frac{F-6f}{6M}\right)+3f=\frac{F}{2}$$

10 A man of mass *M* is standing on a weighing scale in an elevator. The motion of the elevator undergoes several stages of motions as described below.

Stage of motion of elevator	Weighing scale reading
Moving downward with increasing speed	N_1
Moving downward with constant speed	N_2
Moving downward with decreasing speed	N_3

Which of the following is correct?

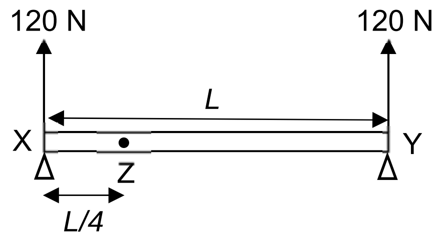
A $N_1 = N_2 = N_3$

B $N_1 = N_3 < N_2$

C $N_1 < N_2 < N_3$

D $N_3 < N_2 < N_1$

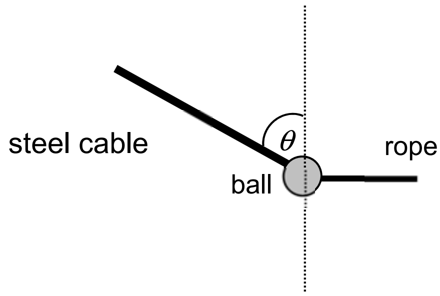
11 A uniform plank of length L is supported by initially equal forces of 120 N at X and Y. If the force at X is now moved to Z such that the plank is kept horizontal, what is the magnitude of the force at Y?



A 60 N **B** 80 N **C** 120 N **D** 160 N

Weight of plank is 240 N acting through the centre.
When force is moved to point Z, taking moment about point Z,
240 x L/4 = Force at Y x 3L/4
Force at Y = 80 N

12 A massive iron ball of mass 200 kg is hung from a steel cable with an angle θ to the vertical. It is held back by a horizontal rope. If the rope cannot safely tolerate a tension of more than 1000 N, what is the maximum value of θ for the steel supporting cable?



A 11° **B** 27° **C** 63° **D** 79°

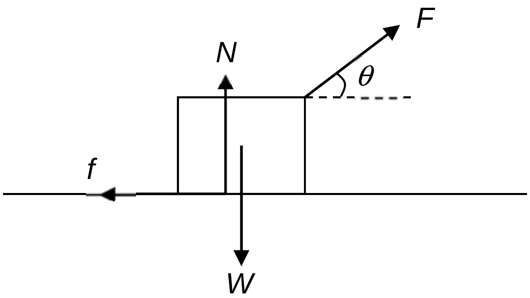
Let tension in steel cable be T_s, tension in rope be T_r.

$T_s \cos \theta = mg$

$T_s \sin \theta = T_r$

$\theta = \tan^{-1} (T_r/mg) = \tan^{-1} (1000/200\text{x}9.81) = 27°$

13 A box on a rough horizontal surface is *just* about to move when subjected to a force F applied at an angle θ to the horizontal as shown in the figure below.



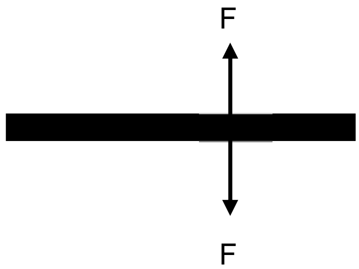
If the frictional force between the box and the surface is f, the weight of the box is W and the normal contact force is N, which of the following are the correct equations for forces considered in the vertical and horizontal directions?

	Vertical	**Horizontal**
A	$N + F \sin \theta = W$	$F \cos\theta = f$
B	$N = W$	$F \cos\theta = f$
C	$N = W$	$F \sin\theta = f$
D	$N + F \cos \theta = W$	$F \sin\theta = f$

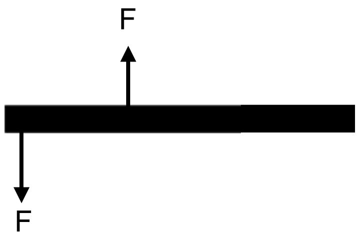
14 In which situation could the pair of forces applied to the rigid object produce a couple?

A

B

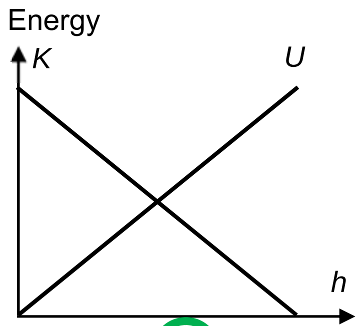


C

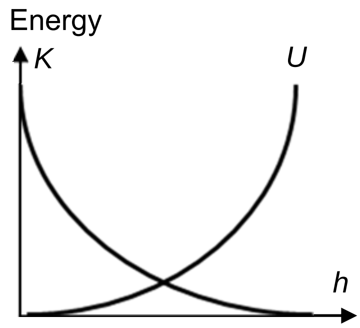


D

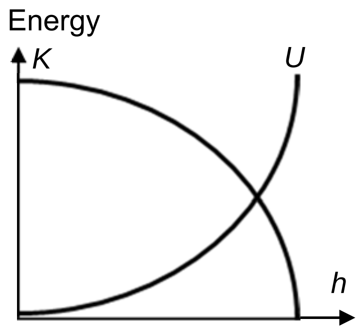
15 A ball is projected vertically upwards. At a height *h*, the kinetic energy of the ball is *K* and its potential energy is *U*. Taking air resistance to be negligible, which graph correctly shows the variations of *K* and *U* with *h*?



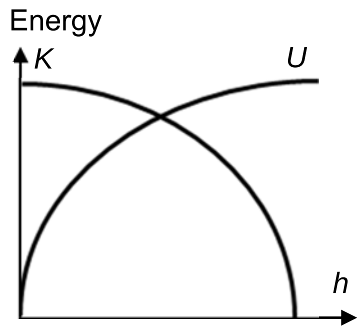
A



B



C



D

U = m g h → U varies linearly with h.

K + U = Total energy (constant)

16 The engine of a car has maximum output power of 54 kW. The air resistance acting on the car when it is moving with speed *v* is cv^2, where *c* is 2.0 kg m^{-1}. What is the maximum speed that can be achieved by the car on level road?

A 3.0 m s^{-1} **B** 5.0 m s^{-1} **C** 30 m s^{-1} **D** 160 m s^{-1}

At max speed, rate of work done against air resistance = 54×10^3 W

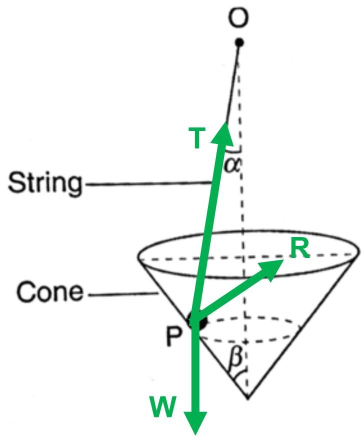
$F\,v = cv^2 \times v = 54\times10^3$ → $v = 30$ m s^{-1}

17 A wire is stretched elastically by a force of 200 N, causing an extension of 4.00 mm. The force is then steadily increased to 250 N such that the wire still behaves elastically.

How much extra work is done in producing the additional extension?

A 0.225 J **B** 0.250 J **C** 225 J **D** 250 J

18 A pendulum bob at the end of the string which is fixed at O moves in a horizontal circle on the inside of a cone as shown.



If the tension in the string is T and the normal contact force by the cone is R, which of the following gives the centripetal force on the bob?

A $T \sin\alpha + R \cos\beta$

B $T \sin\alpha - R \cos\beta$

C $T \cos\alpha + R \sin\beta$

D $T \cos\alpha - R \sin\beta$

19 A geostationary satellite orbits at an altitude of 35800 km above the surface of the Earth. Given that the radius of the Earth is 6400 km, what are its angular speed and centripetal acceleration?

	angular speed / rad s^{-1}	centripetal acceleration / m s^{-2}
A	7.27×10^{-5}	1.89×10^{-1}
B	7.27×10^{-5}	2.23×10^{-1}
C	1.75×10^{-3}	1.09×10^{2}
D	4.36×10^{-3}	8.03×10^{2}

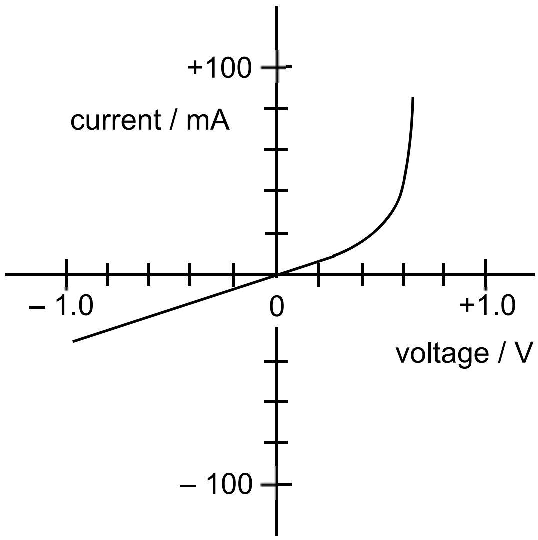
Ans: B

$T = 24 \times 60 \times 60 = 8.64\times10^4$ s

$\omega = 2\pi / T = 7.27\times10^{-5}$ rad s^{-1}

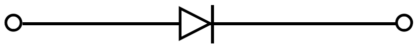
$a = r\,\omega^2 = (35800 + 6400)\times10^3 \times (7.27\times10^{-5})^2 = 0.223$ m s^{-2}

20 A student is given a sealed box containing a concealed electrical circuit. The student plots the current-voltage characteristics below.

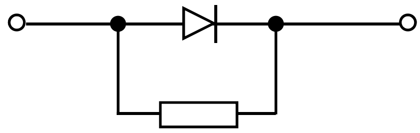


Which circuit is most likely to be enclosed within the box?

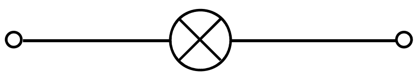
A



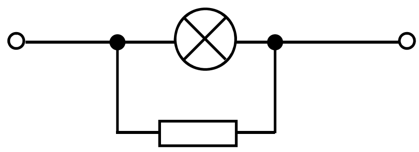
B



C



D



21 The terminal p.d. of a battery is observed to change when the battery supplies a current to an external resistor.

Which pair of quantities are needed to calculate the change in p.d.?

A the battery's e.m.f. and its internal resistance

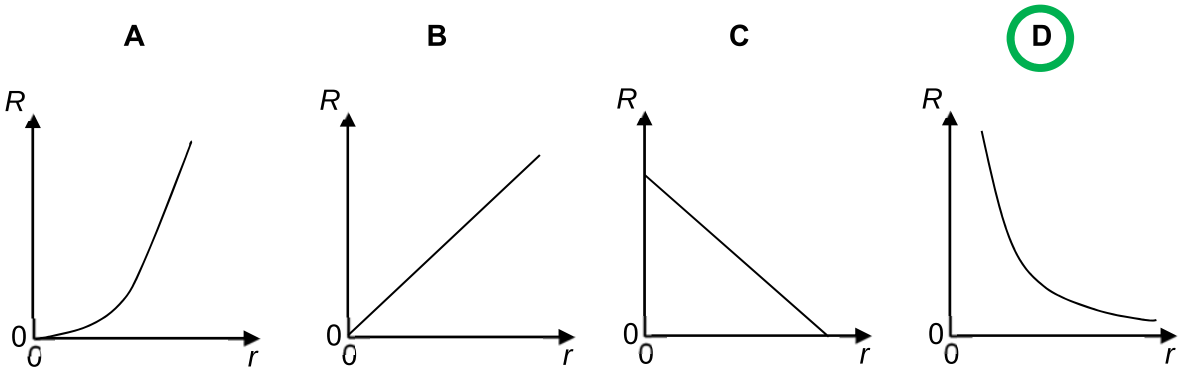
B the battery's e.m.f. and the current

C the current and the external resistance

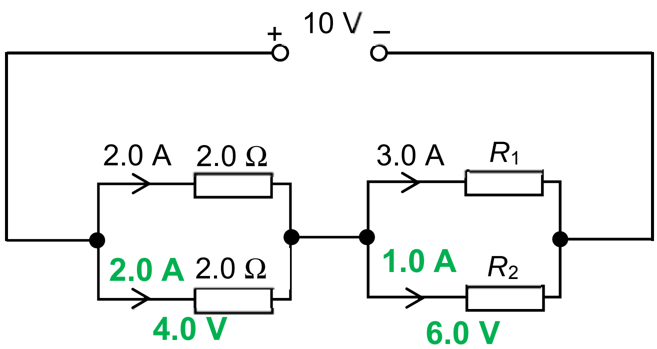
D the current and the internal resistance of the battery

22 A number of wires of the same material have the same length but different radii.

Which graph shows the variation with radius r of resistance R of the wires?



