NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 1

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS

8867/01

Paper 1 Multiple Choice

Additional Materials: Multiple Choice Answer Sheet

11 Sep 2017

1 hour

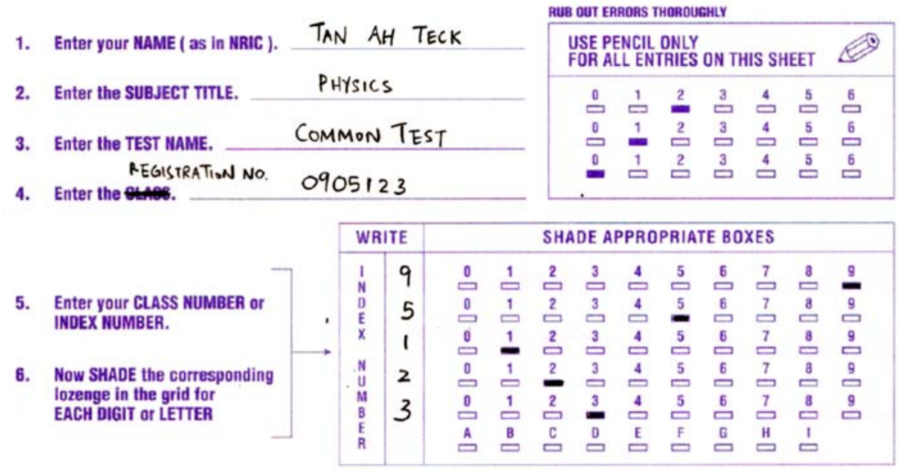
READ THE INSTRUCTION FIRST

There are **thirty** questions on this paper. Answer **all** questions. For each question there are 4 possible answers, **A, B, C** and **D.** Choose the **one** you consider correct and **shade** your choice in the boxes on the OAS.

Fill in the following information on the **Optical Answer Sheet** (OAS) provided.

Use a soft pencil (B or 2B). Rub out any answer you wish to change.

The Index Number is a 5 digit format, which is made up of the 2nd digit and the last four digits of the student's Registration Number. For e.g. If student's Reg Number is 0**9**0**5123**, then the OAS registration number will be **95123**.



.

This document consists of 15 printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ ms^{-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	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall	$g = 9.81$ ms^{-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	$1/R = 1/R_1 + 1/R_2 + \cdots$

1 Which of the following ratios is **wrong**?

A The ratio of the size of an atom's diameter to the diameter of a nucleus is of the order of 10^5 : 1.

B The ratio of the mass of an electron to the mass of a proton is 1 : 1836.

C The ratio of the period of a 100 kg satellite orbiting the Earth to the period of a 200 kg satellite orbiting Earth at twice the distance 2R is 1 : 2.8.

D The ratio of the speed of an electron orbiting the atom to the speed of light is 1 :10.

2 The diameter of a wire, known to be 0.27 mm at room temperature, is measured with an instrument that gives readings to 0.001 mm.

Readings are taken, at room temperature, at three different points along the wire. Two perpendicular values are taken at each point.

The six readings obtained, in mm, are 0.247, 0.247, 0.248, 0.248, 0.249 and 0.247.

Which statement is true?

A The readings are accurate since the spread of the values is within 0.002 mm.
B The readings are precise since all the values are recorded to the third decimal place.
C The readings are inaccurate since the readings are consistently less than the actual value.
D The readings are not precise since the readings are consistently less than the actual value.

3 A radio aerial of length *L* emits a signal of wavelength *λ* and power *P* when the current is *I*. These quantities are related by

$$P = kI^2L^2\lambda^{-2}$$

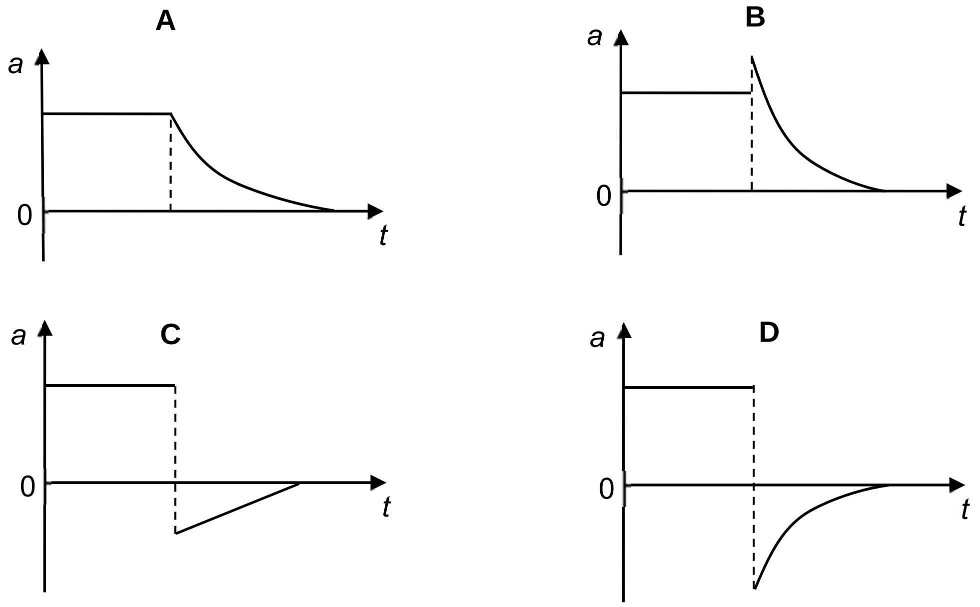
where *k* is a constant.

Which SI base unit, if any, should be used for the constant *k*?

A kg m^2 s^{-3} A^{-2}
B kg m^2 s^{-3} A^{-1}
C kg m^2 s^{-3}
D no unit

4 A small sphere is dropped from rest at a height of one metre from the surface of a viscous liquid. From the point of entering the liquid, the sphere slows down due to a viscous force that is proportional to its velocity.

Which one of the following graphs most clearly represents the variation of acceleration a with time t of the sphere?