23 Four resistors are connected across a 10 V supply as shown in the circuit below.



What are the resistances R_1 and R_2?

	R_1	R_2
A	1.0 Ω	3.0 Ω
B	2.0 Ω	2.0 Ω
C	2.0 Ω	6.0 Ω
D	3.0 Ω	3.0 Ω

24 Which combination of 12 Ω resistors will give an overall resistance of 42 Ω?

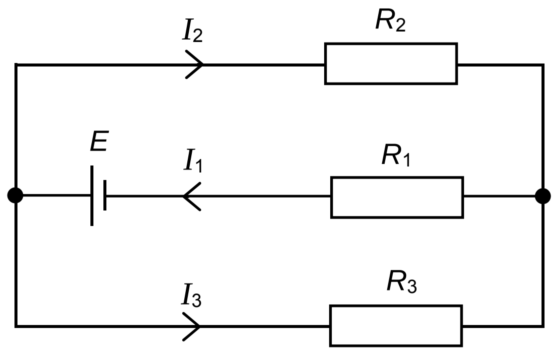
A two in series connected in series with two in parallel

B two in series connected in series with three in parallel

C three in series connected in series with two in parallel

D three in series connected in series with three in parallel

25 A cell of e.m.f. E and negligible internal resistance is connected in a circuit causing currents I_1. I_2 and I_3 in the three resistors of resistance R_1, R_2 and R_3 respectively.



Which equation relating to this circuit is correct?

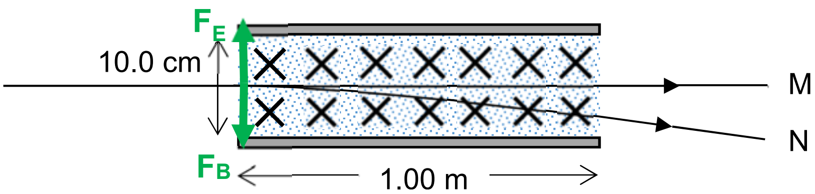
A $E + I_3R_3 = I_1R_1$

B $E - I_2R_2 = I_1R_1$

C $E + I_1R_1 = I_1R_2R_3 / (R_2 + R_3)$

D $E - I_1R_1 = I_2R_2 + I_3R_3$

26 In the region of dimensions 10.0 cm by 1.00 m between two charged plates with a p.d. of 100 V, there is a uniform magnetic field of strength 100 mT directed into the page.



M and N are the paths made by electrons of different speeds.

Which of the following correctly describes the speed of the electron that made N?

A slightly smaller than 1.00×10^4 m s^{-1}

B slightly greater than 1.00×10^4 m s^{-1}

C slightly smaller than 1.00×10^5 m s^{-1}

D slightly greater than 1.00×10^5 m s^{-1}

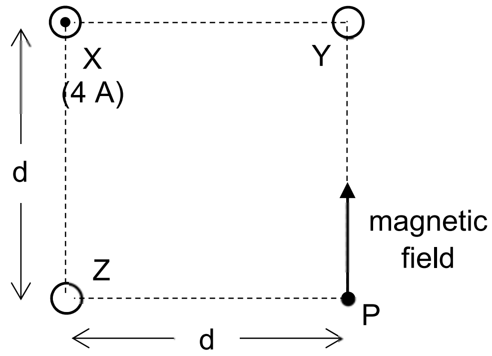
M: $F_B = F_E \rightarrow B\,q\,v = q\,E$

$v = E / B = V / d\,B = 1.00\times10^4$ m s^{-1}

N: $F_B > F_E$

$v > 1.00\times10^4$ m s^{-1}

27 Three current carrying conductors X, Y and Z are arranged as shown below. The current in X is directed out of the page. The resultant magnetic field due to the three conductors at P is directed towards Y.



Which of the following correctly states the direction of the currents in Y and Z?

	Y	Z
A	into page	out of page
B	out of page	out of page
C	into page	into page
D	out of page	into page

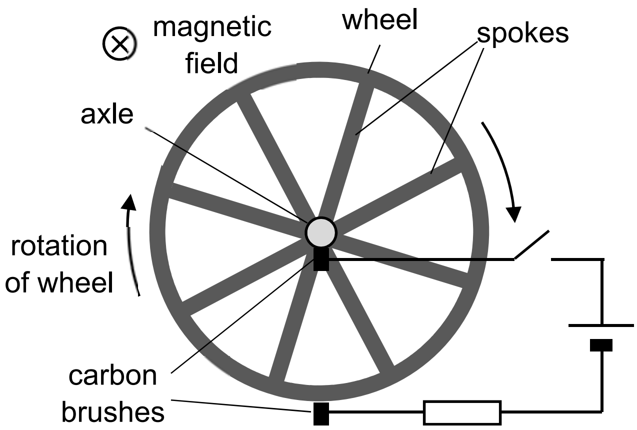
B_X Z → (B_Y + B_Z) ⊥ → B_Y ← → current in Y into page

→ B_Z ↑ → current in Z out of page

B_Y (= B_Z) = B_X / √2 → I_Y / d_Y (= I_Z / d_Z) = I_X / √2 d_X

d_Y (= d_Z) = d_X / √2 → I_Y / I_X = d_Y / √2 d_X = ½ → I_Y = ½ I_X = 2 A

28 A copper wheel with eight spokes is placed in a uniform magnetic field that is directed into the page. The rim and axle of the wheel is connected to an electrical circuit as shown below. The wheel is initially rotating about its axle at a constant angular speed with the switch open.



What is likely to happen to the rotation of the wheel when the switch is closed?

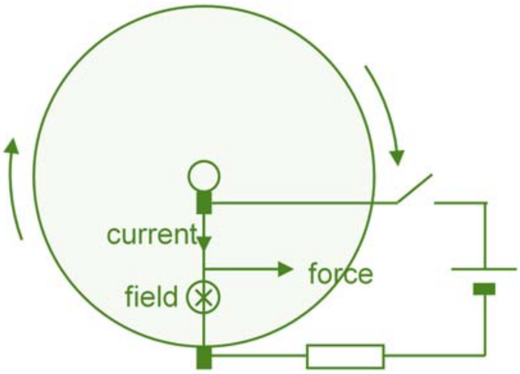
A Rotation will slow down.

B Rotation will speed up.

C Rotation will slow down then speed up cyclically.

D Rotation will not be affected.

Ans: A



Force produces an anti-clockwise moment to oppose the rotation.

29 Two radioactive isotopes P and Q have half-lives of 10 minutes and 15 minutes respectively. A sample initially contains the same number of atoms of each isotope. After 30 minutes, the ratio of the number of atoms of P to the number of atoms of Q will be

A 0.25 **B** 0.50 **C** 1.0 **D** 2.0

$$\frac{\text{the number of atoms of P}}{\text{the number of atoms of Q}} = \frac{\left(\frac{1}{2}\right)^{30/10}}{\left(\frac{1}{2}\right)^{30/15}} = \frac{\left(\frac{1}{2}\right)^{3}}{\left(\frac{1}{2}\right)^{2}} = \tfrac{1}{2} = 0.5$$

30 Some data are provided below:

mass of proton = 1.6726×10^{-27} kg

mass of neutron = 1.6750×10^{-27} kg

mass of ${}^{58}_{28}\text{Ni}$ nuclide = 9.6178×10^{-26} kg

What is the binding energy of ${}^{58}_{28}\text{Ni}$?

A 9.05×10^{-28} J **B** 2.71×10^{-19} J **C** 8.13×10^{-11} J **D** 8.66×10^{-9} J

End of Paper

1	2	3	4	5	6	7	8	9	10
C	**D**	**D**	**C**	**C**	**A**	**A**	**C**	**A**	**C**
11	12	13	14	15	16	17	18	19	20
B	**B**	**A**	**C**	**A**	**C**	**A**	**A**	**B**	**B**
21	22	23	24	25	26	27	28	29	30
D	**D**	**C**	**C**	**B**	**B**	**B**	**A**	**B**	**A**

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 8867/02

Structured Questions

12 September 2018

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 8**
2	**/ 6**
3	**/ 10**
4	**/ 8**
5	**/ 8**
6	**/ 20**
Section B	
7	**/ 20**
8	**/ 20**
Total	**/ 80**

This document consists of **22** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
elementary charge	e	=	1.60×10^{-19} C
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + ½at^2$
	v^2	=	$u^2 + 2as$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

For Examiner's Use

1 In 2018, the Singapore government announced that personal mobility devices (PMDs) such as e-scooters used on public paths must not have a device speed exceeding 25 km h^{-1} or weigh more than 20 kg.

(a) Suggest why there is a need to set a speed limit and weight limit on PMDs.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

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

(b) Given that a typical e-scooter with rider has a total mass of 100 kg and that the time of impact is 0.20 s, determine the average force this scooter could cause. Assume that the e-scooter comes to rest after impact.

average force = ……………………. N [2]

(c) Other than the speed and weight of PMDs, state and explain one other factor that can contribute to the magnitude of the force of impact caused in an accident involving PMDs.

…………………………………………………………………………………………………...

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…………………………………………………………………………………………………...

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

(d) It is suggested that an infra-red sensor can be fixed at the front end of a PMD such that once an obstacle is detected within 30 cm, the PMD will decelerate to a stop. By reference to the maximum allowable speed of 25 km h^{-1}, explain whether this is feasible.

…………………………………………………………………………………………………...

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

For Examiner's Use

2 A grenade is launched at ground level with velocity of 75 m s^{-1} and angle 20^0 from the horizontal to hit a sniper on top of a 30 m tall building at a position 245 m from the foot of the building. The sniper is standing at a distance *x* from the edge of the building.

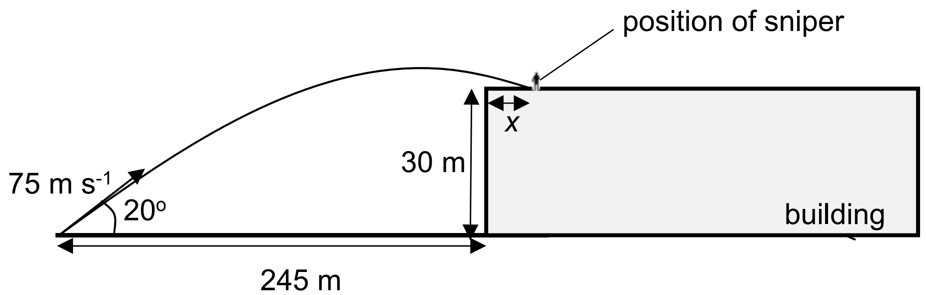

Fig. 2.1

(a) Show that the time for the grenade to reach the sniper is 3.5 s.

[1]

(b) Calculate the speed of the grenade just before impact.

speed = …………………… m s^{-1} [2]

(c) Determine the distance, *x*, of the sniper from the edge of the building.

x = …………………… m [2]

(d) The sniper runs away immediately from the edge of the building when the grenade is launched. Given that the grenade has a 'kill radius' of 10 m, calculate the minimum constant acceleration at which the sniper should run in order to escape.

minimum acceleration = …………………… m s^{-2} [1]

For Examiner's Use

3 **(a)** Derive an expression for the gravitational potential energy of a body near the surface of the earth from work done on the body.

[2]

(b) A 60.0 kg deliveryman attempts to move a 20.0 kg crate into the back of a truck by pushing it up a ramp as shown in Fig. 3.1. The truck's bed is at a height of 0.800 m above the ground, and the man moves up the slope with the load as he pushes.

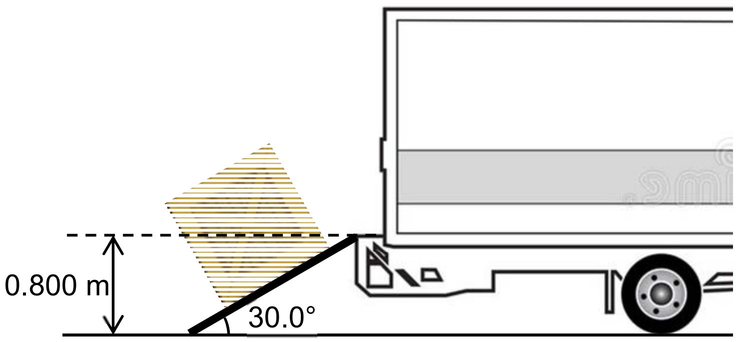

Fig. 3.1

(i) Determine the change in gravitational potential energy of the crate as it is transported from ground level into the truck.

change in gravitational potential energy = ……………………. J [2]

(ii) Given that 20.0 W of power is used to push the crate up the ramp, calculate the minimum time it takes the deliveryman to move the crate into the truck.

time = ……………………. s [2]

For Examiner's Use

(iii) Determine the force exerted by the deliveryman on the crate to push it up the ramp if its kinetic energy remains constant throughout.

force = ……………………. N [2]

(c) The actual work done by the man in moving the crate up the ramp is greater than the value in **(b)(i)**. Give two reasons for this observation.

1. ………………………………………………………………………………………………...

………………………………………………………………………………………………………...

2. ………………………………………………………………………………………………...

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

4 Fig. 4.1 shows a circuit consisting of two resistors connected in series to a d.c. supply.

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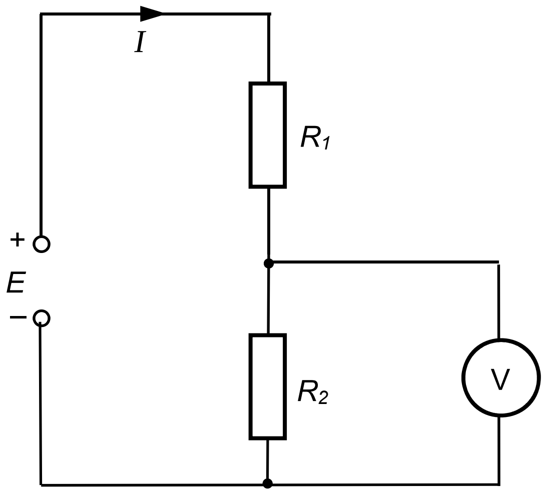

Fig. 4.1

The resistors have resistances R_1 and R_2. The supply has e.m.f. E and negligible internal resistance. The current from the supply is I. The voltmeter has an infinite resistance.

(a) By using Ohm's Law, show that the voltmeter reading V is given by the relation

$$V = \left(\frac{R_2}{R_1 + R_2} \right) E.$$

[2]

(b) Fig. 4.2 shows a circuit that includes a thermistor.

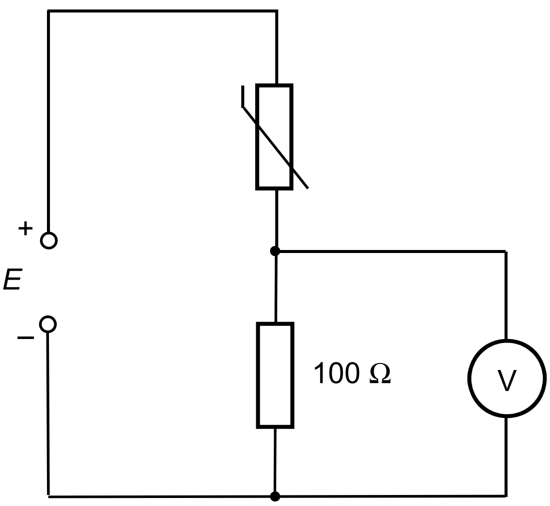

Fig. 4.2

Describe and explain how the voltmeter reading changes as the temperature of the thermistor is increased.

…………………………………………………………………………………………...

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…………………………………………………………………………………………...

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

(c) Fig. 4.3 shows a circuit that includes a resistance wire. A voltmeter showing a reading of V_b is connected across length b of the resistance wire.

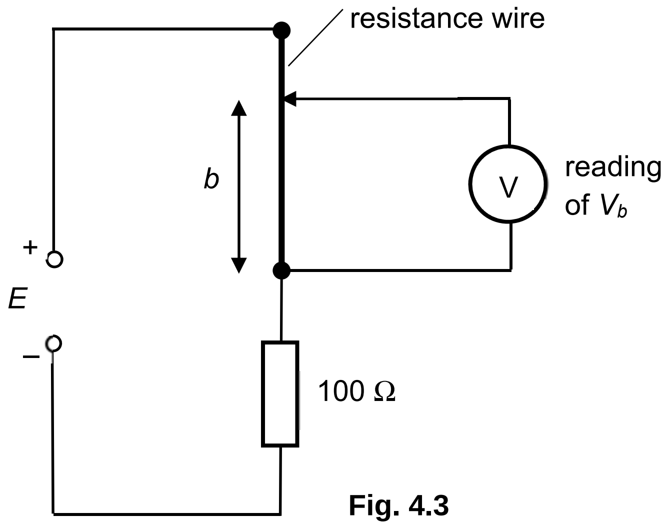


Fig. 4.3

(i) The resistance wire, of 1.00 m long, is made of nichrome wire of resistivity 1.57×10^{-6} Ω m and has a uniform radius of 0.10 mm. Determine the resistance of the resistance wire.

resistance = ……………………. Ω [2]

(ii) Express, in terms of E, the voltmeter reading, V_b when the length b is 1.00 m, the full length of the resistance wire.

V_b = ……………………. [1]

(iii) Express, in terms of E, the voltmeter reading, V_b when the length b is 0.50 m, half the length of the resistance wire.

V_b = ……………………. [1]

5 **(a)** Define *magnetic flux density*.

…………………………………………………………………………………………………….

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

(b) A 1.0 m long wire carrying a current of 2.0 A is placed in a magnetic field. When it is aligned with XX' as shown in Fig. 5.1A, it experiences a force of 0.50 N that is directed into the page. When it is aligned with YY' as shown in Fig. 5.1B, it experiences a force of 0.80 N that is directed out of the page.

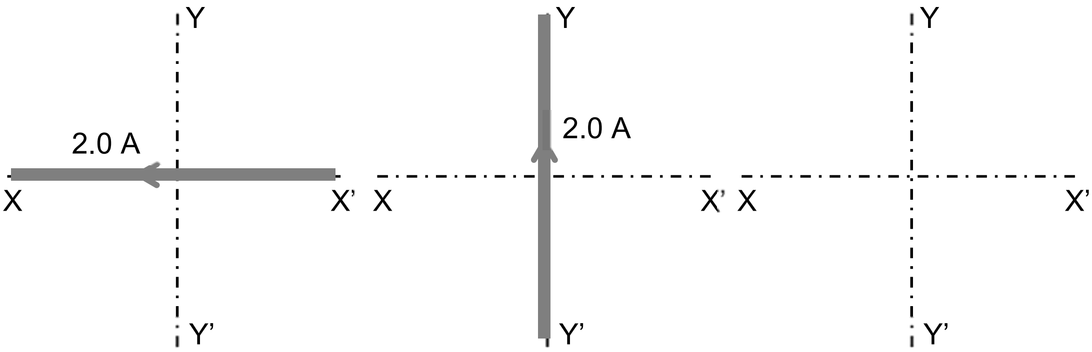


Fig. 5.1A **Fig. 5.1B** **Fig. 5.1C**

(i) Calculate the magnetic flux density of the field present.

magnetic flux density = …………………… T [3]

(ii) Determine the position of the wire such that it experiences a force of the maximum magnitude. Draw <u>accurately</u> the position of the wire in Fig. 5.1C.

[2]

(c) The current-carrying wire in **(b)** has a magnetic field of its own whose flux density is given by

$$B = \frac{\mu_0 I}{2\pi d}$$

where I is the current in the wire, d is the distance from the wire and μ_0 is a constant of value $4\pi\times10^{-7}$ H m^{-1}.

Show, by calculation, that it is impossible to find a point near the wire such that its magnetic flux density at that point has the same magnitude as the field present.

[2]

6 A transformer is an apparatus for decreasing or increasing the voltage of an alternating current. It consists of a primary coil and a secondary coil. The voltage in the primary coil, V_i can be transformed to a higher or lower voltage V_o in the secondary coil by varying n_i and n_o, the number of turns in the primary and secondary coils respectively.

Fig. 6.1 shows how the voltage V_i in a primary circuit is transformed to V_o in a secondary circuit using a transformer. Note that the two coils are not in electrical contact.

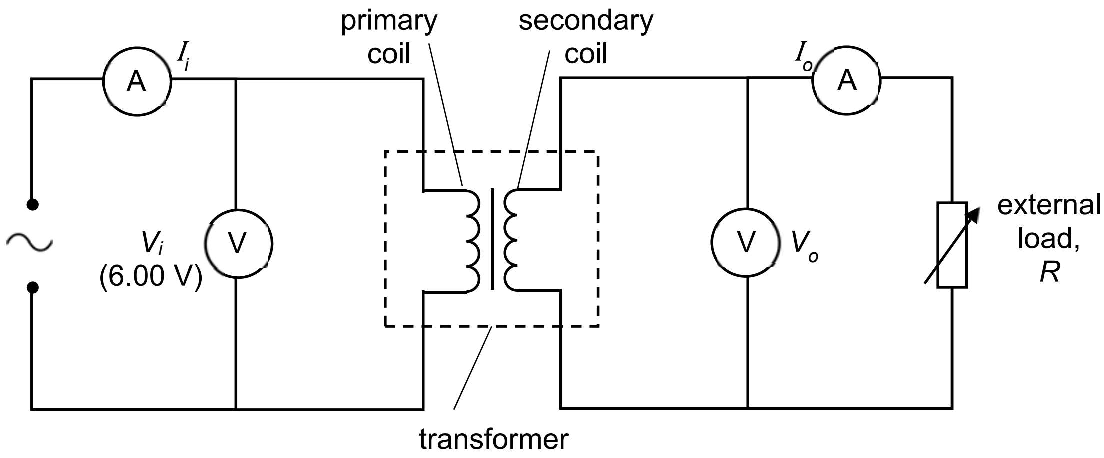


Fig 6.1

The resistance of each coil is as follows:

Primary coil 470 Ω

Secondary coil 2950 Ω

V_i, the voltage across the primary coil is maintained at 6.00 V.

The efficiency ε of the transformer is defined as

$$\varepsilon = \frac{\text{output power}}{\text{input power}}$$

The ratio of $\frac{V_o}{V_i}$ is represented by G.

Fig. 6.2 illustrates the variation of ε and G with R, the resistance of the external load.