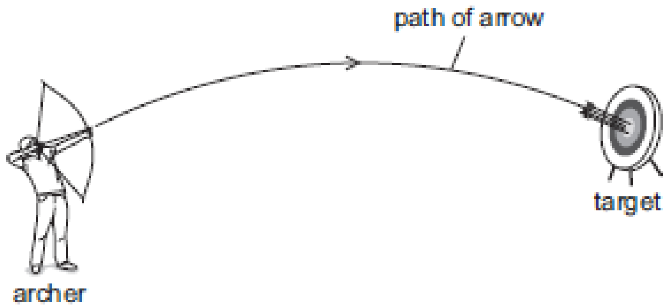


5 A coin of mass *m* is dropped from the top of a tall building. The acceleration of free fall is *g.*

When the coin is falling at a constant velocity, which of the following information about the coin is correct?

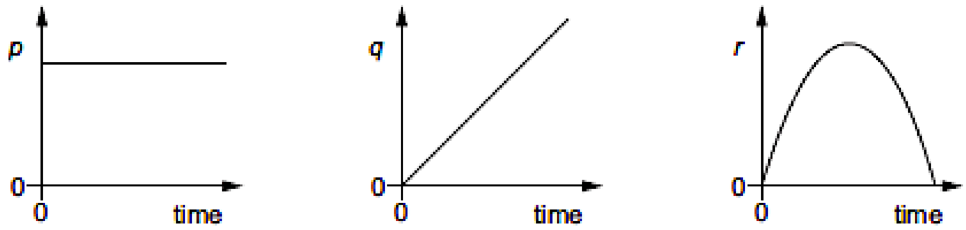
	Magnitude of the acceleration	Magnitude of the force of gravity	Magnitude of the force of air resistance
A	*g*	zero	*mg*
B	zero	*mg*	*mg*
C	zero	zero	*mg*
D	zero	*mg*	zero

6 An archer shoots an arrow at a target. The diagram shows the path of the arrow.



Air resistance is assumed to be negligible.

The graphs show how three different quantities, *p*, *q* and *r*, relating to the motion of the arrow vary with time.



Which quantity is the horizontal component of displacement and which quantity is the vertical component of displacement of the arrow?

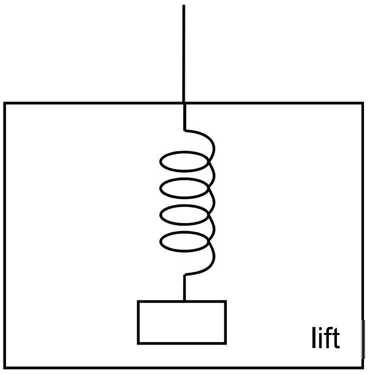
	Horizontal component of displacement	Vertical component of displacement
A	*q*	*r*
B	*p*	*q*
C	*r*	*p*
D	*r*	*q*

7 In an ice-hockey match, two players skated towards each other. After colliding head-on, only one of them was thrown backward.

The player was thrown backwards because he

A exerted a smaller force on the other player.
B had a smaller initial momentum.
C had a lower initial speed.
D had a smaller mass.

8 A light spring of unstretched length 25.0 cm is suspended from the ceiling of a lift. A mass is hung from the end of the spring as shown in the diagram.



When the lift is moving downwards at a constant speed, the length of the spring is 50.0 cm. The lift then slows down with a constant acceleration of 4.0 m s^{-2} and the spring is

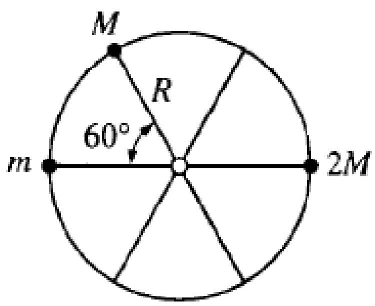
A shortened by 10.2 cm.

B extended further by 10.2 cm.

C shortened by 20.4 cm.

D The spring extended further by 20.4 cm.

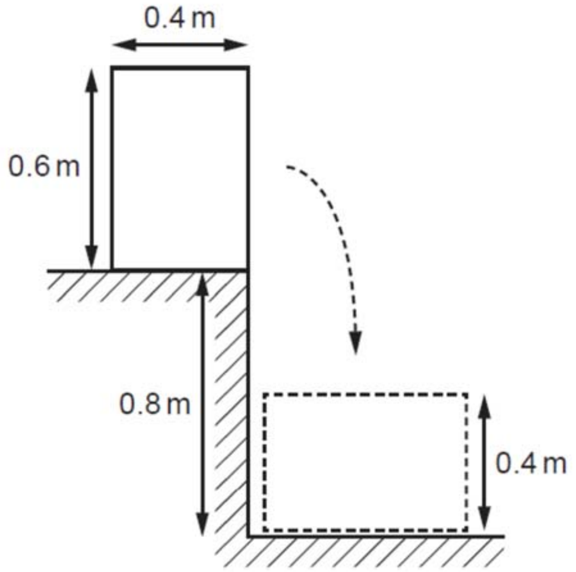
9 A wheel of radius *R* and negligible mass is mounted on a horizontal frictionless axle so that the wheel is in a vertical plane. Three small objects, each of masses *m*, *M* and 2*M*, respectively, are mounted on the rim of the wheel as shown in the diagram.



If the system is in static equilibrium, the value of *m* in terms of *M* is

A *M* / 2 **B** *M* **C** 3*M* / 2 **D** 5*M* / 2

10 A uniform solid block has a weight 500 N, width 0.4 m and height 0.6 m. The block rests on the top a ledge that is 0.8 m from the floor, as shown in the diagram.

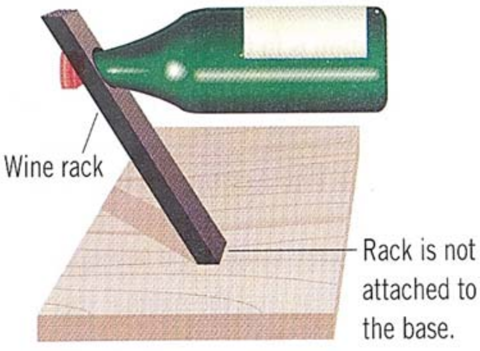


The block is knocked over the edge of the ledge and landed on the floor after rotating 90° clockwise.

What is the change in gravitational potential energy of the block?