For Examiner's Use

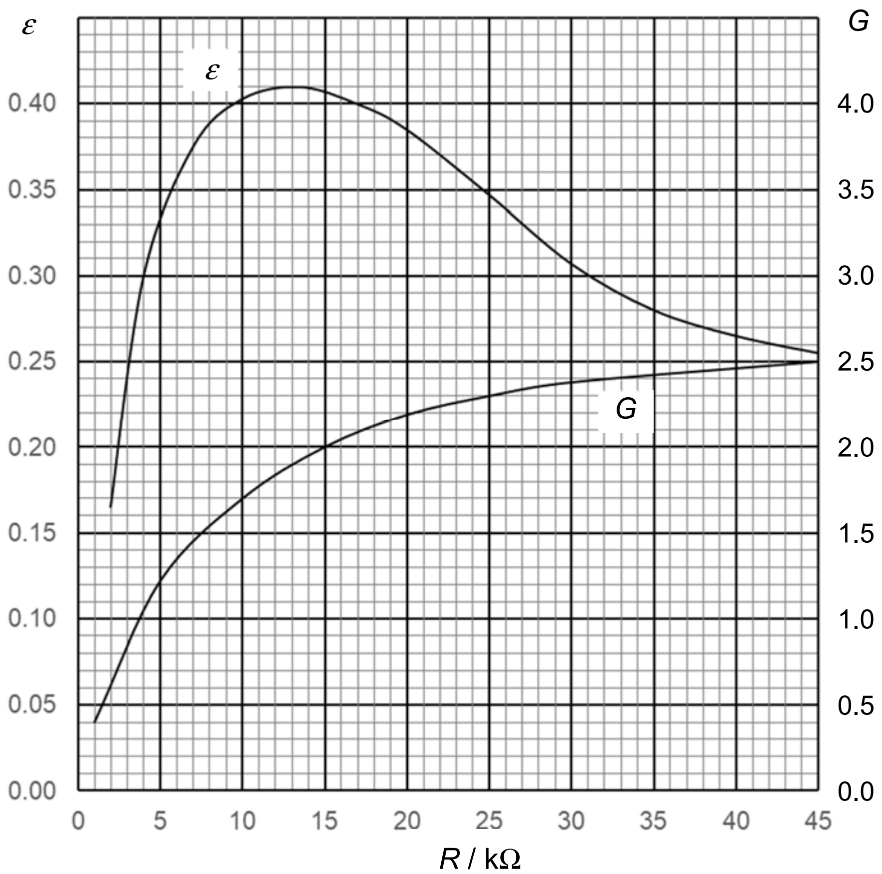


Fig. 6.2

(a) The primary and secondary coils are wires of the same metal and cross-sectional area, and their turns are of the same diameter.

Determine the ratio $\dfrac{n_o}{n_i}$.

ratio = ……………………. [2]

(b) Read from Fig. 6.2 a value for the maximum efficiency of the transformer.

maximum efficiency = ……………………. [1]

For Examiner's Use

(c) For the case where the transformer is operating at maximum efficiency, determine

(i) the value of G,

G = ... [1]

(ii) the value of R,

R = ... kΩ [1]

(iii) the current I_o,

I_o = ... A [2]

(iv) the power dissipated in R,

power = ... W [1]

(v) the input current I_i,

I_i, = ... A [2]

(d) Using your answers in **(c)** and any other data provided, calculate the following for the transformer when operating at maximum efficiency:

(i) the total power loss in the transformer,

power loss = ... W [1]

For Examiner's Use

(ii) the power loss due to the resistance of the primary coil,

power loss = …………………… W [1]

(iii) the power loss due to the resistance of the secondary coil.

power loss = …………………… W [1]

(e) A student suggests that the loss of efficiency in the transformer is due to the high resistance of the primary and secondary coils.

With reference to your answers in **(d)**, comment on the validity of the student's suggestion.

[3]

(f) Deduce the effect on the efficiency of the transformer of each of the following:

(i) Using a very small external load,

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(ii) Using a very large external load.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

For Examiner's Use

(g) Describe what would be the practical limitation on the use of this transformer if efficiencies of less than 0.30 is unacceptable during operation.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

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

For Examiner's Use

Section B

Answer **one** question from this section in the spaces provided.

7 **(a)** Explain the meaning of the term *centripetal* acceleration.

....

....

.... [2]

(b) Fig. 7.1 shows the top and side views of a roulette bowl of diameter 80 cm. The stator has a circular track that consists of a track back that is vertical and a track bottom that is inclined to the horizontal at an angle of 15°.

A small ball of mass 9.1 g is launched tangentially with a speed of 6.0 m s^{-1}, causing it to run along a circular track against the track back.

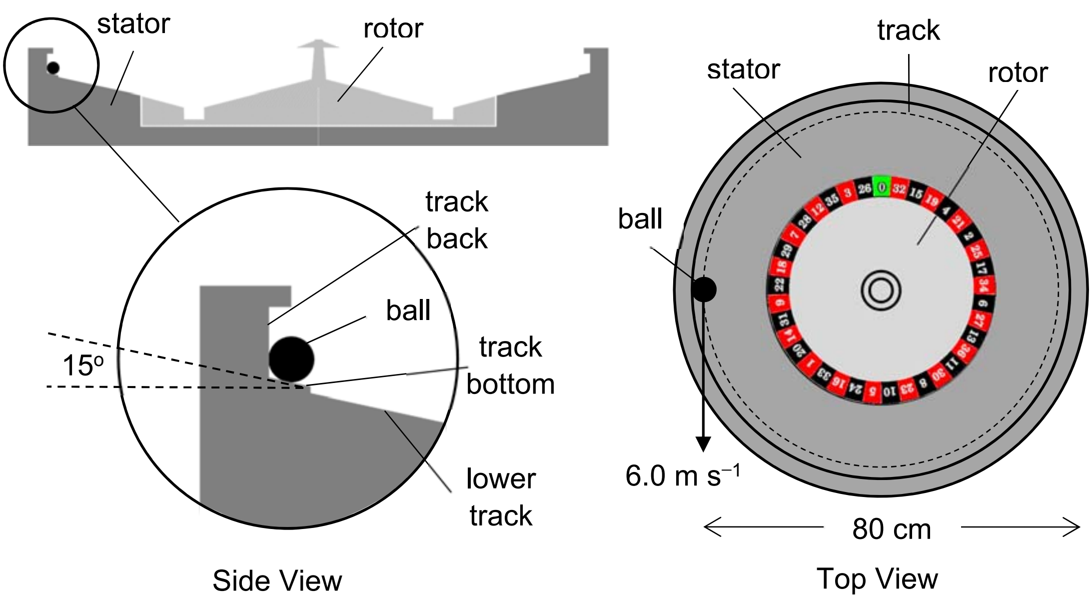


Fig 7.1

(i) Assuming that the track bottom is smooth, draw and label the forces acting on the ball in Fig. 7.2 below.

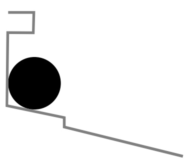


Fig. 7.2

[2]

For Examiner's Use

(ii) Show that the force exerted by the track bottom on the ball is 0.092 N.

[2]

(iii) Calculate the centripetal acceleration of the ball immediately after it has been launched.

acceleration = ……………………. m s^{-2} [2]

(iv) Determine the force exerted by the track back on the ball in order for the ball to accelerate at the value in **(b)(iii)**.

force = ……………………. N [3]

(c) As the ball runs along the track, it will slow down due to frictional force by the track back and the track bottom. After 20 s, the ball loses contact with the track back and falls to the lower track.

(i) Show that when the ball loses contact with the track back, its speed is 1.0 m s^{-1}.

[2]

For Examiner's Use

(ii) Calculate the change in magnitude of the momentum of the ball during the first 20 s.

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

(iii) Hence determine the average magnitude of the total frictional force exerted by the track back and track bottom on the ball during the first 20 s.

total frictional force = …………………… N [1]

(iv) The value in **(b)(ii)** is calculated based on the assumption that the track bottom is smooth. With reference to your answer to **(c)(iii)**, comment on the effect this assumption has on the accuracy of the value in **(b)(ii)**.

…………………………………………………………………………………………...

…………………………………………………………………………………………...

………………………………………………………………………………………… [2]

(v) The actual average frictional force experienced by the ball may vary by ±10% from instance to instance. Determine how much the actual time taken for the ball to fall to the lower track may differ from the stated value of 20 s.

difference in time taken = ± …………………… s [2]

For Examiner's Use

8 **(a)** Fig. 8.1 below shows a Rutherford scattering experiment in which α-particles are directed at a gold foil. The detector is shown in two positions in the evacuated chamber.

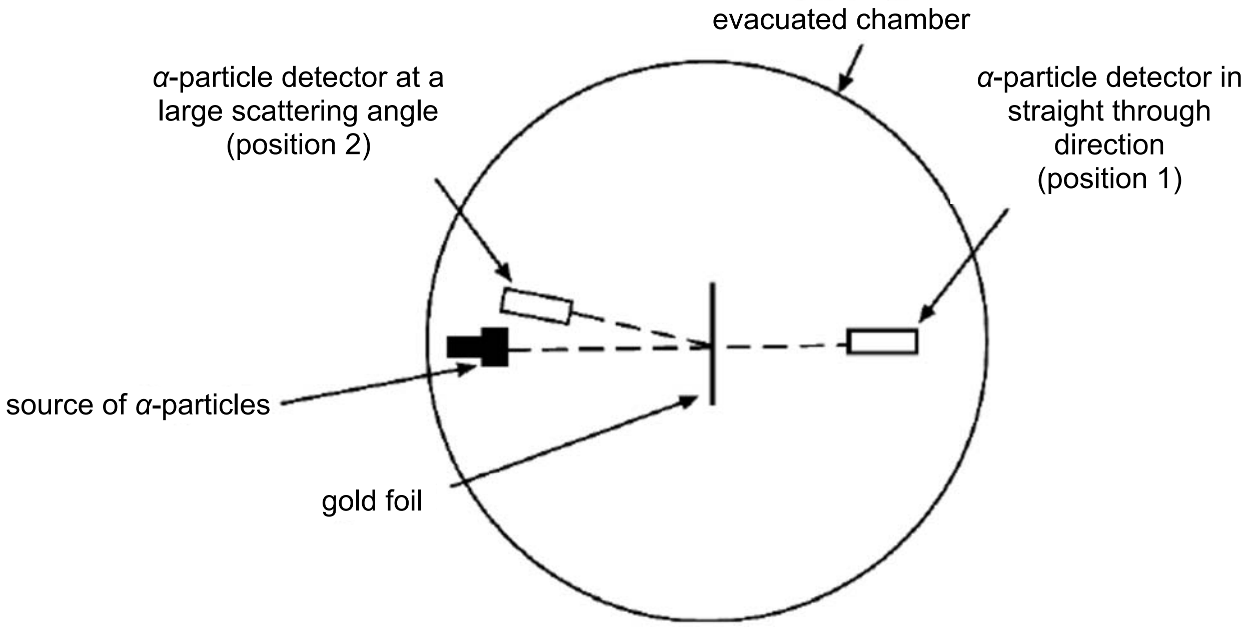


Fig. 8.1

(i) Explain why air needs to be removed from the apparatus.

....

.... [1]

(ii) Explain why the gold foil should be very thin.

....

.... [1]

(iii) State what can be deduced, from the following observations, about the structure of the atom and the properties of the gold nucleus:

1. A high count rate is detected by the α-particle detector in position 1.

....

.... [1]

2. A low count rate is detected by the α-particle detector in position 2.

....

....

.... [2]

(b) The graph in Fig. 8.2 shows how the binding energy per nucleon varies with mass number. Nuclei on the left of Fe-56 tend to undergo nuclear fusion while those to the right tend to undergo nuclear fission.

Fig. 8.2

Both fission and fusion are processes that involve the release of a huge amount of energy. However fusion is often said to be a more "mass-energy efficient" process than fission, yielding about six times as much energy per gram of active material as fission.