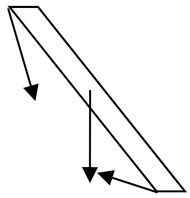
A 300 J **B** 400 J **C** 450 J **D** 550 J

11 The diagram shows a wine rack with a bottle of wine that is balanced on the table.

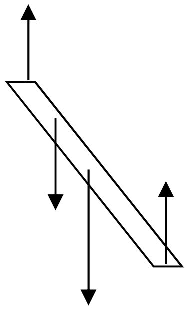


Which of the following diagrams correctly shows the directions of the forces acting on the wine rack?

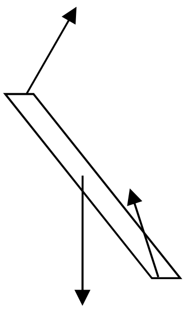
A



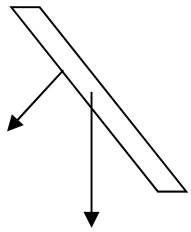
B



C



D



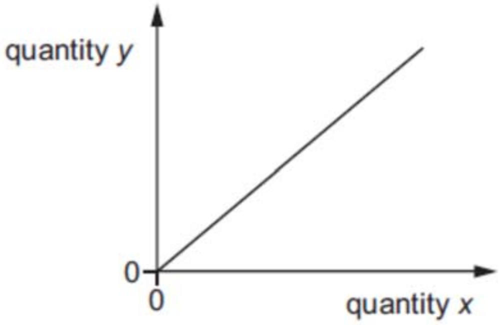
12 An escalator in an underground station has 250 people standing on it and is moving with a velocity of 4.3 m s^{-1}. The average mass of a person is 78 kg and the angle of the escalator to the horizontal is 40°.

What is the minimum power required to lift these people?

A 54 kW **B** 64 kW **C** 530 kW **D** 630 kW

[Turn Over

13 The graph shows the variation of a quantity y with a quantity x for a body that is falling in air at terminal velocity in a uniform gravitational field.



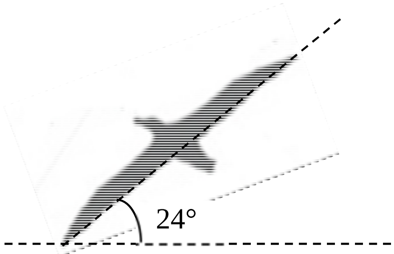
Which quantities could *x* and *y* represent?

	x	*y*
A	loss of potential energy	work done against air resistance
B	loss of height	gain in kinetic energy
C	air resistance	acceleration
D	time	velocity

14 A stone is attached to a string of negligible mass and then made to rotate in a vertical circle. Which of the following statements is false?

A The angle of the string to the vertical cannot be zero as it rotates.
B The velocity of the stone is the same as long as the stone is at the same height from the ground.
C The magnitude of the tension is increasing when the stone moves from the highest position to the lowest position.
D The difference in the tension when the stones is at the top and the bottom of the circle is proportional to the mass of the stone.

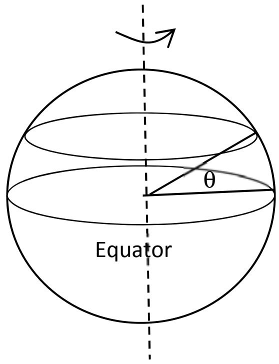
15 A bird is soaring in a horizontal circular path of radius 2.0 m. Its bank angle relative to the horizontal is 24° as shown in the diagram below.



What is the speed of the bird?

A 1.5 m s^{-1} **B** 3.0 m s^{-1} **C** 6.6 m s^{-1} **D** 8.7 m s^{-1}

16 The earth has a radius of 6.38×10^6 m, and rotates on its axis once every 24 hours. At what latitude (i.e., the angle in the drawing) is the tangential speed of a person one third that of a person living at the equator?



A 20.5° **B** 30.5° **C** 60.5° **D** 70.5°

17 The Moon remains in its orbit around the Earth rather than falling towards the Earth because

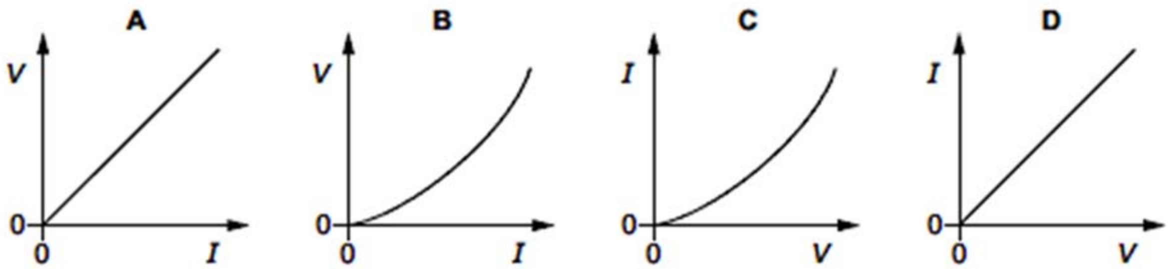
A the net force on the Moon is zero.

B it is outside of the gravitational influence of the Earth

C it is in balance with the gravitational forces from the Sun and other planets.

D the gravitational force exerted by the Earth on the Moon provides the net force that causes the Moon's centripetal acceleration.

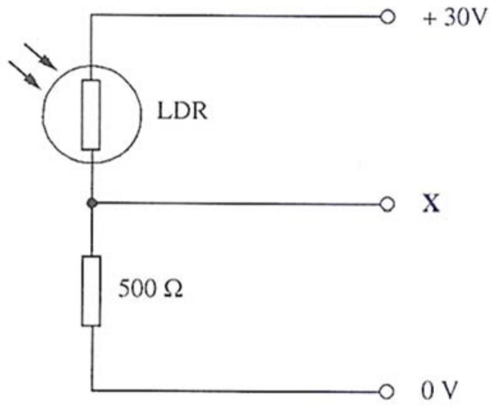
18 Which graph represents a metallic conductor, where the resistance of the conductor is given by the gradient of the graph?



19 A typical mobile phone battery has an e.m.f. of 5.0 V and an internal resistance of 200 mΩ. What is the terminal p.d. of the battery when it supplies a current of 500 mA?

A 4.8 V **B** 4.9 V **C** 5.0 V **D** 5.1 V

20 The light dependent resistor (LDR) and a 500 Ω resistor form a potential divider between voltage lines held at +30 V and 0 V as shown in the diagram.