(i) State what is meant by the *binding energy* of a nucleus.

....

....

.... [2]

(ii) Explain why binding energy per nucleon is an indicator of the stability of a nucleus.

....

....

....

.... [2]

For Examiner's Use

(c) A stationary radon nucleus may decay spontaneously into a polonium nucleus and an α-particle as shown:

$$^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He}$$

The rest-masses of the nuclei are:

$$^{222}_{86}\text{Rn} = 222.0176\ u$$

$$^{218}_{84}\text{Po} = 218.0090\ u$$

$$^{4}_{2}\text{He} = 4.0026\ u$$

(i) Calculate the kinetic energy of the products in the above reaction.

kinetic energy = …………………… J [3]

(ii) State the principle of conservation of momentum.

....

.... [1]

(iii) Hence, determine the speed of the polonium nucleus and α-particle.

speed of polonium = …………………… m s^{-1}

speed of α-particle = …………………… m s^{-1} [4]

For Examiner's Use

(d) A radioactive nuclide P undergoes decay to form a stable nuclide Q. P has a half-life of 4.2 hours.

On Fig. 8.3, sketch labelled graphs to show the variation with time t of N_p the number of P and N_Q the number of Q nuclei present for a period of 2 half-lives.

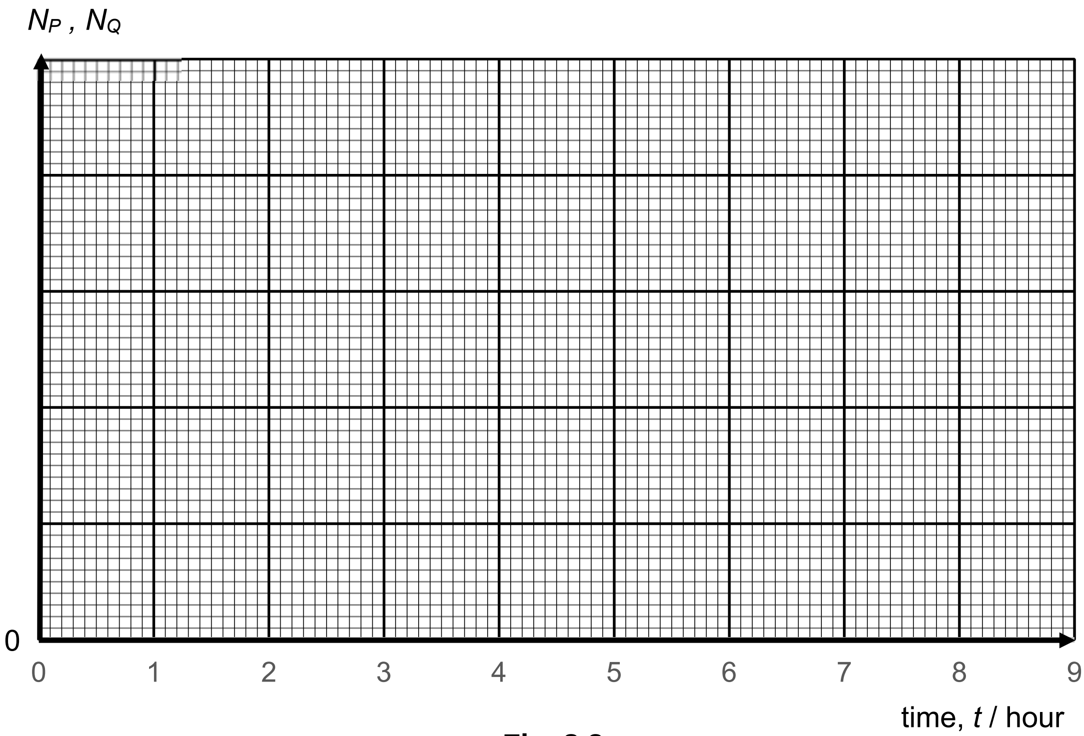


Fig. 8.3

[3]

End of Paper

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS **8867/02**

Structured Questions **12 September 2018**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 8**
2	**/ 6**
3	**/ 10**
4	**/ 8**
5	**/ 8**
6	**/ 20**
Section B	
7	**/ 20**
8	**/ 20**
Total	**/ 80**

This document consists of **22** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
elementary charge	e	=	1.60×10^{-19} C
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

For Examiner's Use

1 In 2018, the Singapore government announced that personal mobility devices (PMDs) such as e-scooters used on public paths must not have a device speed exceeding 25 km h^{-1} or weigh more than 20 kg.

(a) Suggest why there is a need to set a speed limit and weight limit on PMDs. [2]

Momentum is the product of mass and velocity, which are related to weight and speed of PMD. [1] As force is proportional to rate of change of momentum, the amount of force a PMD can inflict is controlled. [1]
Note: award one mark only answer only state 'Setting speed limit so that rider will not be thrown outward due to sudden stop/deceleration' [1]

(b) Given that a typical e-scooter with rider has a total mass of 100 kg and that the time of impact is 0.20 s, determine the average force this scooter could cause. Assume that the e-scooter comes to rest after impact. [2]

$$F = \frac{\Delta P}{t} = \frac{(100)(0 - \frac{25\times10^3}{60\times60})}{0.20} = 3472 = 3500\text{ N}$$

(c) Other than the speed and weight of PMDs, state and explain one other factor that can contribute to the magnitude of the force of impact caused in an accident involving PMDs. [2]

- mass of the load on the PMD. A greater load increases the momentum of the PMD/load system, contributing to a large force.

Or

- material of PMD (Hardness of material): Harder material causes shorter time of impact and by N2L, larger force.

(Area of contact is not accepted as it affects the pressure, but not the force)

(d) It is suggested that an infra-red sensor can be fixed at the front end of a PMD such that once an obstacle is detected within 30 cm, the PMD will decelerate to a stop. By reference to the maximum allowable speed of 25 km h^{-1}, explain whether this is feasible. [2]

$$v^2 = u^2 + 2as$$

$$0 = \left(\frac{25\times10^3}{60\times60}\right)^2 + 2a(0.30)$$

$$a = -80\text{ m s}^{-2} \approx -8g \qquad [1]$$

Not feasible as the deceleration is several times that of *g*/deceleration is too large. [1]

2 A grenade is launched at ground level with velocity of 75 m s^{-1} and angle 20^0 from the horizontal to hit a sniper on top of a 30 m tall building at a position 245 m from the foot of the building. The sniper is standing at a distance *x* from the edge of the building.

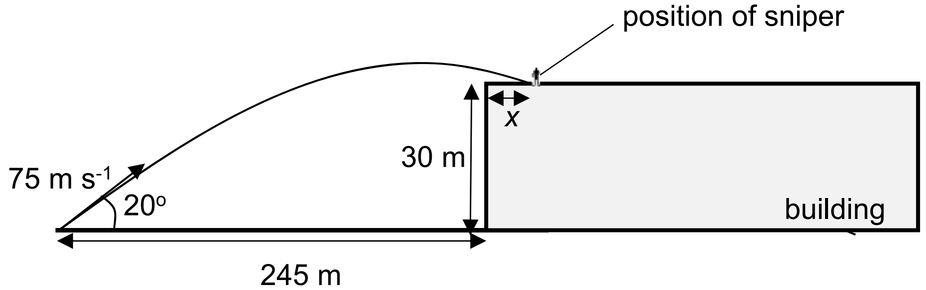


Fig. 2.1

(a) Show that the time for the grenade to reach the sniper is 3.5 s.

$$s_y = u_y t + \frac{1}{2} g t^2$$

$$30 = 75 \sin 20^\circ t - \frac{1}{2} x 9.81 t^2 \qquad \Rightarrow t = 3.5 \ s$$

[1]

(b) Calculate the speed of the grenade just before impact.

$$v_y = u_y + at$$

$$= 75 \sin 20^\circ - \frac{1}{2} x 9.81 x 3.5$$

$$= 8.5 \ ms^{-1}$$

$$v_x = 75 \cos 20^\circ = 70.5 \ ms^{-1}$$

$$v = \sqrt{8.5^2 + 70.5^2} = 71 \ ms^{-1}$$

speed = ... m s^{-1} [2]

(c) Determine the distance, *x*, of the sniper from the edge of the building.

$$u_x t = 245 + x$$

$$75 \cos 20^\circ x 3.5 = 245 + x$$

$$x = 1.7 \ m$$

x = ... m [2]

(d) The sniper runs away immediately from the edge of the building when the grenade is launched. Given that the grenade has a 'kill radius' of 10 m, calculate the minimum constant acceleration at which the sniper should run in order to escape.

$$s = u t + \frac{1}{2} a t^2$$

$$10 = \frac{1}{2} a.(3.5)^2$$

$$a = 1.6 \ ms^{-2}$$

minimum acceleration = ... m s^{-2} [1]

3 **(a)** Derive an expression for the gravitational potential energy of a body near the surface of the earth from work done on the body.

work done by gravity when body of mass *m* falls through a distance *h*

= *F x s* in the direction of force

= (*mg*)(−*h*)

Hence, work done against gravity by force pushing a body upwards with constant KE

= *mgh*

For Examiner's Use

[2]

(b) A 60.0 kg deliveryman attempts to move a 20.0 kg crate into the back of a truck by pushing it up a ramp as shown in Fig. 3.1. The truck's bed is at a height of 0.800 m above the ground, and the man moves up the slope with the load as he pushes.

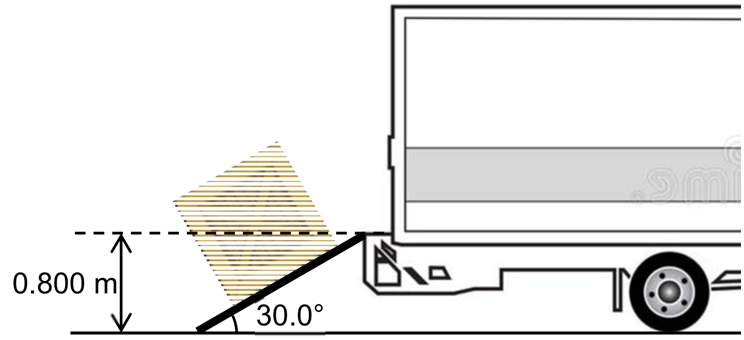


Fig. 3.1

(i) Determine the change in gravitational potential energy of the crate as it is transported from ground level into the truck.

mgh = (20.0)(9.81)(0.800) = 157 J

change in gravitational potential energy = …………………… J [2]

(ii) Given that 20.0 W of power is used to push the crate up the ramp, calculate the minimum time it takes the deliveryman to move the crate into the truck.

$t = E/P$ = 157/20.0 = 6.28 s

or calculation by kinematics

time = …………………… s [2]

(iii) Determine the force exerted by the deliveryman on the crate to push it up the ramp if its kinetic energy remains constant throughout.

F = W/d = 157/(0.800/sin30) = 98.1 N

Or resolve mg upslope

force = …………………… N [2]

For Examiner's Use

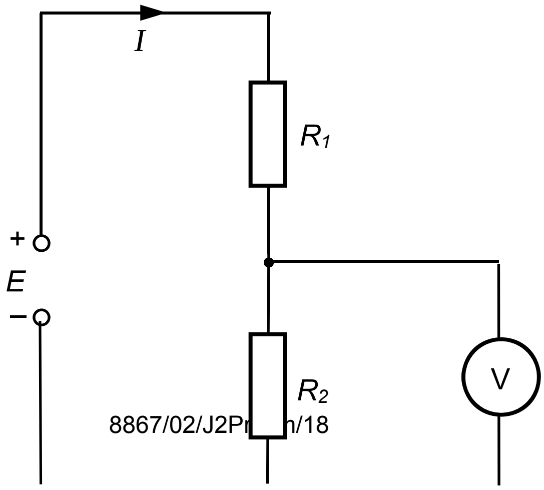
(c) The actual work done by the man in moving the crate up the ramp is greater than the value in **(b)(i)**. Give two reasons for this observation.