The resistance of the LDR is 1000 Ω in the dark but then drops to 100 Ω in bright light. What is the corresponding change in the potential at X?

A A decrease of 25 V

B A decrease of 15 V

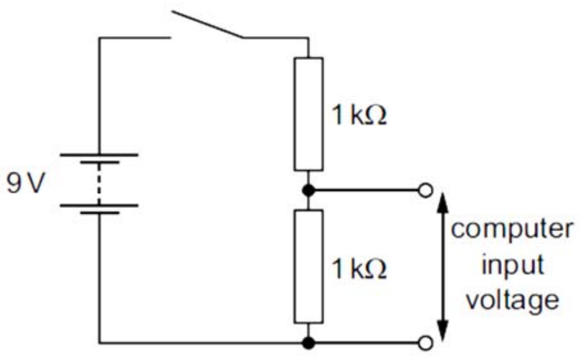
C An increase of 10 V

D An increase of 15 V

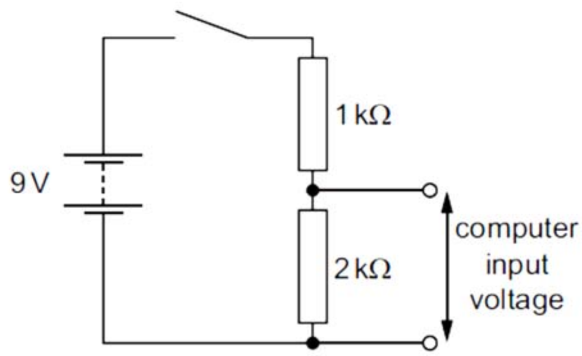
21 A computer is used to detect the change of position of a switch. To detect the change of position, the computer requires a potential difference (p.d.) of 0 V to its input at one switch position and a p.d. of between 5 V and 7 V at the other switch position.

For each of the circuits, assume the battery has negligible internal resistance. Which circuit provides an input voltage to the computer that enables it to detect the change of position of the switch?

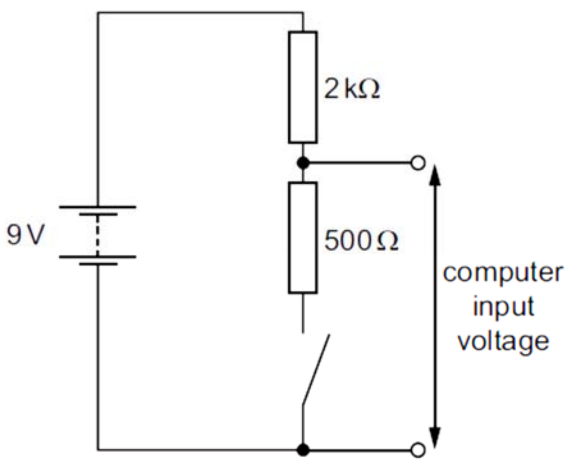
A



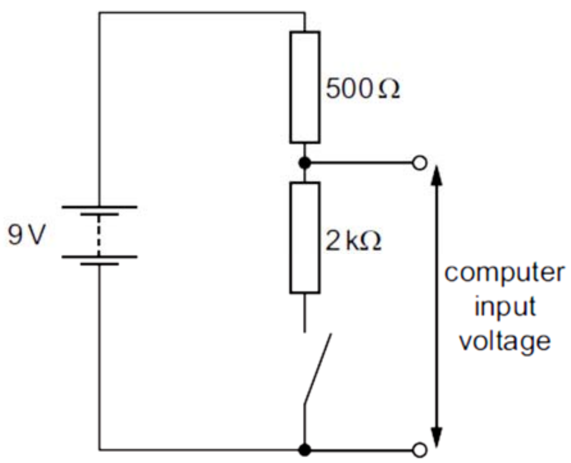
B



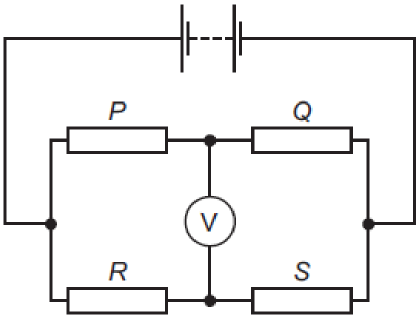
C



D



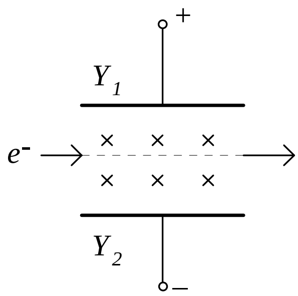
22 The circuit diagram shows four resistors of different resistances *P*, *Q*, *R* and *S* connected to a battery.



The voltmeter reading is zero. Which equation is correct?

A *PS* = *QR*
B *PQ* = *RS*
C *P* - *S* = *Q* - *R*
D *P* - *Q* = *R* - *S*

23 In a classical experiment to measure the charge to mass ratio, an electron of mass *m* is accelerated from rest through a p.d. *V* (not shown) and then passes without any deflection through a region with mutually perpendicular electric and magnetic fields.



The electric field is provided by the deflecting plates Y_1, Y_2 with p.d. *V* and separation *d*. The applied uniform magnetic field is *B*. The charge to mass ratio (*e*/*m*) of an electron is given by

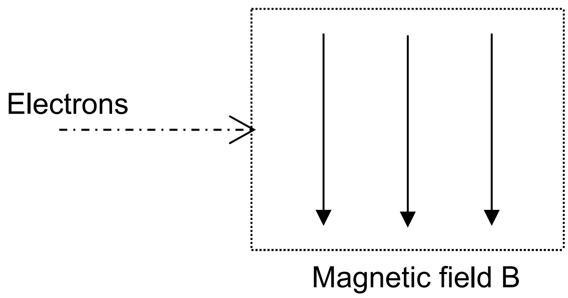
A $\dfrac{V}{2B^2d^2}$ **B** $\dfrac{2B^2d^2}{V}$ **C** $\dfrac{B^2d^2}{2V}$ **D** $\dfrac{2V}{B^2d^2}$

24 A vertical wire 0.40 m long carries a current of 5.0 A is placed in a magnetic field of uniform flux density 1.0 mT. The magnetic field dips at an angle of 30° relative to the horizontal.