1. Man also gains GPE from work done [1]

2. Work has to be done to overcome friction [1]

[2]

4 Fig. 4.1 shows a circuit consisting of two resistors connected in series to a d.c. supply.



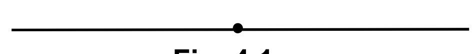


Fig. 4.1

The resistors have resistances R_1 and R_2. The supply has e.m.f. E and negligible internal resistance. The current from the supply is I. The voltmeter has an infinite resistance.

(a) By using Ohm's Law, show that the voltmeter reading V is given by the relation

$$V = \left(\frac{R_2}{R_1 + R_2}\right)E.$$

By Ohm's Law, $E = IR_{tot}$

$$I = \frac{E}{R_{tot}} = \frac{E}{R_1 + R_2}$$

Potential difference across R_2, $V = IR_2$

$$= \left(\frac{E}{R_1 + R_2}\right)R_2$$

$$= \left(\frac{R_2}{R_1 + R_2}\right)E \quad \text{[shown]}$$

[2]

(b) Fig. 4.2 shows a circuit that includes a thermistor.

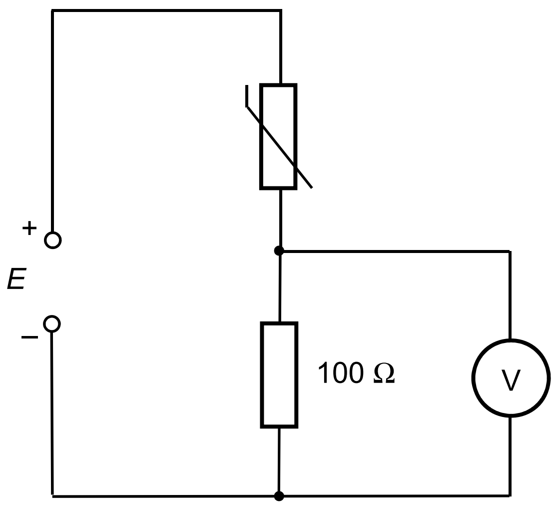


Fig. 4.2

Describe and explain how the voltmeter reading changes as the temperature of the thermistor is increased.

As the temperature of the thermistor is increased, the resistance of the thermistor will decrease (R_1 decreases). As the resistance of the 100 Ω resistor remains constant, the ratio of its resistance to the total resistance will increase, i.e. $R_2/(R_1 + R_2)$ will increase. As such the potential difference across the 100 Ω resistor increases and the voltmeter will register a higher reading

.... [2]

For Examiner's Use

(c) Fig. 4.3 shows a circuit that includes a resistance wire. A voltmeter showing a reading of V_b is connected across length b of the resistance wire.

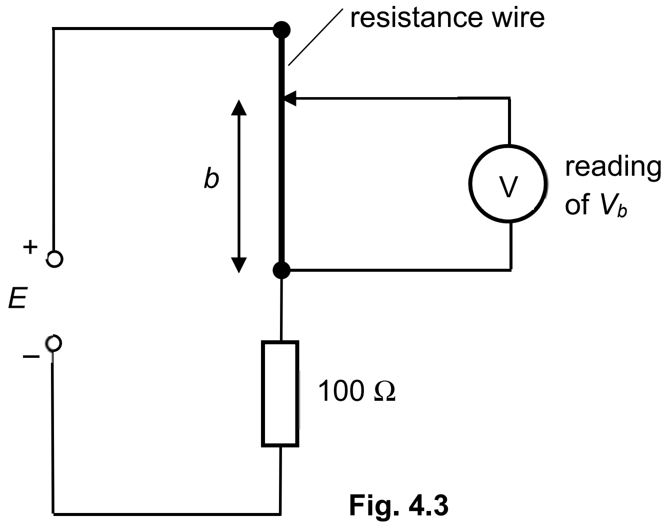


Fig. 4.3

(i) The resistance wire, of 1.00 m long, is made of nichrome wire of resistivity 1.57×10^{-6} Ω m and has a uniform radius of 0.10 mm. Determine the resistance of the resistance wire.

$$R = \frac{\rho l}{A}$$
$$= \frac{\rho l}{\pi r^2}$$
$$= \frac{1.57\times10^{-6}(1.00)}{\pi(0.10\times10^{-3})^2}$$
$$= 50\ \Omega$$

resistance = ... Ω [2]

(ii) Express, in terms of E, the voltmeter reading, V_b when the length b is 1.00 m, the full length of the resistance wire.

Potential across potentiometer wire $= \dfrac{50}{50+100} \times E = 0.333\ E$

V_b = ... [1]

(iii) Express, in terms of E, the voltmeter reading, V_b when the length b is 0.50 m, half the length of the resistance wire.

Balance length b $= \dfrac{\frac{1}{2}x50}{50+100} \times E = 0.167\ E$

V_b = ... [1]

5 **(a)** Define *magnetic flux density*.

Magnetic flux density is defined as the force acting per unit length per unit current on a conductor carrying current placed at right angles to the magnetic field.

For Examiner's Use

…………………………………………………………………………………………………… [1]

(b) A 1.0 m long wire carrying a current of 2.0 A is placed in a magnetic field. When it is aligned with XX' as shown in Fig. 5.1A, it experiences a force of 0.50 N that is directed into the page. When it is aligned with YY' as shown in Fig. 5.1B, it experiences a force of 0.80 N that is directed out of the page.

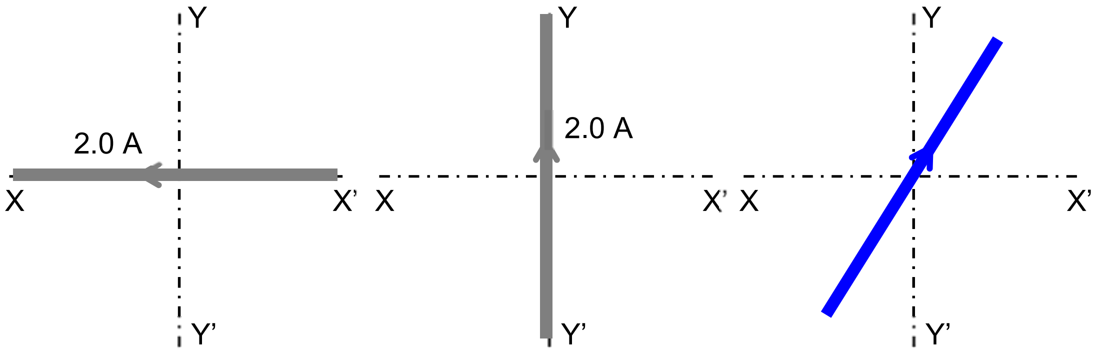


Fig. 5.1A **Fig. 5.1B** **Fig. 5.1C**

(i) Calculate the magnetic flux density of the field present.

$(F/L)_x = B_y I \rightarrow B_y = 0.50 / 2.0 = 0.25$ T ↑
$(F/L)_y = B_x I \rightarrow B_x = 0.80 / 2.0 = 0.40$ T ←
$B = \sqrt{(0.25^2 + 0.40^2)} = 0.47$ T

magnetic flux density = …………………… T [3]

(ii) Determine the position of the wire such that it experiences a force of the maximum magnitude. Draw accurately the position of the wire in Fig. 5.1C.

$\theta = \tan^{-1}(0.25 / 0.40) = 32^o$
Direction of B is $\perp$ 32^{o} → Alignment of wire for maximum force is $\angle 58^o$

[2]

For Examiner's Use

(c) The current-carrying wire in **(b)** has a magnetic field of its own whose flux density is given by

$$B = \frac{\mu_0 I}{2\pi d}$$

where I is the current in the wire, d is the distance from the wire and μ_0 is a constant of value $4\pi\times10^{-7}$ H m^{-1}.

Show, by calculation, that it is impossible to find a point near the wire such that its magnetic flux density at that point has the same magnitude as the field present.

$B = \mu_0 I / 2\pi d \rightarrow 0.47 = 2\times10^{-7} \times 2.0 / d$
$d = 8.5\times10^{-7}$ m
distance is much smaller than thickness of wire → not possible

[2]

For Examiner's Use

6 A transformer is an apparatus for decreasing or increasing the voltage of an alternating current. It consists of a primary coil and a secondary coil. The voltage in the primary coil, V_i can be transformed to a higher or lower voltage V_o in the secondary coil by varying n_i and n_o, the number of turns in the primary and secondary coils respectively.

Fig. 6.1 shows how the voltage V_i in a primary circuit is transformed to V_o in a secondary circuit using a transformer. Note that the two coils are not in electrical contact.

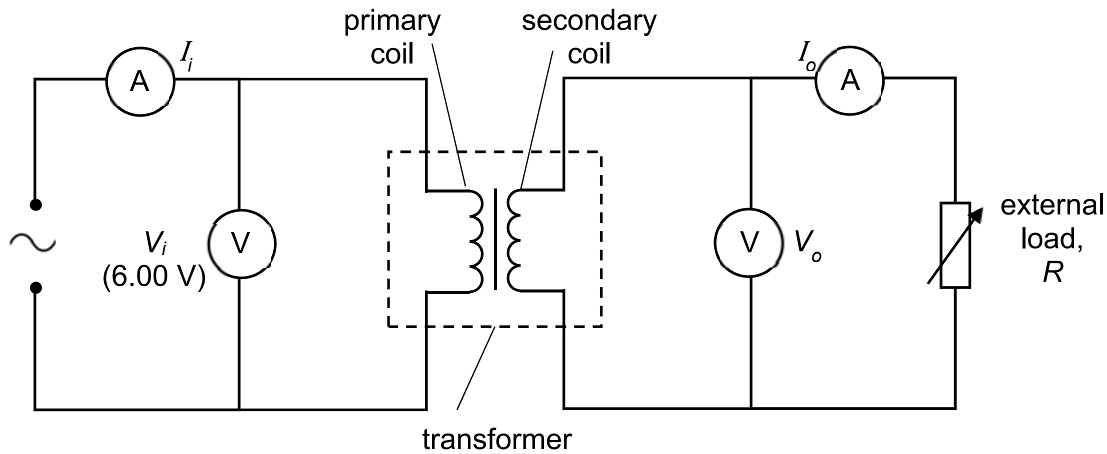


Fig 6.1

The resistance of each coil is as follows:

Primary coil 470 Ω

Secondary coil 2950 Ω

V_i, the voltage across the primary coil is maintained at 6.00 V.

The efficiency ε of the transformer is defined as

$$\varepsilon = \frac{\text{output power}}{\text{input power}}$$

The ratio of $\frac{V_o}{V_i}$ is represented by G.

Fig. 6.2 illustrates the variation of ε and G with R, the resistance of the external load.

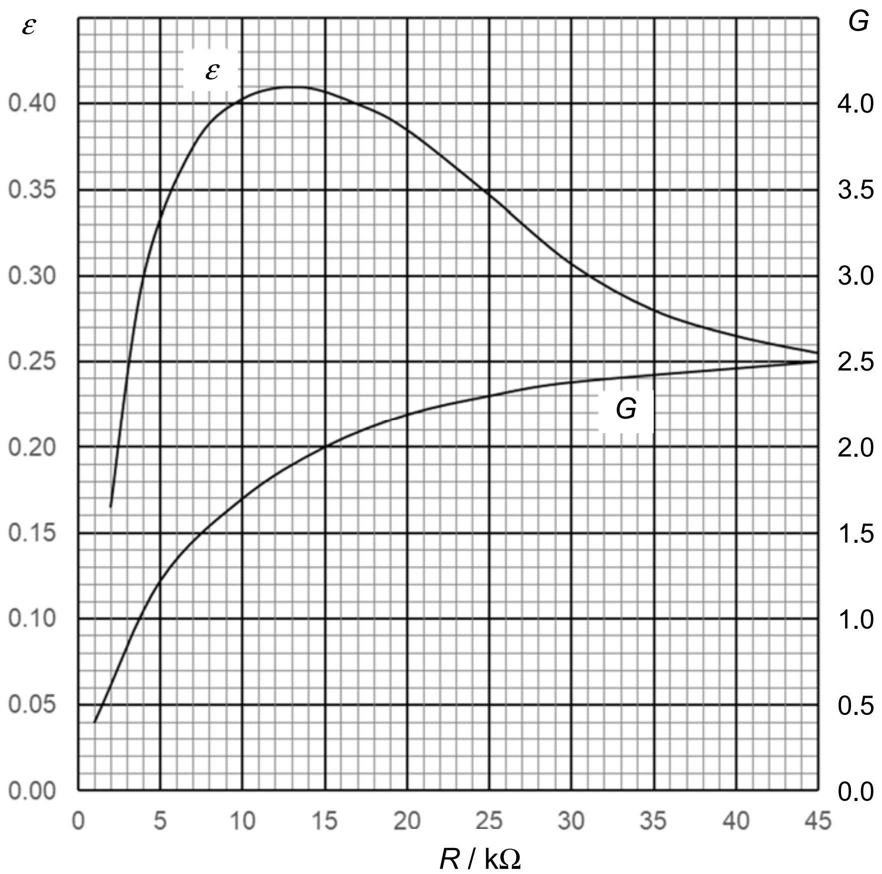


Fig. 6.2

(a) The primary and secondary coils are wires of the same metal and cross-sectional area, and their turns are of the same diameter.

Determine the ratio $\frac{n_o}{n_i}$.

$R = \rho L / A \propto L \propto n$

$n_o/n_i = R_{sec}/R_{pri} = 2950 / 470 = 6.28$

ratio = ……………………. [2]

(b) Read from Fig. 6.2 a value for the maximum efficiency of the transformer.

0.410

maximum efficiency = ……………………. [1]

For Examiner's Use

(c) For the case where the transformer is operating at maximum efficiency, determine

(i) the value of *G*,

1.90

G = …………………… [1]

(ii) the value of *R*,

13.0 kΩ

R = …………………… kΩ [1]

(iii) the current I_o,

$V_o = 1.90 \times 6.00 = 11.4$ V

$I_o = 11.4 / 13.0\times10^3 = 8.77\times10^{-4}$ A

I_o = …………………… A [2]

(iv) ~~the power dissipated in *R*,~~

$P_o = I_o V_o = 8.77\times10^{-4} \times 11.4 = 1.00\times10^{-2}$ W

power = …………………… W [1]

(v) the input current I_i,

$P_i = 1.00\times10^{-2} / 0.410 = 2.44\times10^{-2}$ W

$I_i = P_i / V_i = 2.44\times10^{-2} / 6.00 = 4.06\times10^{-3}$ A

I_i = …………………… A [2]

(d) Using your answers in **(c)** and any other data provided, calculate the following for the transformer when operating at maximum efficiency:

(i) the total power loss in the transformer,

Power loss = $(2.44 - 1.00)\times10^{-2} = 1.44\times10^{-2}$ W

power loss = …………………… W [1]

For Examiner's Use

(ii) the power loss due to the resistance of the primary coil,

Power loss = $I_i^2 R_{pri} = (4.06\times10^{-3})^2 \times 470 = 7.75\times10^{-3}$ W

power loss = ... W [1]

(iii) the power loss due to the resistance of the secondary coil.

Power loss = $I_o^2 R_{sec} = (8.77\times10^{-4})^2 \times 2950 = 2.27\times10^{-3}$ W

power loss = ... W [1]

(e) A student suggests that the loss of efficiency in the transformer is due to the high resistance of the primary and secondary coils.

With reference to your answers in **(d)**, comment on the validity of the student's suggestion.

Total power loss due to resistance of coils = $(7.75 + 2.27)\times10^{-3}$

$= 1.00\times10^{-2}$ W < 1.44×10^{-2} W

Most of the power loss in the transformer is due to the resistance of the coils. However, there is still a significant amount of power loss that must be due to other causes.

[3]

(f) Deduce the effect on the efficiency of the transformer of each of the following:

(i) Using a very small external load,

Efficiency will be close to zero.

.... [1]

(ii) Using a very large external load.

Efficiency will be between 0.20 and 0.25.

.... [1]

For Examiner's Use

(g) Describe what would be the practical limitation on the use of this transformer if efficiencies of less than 0.30 is unacceptable during operation.

This transformer can only be used for external loads of between 4 kΩ and 31 kΩ.

....

....

.... [2]

For Examiner's Use

Section B

Answer **one** question from this section in the spaces provided.

7 **(a)** Explain the meaning of the term *centripetal* acceleration.

Acceleration to move in a circle

directed towards centre of the circle.

[2]

(b) Fig. 7.1 shows the top and side views of a roulette bowl of diameter 80 cm. The stator has a circular track that consists of a track back that is vertical and a track bottom that is inclined to the horizontal at an angle of 15°.

A small ball of mass 9.1 g is launched tangentially with a speed of 6.0 m s^{-1}, causing it to run along a circular track against the track back.

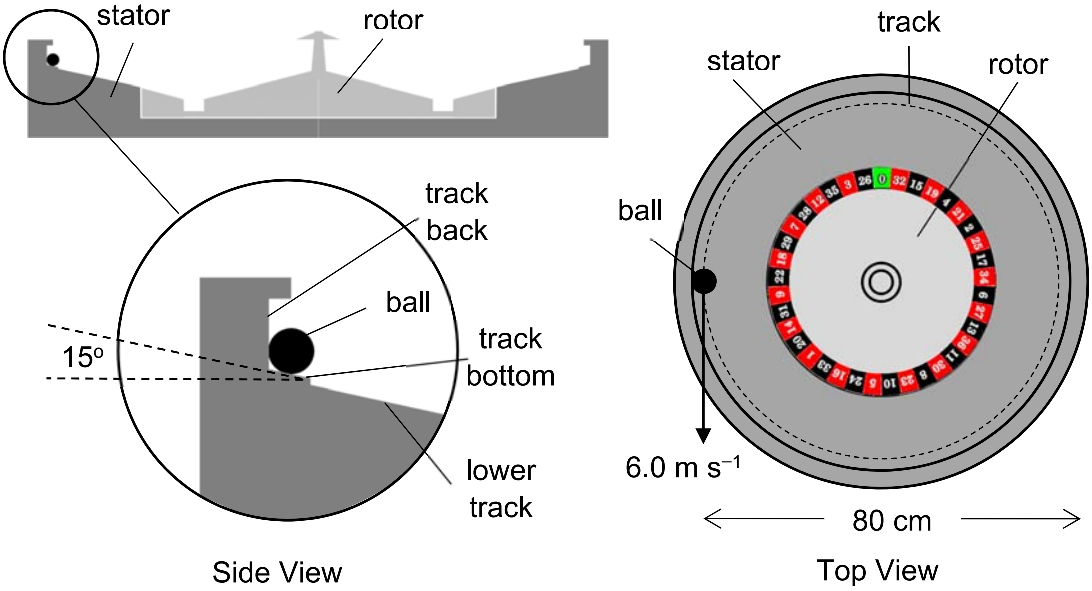


Fig 7.1

(i) Assuming that the track bottom is smooth, draw and label the forces acting on the ball in Fig. 7.2 below.

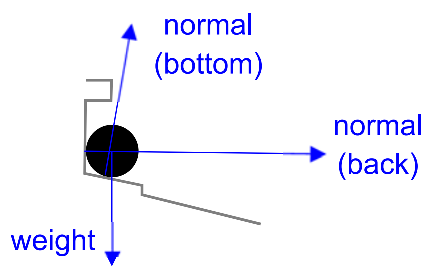


Fig. 7.2

[2]

For Examiner's Use

(ii) Show that the force exerted by the track bottom on the ball is 0.092 N.

$\Sigma F_y = m\,a \rightarrow N \cos 15^\circ - m\,g = 0$

$N = 0.0091 \times 9.81 / \cos 15^\circ = 0.092$ N

[2]

(iii) Calculate the centripetal acceleration of the ball immediately after it has been launched.

$a_c = v^2 / r = 6.0^2 / 0.40 = 90$ m s^{-2}

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

(iv) Determine the force exerted by the track back on the ball in order for the ball to accelerate at the value in **(b)(iii)**.

$\Sigma F_r = m\,a_c \rightarrow N \sin 15^\circ + R = m\,a_c$

$R = 0.0091 \times 90 - 0.092 \sin 15^\circ = 0.795$ N

force = ... N [3]

(c) As the ball runs along the track, it will slow down due to frictional force by the track back and the track bottom. After 20 s, the ball loses contact with the track back and falls to the lower track.

(i) Show that when the ball loses contact with the track back, its speed is 1.0 m s^{-1}.

Lose contact $\rightarrow R = 0$

$N \sin 15^\circ = m\,v^2 / r$

$v = 1.0$ m s^{-1}

[2]

For Examiner's Use

(ii) Calculate the change in magnitude of the momentum of the ball during the first 20 s.

$\Delta p = 0.0091\ (6.0 - 1.0)$

$= 0.046\ (0.0455)$ kg m s^{-1}

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

(iii) Hence determine the average magnitude of the total frictional force exerted by the track back and track bottom on the ball during the first 20 s.

$\langle F \rangle = \Delta p / \Delta t = 0.0455 / 20$

$= 0.0023\ (0.00228)$ N

total frictional force = ... N [1]

(iv) The value in **(b)(ii)** is calculated based on the assumption that the track bottom is smooth. With reference to your answer to **(c)(iii)**, comment on the effect this assumption has on the accuracy of the value in **(b)(ii)**.

Frictional force in (c)(iii) is 0.0023 / 0.092 = 2.5% of the normal reaction force (b)(ii).

Calculated value is to 2 significant figures and is not likely to be significantly affected.

.... [2]

(v) The actual average frictional force experienced by the ball may vary by ±10% from instance to instance. Determine how much the actual time taken for the ball to fall to the lower track may differ from the stated value of 20 s.

$\langle F \rangle = m(v - u) / t \rightarrow t = m(v - u) / \langle F \rangle$

$\pm \Delta t / t = \pm \Delta F / F = 0.10$

$\Delta t = 0.10 \times 20 = \pm 2$ s

difference in time taken = ± .... s [2]

For Examiner's Use

8 **(a)** Fig. 8.1 below shows a Rutherford scattering experiment in which *α*-particles are directed at a gold foil. The detector is shown in two positions in the evacuated chamber.