The force on the wire is

A 0.87×10^{-3} N **B** 1.0×10^{-3} N **C** 1.5×10^{-3} N **D** 1.7×10^{-3} N

25 An electron enters a region of uniform magnetic field with constant speed.



The direction of the force acting on the electron when it just enters the magnetic field is

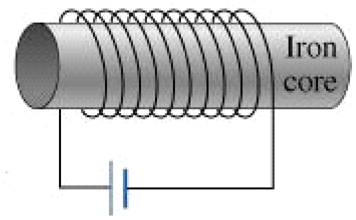
A downwards parallel to the plane of the paper

B upwards parallel to the plane of the paper

C out of the plane of the paper

D into the plane of paper

26 A soft iron core is inserted into the solenoid as shown in the diagram



The magnetic flux density at the end of the solenoid increases because the iron core

A increases the current in the circuit.

B concentrates the magnetic field lines.

C creates more magnetic field lines.

D reduces the resistance of the circuit.

27 A uranium-238 nucleus ($^{238}_{92}U$) decays into uranium-234 ($^{234}_{92}U$) by

A emitting four β-particles

B emitting four γ-rays

C emitting one α-particle and two β-particles

D emitting two α-particles and eight β-particles

28 The number of radioactive nuclides in two different samples *P* and *Q* are initially 4*N* and *N* respectively. If the half-life of *P* is *t* and that of *Q* is 2*t*, the number of radioactive nuclides in *P* will be the same as the number of radioactive nuclides in *Q* after a time of

A $t / 2$ **B** $2t$ **C** $4t$ **D** $8t$

29 A parent nucleus, initially at rest, decays into two particles of masses m_1 and m_2, moving away from each other in opposite directions. If the decay releases energy *E*, what is the kinetic energy of mass m_1?

A $\frac{m_1}{m_2}E$ **B** $\frac{m_2}{m_1}E$ **C** $\frac{m_2}{m_1+m_2}E$ **D** $\frac{m_1}{m_1+m_2}E$

30 Hydrogen bombs operate with tritium, a radioactive isotope of hydrogen with a half-life of 1.7×10^8 s. It has been proposed that if the production of tritium were halted, countries storing hydrogen bombs would have to replenish supplies from existing bombs. Eventually there would not be enough tritium to make any bombs.

A country has a stockpile of 2000 hydrogen bombs. What is the shortest duration that the world had to wait for the country to be unable to make a single bomb?

A 54 years **B** 60 years **C** 10 800 years **D** 1.7×10^9 years

END OF PAPER

Paper 1

Answer key

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

Highlighted in yellow: Same as H2

Red font: Amended

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 1

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

8867/02

Paper 2 Structured Questions **(Section A)**

28 Aug 2018

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name 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 or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answers **all** questions.

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	
1	**/ 8**
2	**/ 8**
3	**/ 7**
4	**/ 10**
5	**/ 7**
6	**/ 20**
Total ~~(60m)~~	**/ 60**

Formatted: Right

Formatted: Font: Bold, Complex Script Font: Bold

This document consists of 15 printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\ \text{ms}^{-1}$
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	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$
acceleration of free fall	$g = 9.81\ \text{ms}^{-2}$

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	$1/R = 1/R_1 + 1/R_2 + \cdots$

[Turn over

Section A (60 marks)

1 A student measures the acceleration of free fall g in an experiment. He releases the ball from rest above the ground and uses a stopwatch to measure the time taken by the ball to hit the ground.

(a) Explain whether the source of error in the time measurement a random error or systematic error.

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

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

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

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

(b) The height of release of the ball is (0.800 ± 0.001) m and the stopwatch reading is (0.35 ± 0.01) s.

(i) Calculate the value of g.

g = ……………… m s^{-2} [1]

(ii) Calculate the actual uncertainty in g.

actual uncertainty in g = ……………… m s^{-2} [2]

(iii) State the value of g and its actual uncertainty to the appropriate number of significant figures.

g = ……………… ± ……………… m s^{-2} [1]

(c) The accepted value for g is 9.81 m s^{-2}.

Suggest, with a reason, why the design of this experiment may not be suitable for the measurement of g.

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

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

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

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

[Turn over

2 An experiment is conducted to measure the standing vertical jump height of a person.

A skilled jumper is employed as the test subject. He stands on a platform embedded with a force sensor. He then exerts maximum effort to jump vertically off the platform. Fig 2.1 shows the stick figures representing 5 different positions of the jumper at successive times. Assume air resistance is negligible.

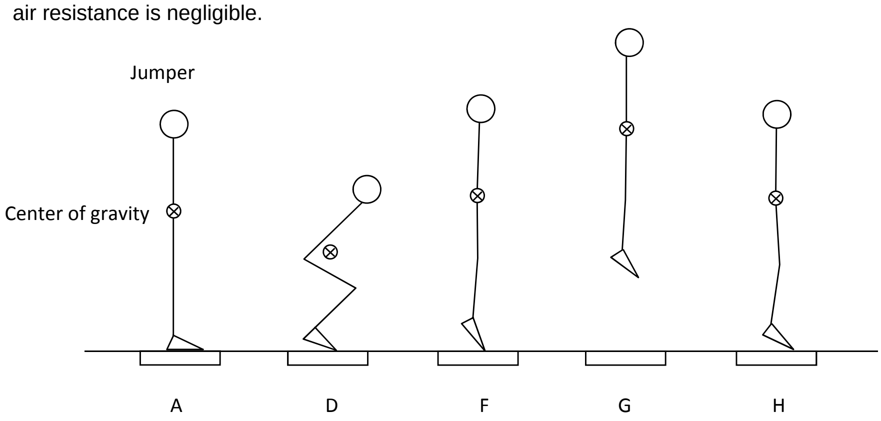


Fig. 2.1

The variation with time of the total force F exerted by the feet on the platform is shown in the graph in Fig 2.2. The time t = 0.80 s is the instant of take-off.