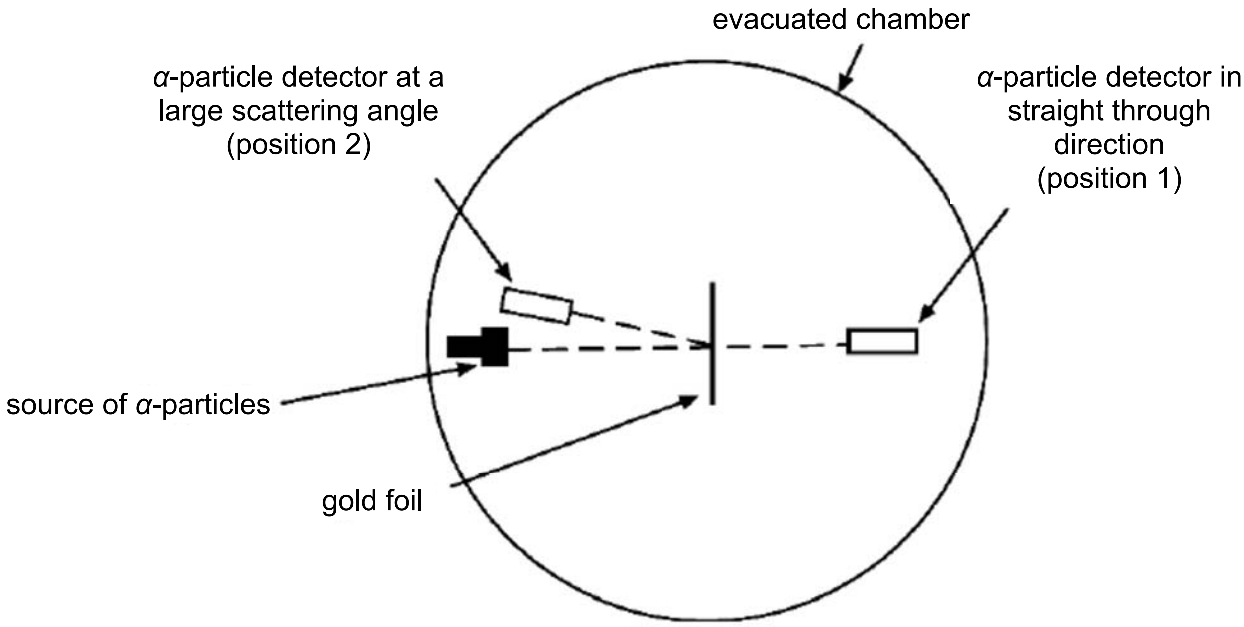


Fig. 8.1

(i) Explain why air needs to be removed from the apparatus.

to minimise collisions between α particles and air molecules) **B1**

Or - **α** particles have a short range in air (3–5 cm) .... **B1** [1]

(or any answer to the same effect)

(ii) Explain why the gold foil should be very thin.

the **α** particles must only be scattered once **B1**

Or

- the **α** particles must not be absorbed by the foil .... **B1** [1]

(or any answer to the same effect)

(iii) State what can be deduced, from the following observations, about the structure of the atom and the properties of the gold nucleus:

1. A high count rate is detected by the *α*-particle detector in position 1.

Most of the **α** particles pass straight through as the atom consists mainly of open space

[1]

2. A low count rate is detected by the α-particle detector in position 2.

The nucleus is positively charged or

the nucleus is very small **in comparison to the size of an atom** or

the nucleus is very massive

(any two answers) [2]

(b) The graph in Fig. 8.2 shows how the binding energy per nucleon varies with mass number. Nuclei on the left of Fe-56 tend to undergo nuclear fusion while those to the right tend to undergo nuclear fission.

Fig. 8.2

Both fission and fusion are processes that involve the release of a huge amount of energy. However fusion is often said to be a more "mass-energy efficient" process than fission, yielding about six times as much energy per gram of active material as fission.

(i) State what is meant by the *binding energy* of a nucleus.

Binding energy of a nucleus refers to the amount of energy required to break it apart into its separate constituents of protons and neutrons. **B1**

nucleons separated to infinity / completely ……………………. **B1**

[2]

(ii) Explain why binding energy per nucleon is an indicator of the stability of a nucleus.

A nucleus with a higher binding energy per nucleon means that a greater amount of energy is required to completely separate a nucleon.

OR

A nucleus with a higher binding energy per nucleon means that a greater amount of energy is released when a nucleon is assembled.

For Examiner's Use

....

.... [2]

(c) A stationary radon nucleus may decay spontaneously into a polonium nucleus and an α-particle as shown:

$$^{222}_{86}\mathrm{Rn} \rightarrow {}^{218}_{84}\mathrm{Po} + {}^{4}_{2}\mathrm{He}$$

The rest-masses of the nuclei are:

$$^{222}_{86}\mathrm{Rn} = 222.0176\ u$$

$$^{218}_{84}\mathrm{Po} = 218.0090\ u$$

$$^{4}_{2}\mathrm{He} = 4.0026\ u$$

(i) Calculate the kinetic energy of the products in the above reaction.

Decrease in mass of nuclei after reaction

$= 222.0176\ u - 218.0090\ u - 4.0026\ u$

$= 0.0060\ u$

Total kinetic energy of products = energy released in reaction

= energy equivalence of loss in mass

$= (0.0060\ u)\ c^2$

$= (0.0060)(1.66 \times 10^{-27})(3.00 \times 10^{8})^2$

$= 9.0 \times 10^{-13}$ J

kinetic energy = ... J [3]

(ii) State the principle of conservation of momentum.

In the absence of external forces, the total momentum of bodies in a system remains constant.

.... [1]

For Examiner's Use

(iii) Hence, determine the speed of the polonium nucleus and α-particle.

Total momentum is unchanged;

$0 = p_{Po} - p_{\alpha}$

$p_{Po} = p_{\alpha} = p$

Ratio of $(m_{\alpha} / m_{Po}) = 4/218$

$E_{Po} / E_{\alpha} = (p^2/2m_{Po}).(2m_{\alpha}/p^2) = (m_{\alpha} / m_{Po}) = 4/218$

$E_{Po} + E_{\alpha} = E_T$

$E_{\alpha} (1+ (4/218))= E_T$

$E_{\alpha} = E_T (218/222) = 9.0 \times 10^{-13} \text{ x } (218/222) = 8.8 \times 10^{-13}$ J

$E_{Po} = E_T - E_{\alpha} = 9.0 \times 10^{-13} - 8.8 \times 10^{-13} = 0.2 \times 10^{-13}$ J

Speed of polonium = $\sqrt{(2\text{x } 0.2 \times 10^{-13} / 218 \text{ x } 1.66^{-27})} = 3.32 \text{ x}10^5$ m s^{-1}

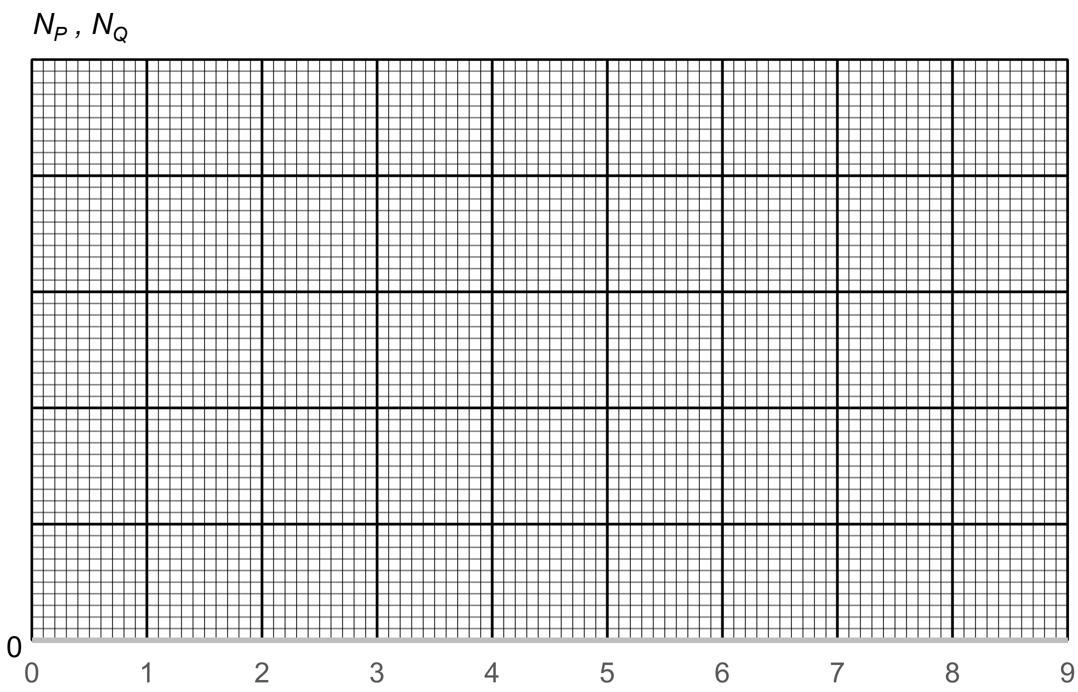
Speed of α-particle = $\sqrt{(2\text{x } 8.8 \times 10^{-13} / 4 \text{ x } 1.66^{-27})} = 1.63 \text{ x}10^7$ m s^{-1}

speed of polonium = …………………… m s^{-1}

speed of α-particle = …………………… m s^{-1} [4]

(d) A radioactive nuclide P undergoes decay to form a stable nuclide Q. P has a half-life of 4.2 hours.

On Fig. 8.3, sketch labelled graphs to show the variation with time *t* of N_p the number of P and N_Q the number of Q nuclei present for a period of 2 half-lives.



[3]

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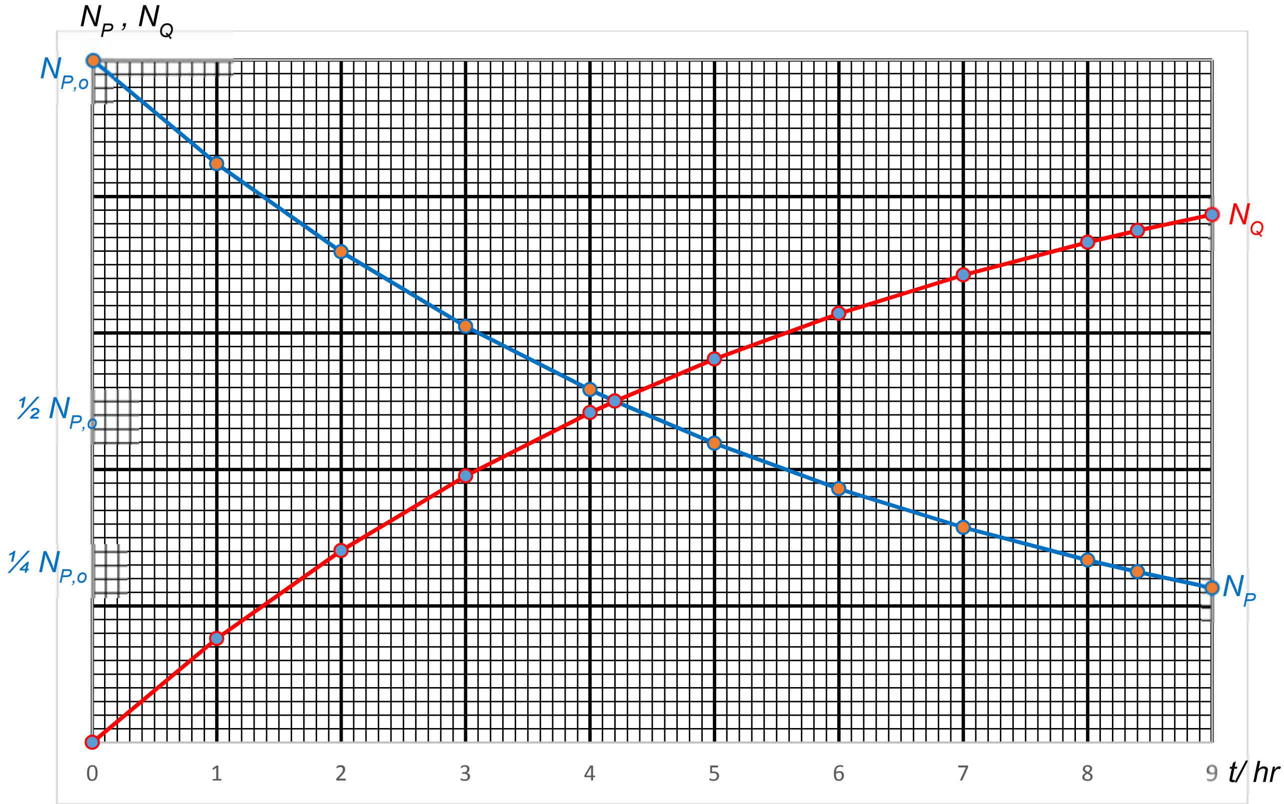

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