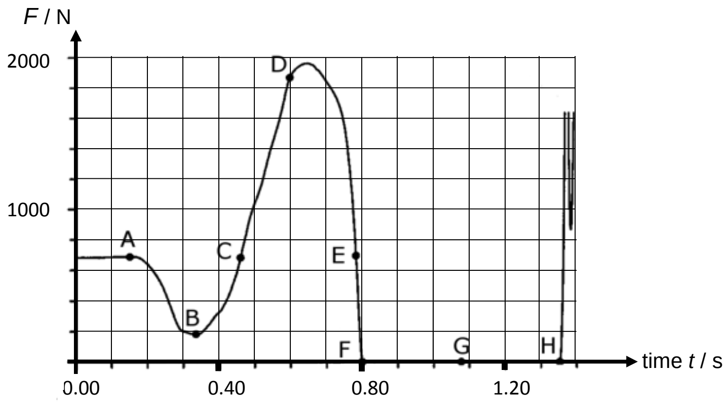


Fig. 2.2

(a) Draw and label the forces on the stick figure in Fig. 2.1 to show the forces acting on the jumper when he is in position D. [1]

(b) **(i)** Use Fig. 2.2 to determine the length of time t_a the jumper is completely airborne. **Indicate the length of time t_a clearly on fig. 2.2**.

t_a = ……………… s [1]

[Turn over

2 **(b)** **(ii)** Show that the vertical velocity v_0 at the instant of take-off is 2.7 m s^{-1}.

[1]

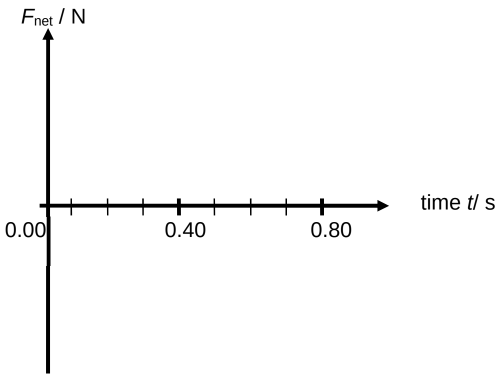
(iii) Hence, calculate the maximum vertical jump height, *h*.

h = ………………. m [2]

(c) By considering all forces acting on the jumper from A to F only, a second method can be used to determine the take-off velocity v_0 which is used to calculate *h*.

(i) Draw a line on the graph in Fig. 2.2 to represent the weight of the jumper. Label this line *W*. [1]

(ii) Hence, sketch the variation with time of the net force F_{net} acting on the jumper from t = 0.00 to 0.80 s (from A to F) on the axes provided in Fig. 2.3.



[1]

Fig. 2.3

(iii) Explain how the vertical velocity v_0 can be calculated from the graph of F_{net} against time.

…………………………………………………………………………………………………

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

[Turn over

3 Fig. 3.1 shows a model of a system being designed to move concrete building blocks from an upper to a lower level.

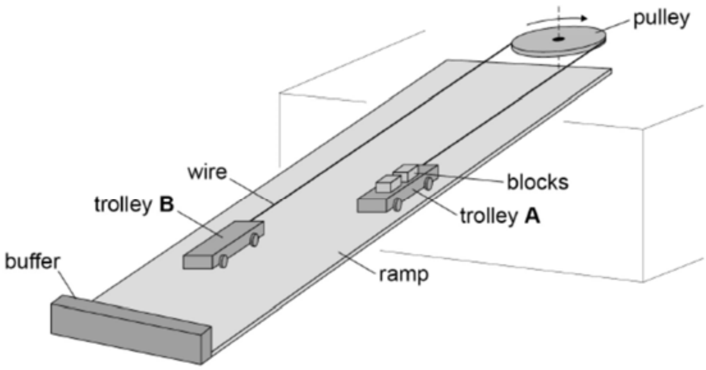


Fig. 3.1

The model consists of two identical trolleys of mass M on a ramp which is at 35° to the horizontal. The trolleys are connected by a light wire that passes around a pulley of negligible mass at the top of the ramp.

Two concrete blocks each of mass m are loaded onto trolley **A** at the top of the ramp. The trolley is released and accelerates to the bottom of the ramp where it is stopped by a flexible buffer. The blocks are unloaded from the trolley **A** and two blocks are loaded onto trolley **B** that is now at the top of the ramp. The trolleys are released and the process is repeated.

Fig. 3.2 shows the side view of trolley **A** when it is moving down the ramp.

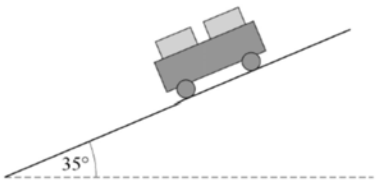


Fig. 3.2

(a) The tension in the wire when the trolleys are moving is T.

Draw and label arrows on Fig. 3.2 to represent the magnitudes and directions of any forces and components of forces acting on trolley **A** parallel to the ramp as it travels down the ramp. [1]

3 **(b)** Assume that no friction acts at the axle of the pulley or at the axles of the trolleys and that air resistance is negligible.

Show that the acceleration a of trolley **A** along the ramp is given by

$$a = \frac{mg \sin 35°}{M + m}$$

[2]

(c) In practice, for safety reasons there is a friction brake in the pulley that provides a resistive force to reduce the acceleration to 25% of the maximum possible acceleration.

(i) Suggest and explain why this friction brake is necessary for the set up in Fig. 3.1.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

(ii) The distance travelled for each journey down the ramp is 9.0 m.

The mass of the trolley is 95.0 kg while the mass of the concrete block is 30.0 kg.

Calculate the time taken for a loaded trolley to travel down the ramp.

time taken = ………………….. s [2]

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

……

……[1]

(b) A child's pogo stick comprises of a spring with spring constant of 1.50×10^4 N m^{-1}. The combined mass of the child and pogo stick is 25.0 kg.

Fig. 4.1 shows the various instances of a child jumping with the pogo stick.

Instance **A**, the spring compression is a maximum and the child is momentarily at rest. The foot rest is 0.200 m below the reference level.

Instance **B**, the spring is relaxed and the child is moving upward.

Instance **C**, the child is again momentarily at rest and at the top of the jump.

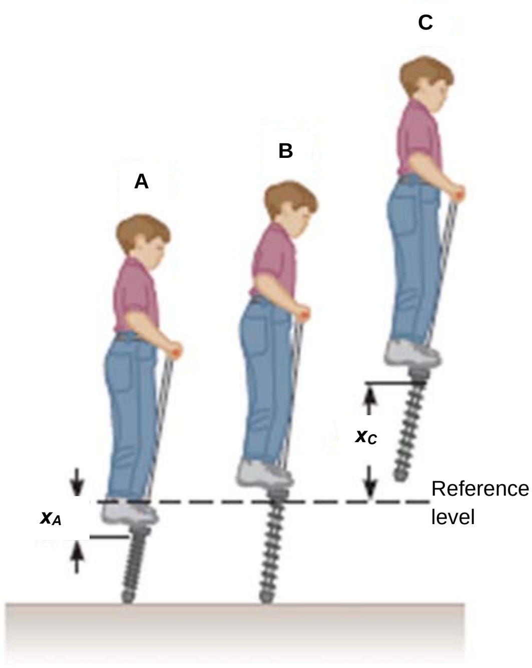


Fig. 4.1

4 **b** **(i)** State the energy changes from instance A to C. Numerical values are not required.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………..[3]

(ii) Determine the value for $\boldsymbol{x_C}$.

$\boldsymbol{x_C}$ = ………………….m [2]

(iii) Determine the maximum speed of the child.

maximum speed = ……………….. m s^{-1} [3]

(iv) State and explain the position of the child relative to instance **B** when maximum speed is attained.

…………………………………………………………………………………………

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

5 **(a)** The age of a piece of bone recovered from an archaeological site may be estimated by Carbon-14 (^{14}C) dating. All living organisms absorb ^{14}C but there is no further intake after death. The proportion of ^{14}C is constant in living organisms.

A 1.0 g sample of a bone from an archaeological site has an average rate of decay of 5.2 Bq due to ^{14}C. A 1.0 g sample of a bone from a modern skeleton has a rate of decay of 6.5 Bq. The counts are corrected for background radiation.

Calculate the age, in years, of bone from the archaeological site.
(half life of ^{14}C = 5730 years)

age = ………………… years [3]

(b) A Uranium-235 ($^{235}_{92}U$) nucleus undergoes fission to produce nuclei of Lanthanum-146 ($^{146}_{57}La$) and Bromine-87 ($^{87}_{35}Br$). The reaction may be represented by the equation

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{146}_{57}La + ^{87}_{35}Br + 3^{1}_{0}n + \text{energy}$$

The binding energies per nucleon of these nuclides are shown below.

nuclide	binding energy per nucleon / MeV
$^{235}_{92}U$	7.6
$^{146}_{57}La$	8.2
$^{87}_{35}Br$	8.6

(i) Use the information from the table to calculate the energy released when a $^{235}_{92}U$ nucleus undergoes fission.

Energy = ……………………… MeV [3]

[Turn over

5 (b) (ii) Explain why the binding energy of the neutron is not used in the calculation of the answer in **(b)(i)**.

………

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

6 Solar cells are used in some appliances for the generation of electrical energy. When light energy is incident on the surface of such a cell, an e.m.f. is generated between the terminals of the cell. Connections of a resistor between these terminals will result in a current and electrical power dissipation in the resistor.

The variation with output potential difference *V* of the current *I* from a solar cell may be investigated using the circuit of Fig. 6.1.

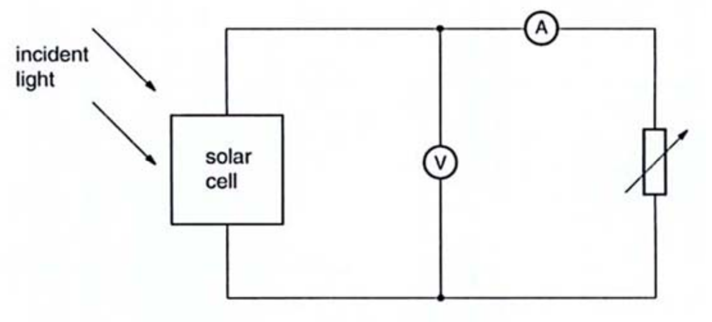


Fig. 6.1

The ammeter has negligible internal resistance and the voltmeter has a very high resistance. Light of constant intensity is incident on the solar cell. The *I* / *V* characteristic of one type of solar cell, when it is illuminated with a certain intensity of light is shown in Fig. 6.2.

6

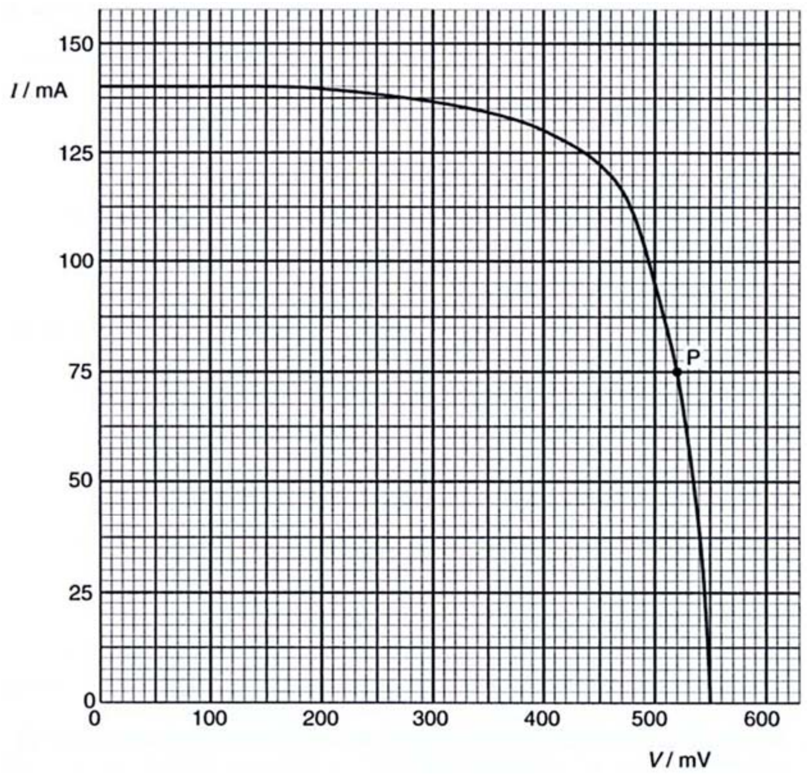


Fig. 6.2

(a) **(i)** Determine the current from the solar cell for an output potential difference of 400 mV.

current = …………………… mA [1]

(ii) Explain how the graph shows that the e.m.f. of the solar cell is 550 mV.

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

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

(iii) Use your answers to (i) and (ii) to determine the internal resistance of the cell at an output potential difference of 400 mV.

Internal resistance = …………………… Ω [2]

[Turn over

6 **(b)** **(i)** Determine the power dissipation in the load resistor for point P on Fig. 6.2.

power dissipation = …………………… W [3]

(ii) On Fig. 6.2, shade an area that represents the power dissipation calculated in **(b)(i)**. [2]

(c) **(i)** By reference to your answer in (b)(ii), state whether the power dissipated in the load resistor increases, stays the same, or decreases when the current

1. increases from 30 mA to 100 mA,

……………………………………………………………………………………..[1]

2. increases from 125 mA to 135 mA,

……………………………………………………………………………………[1]

(ii) Hence, or otherwise, mark with the letter **M** the approximate point on Fig. 6.2 at which the power dissipation is a maximum. [1]

6 **(d)** The solar cell is connected to a load resistor of resistance 4.2 Ω.

(i) Fig. 6.3 is the same graph as Fig. 6.2.

On Fig 6.3, draw a line to show the variation with current *I* of the potential difference *V* across the resistor. [2]

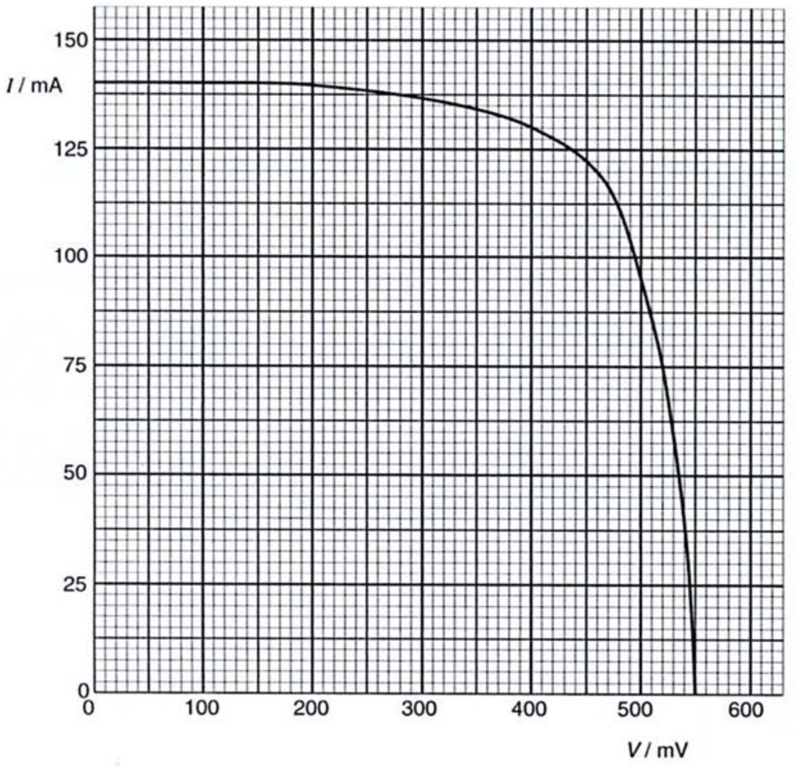


Fig. 6.3

(ii) The cell is illuminated with the same intensity of light as before. The printed curve of Fig. 6.3 is the *I* / *V* characteristics of the solar cell.

Determine the power dissipation in the load resistor.

power dissipation = …………………… W [2]

[Turn over

6 **(e)** A number of identical solar cells of a different type produce an output power of 75 mW at an output potential difference of 0.50 V.

Each cell maybe presented by the symbol shown in Fig. 6.4.

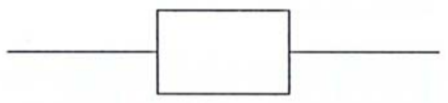


Fig. 6.4

Draw suitable arrangements of solar cells so that the cells may be used to provide

(i) a power of 150 mW at a potential difference of 1.0 V, [1]

(ii) a power of 150 mW at a potential difference of 0.5 V, [1]

(i) a power of 300 mW at a potential difference of 1.0 V. [2]

End of Section A

[Turn over

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 1

CANDIDATE NAME

SUBJECT CLASS | REGISTRATION NUMBER

PHYSICS

Paper 2 Structured Questions **(Section B)**

8867/02

28 Aug 2018
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

For Examiner's Use	
7	**/ 20**
8	**/ 20**
Total	**/ 20**

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name 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 or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section B
Answer any **one** question.

You are advised to spend 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.

This document consists of 10 printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ ms^{-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	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall	$g = 9.81$ ms^{-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	$1/R = 1/R_1 + 1/R_2 + \cdots$

Section B (20 marks)

7 An executive toy consists of five identical steel spheres of mass m suspended so that they are free to move in a vertical plane as shown in Fig. 7.1. Each sphere is suspended using thin inextensible strings of negligible mass.

You may assume that collisions between the spheres are perfectly elastic and air resistance is negligible

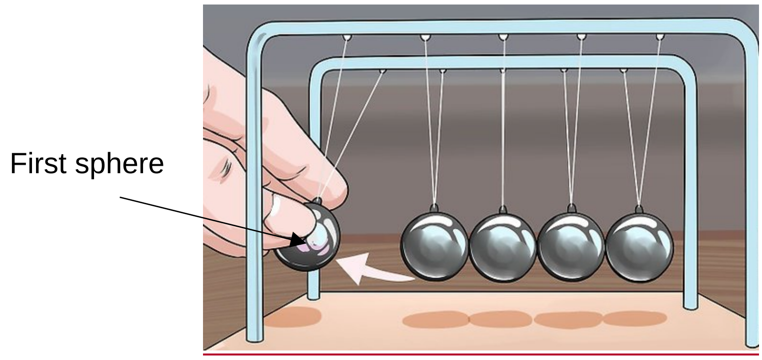


Fig. 7.1

(a) The first sphere is displaced to the left and then released. Describe and explain the resulting motion of the five spheres.

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

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

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

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

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

…………………………………………………………………………………………………[3]

7 **(b)** **(i)** Object **A** has a velocity of u and moves horizontally towards Object **B** which is at rest. The collision between both objects is head-on and perfectly elastic.

The ratio of the mass of Object **A** to the mass of Object **B** is **1:2**.

Determine the ratio of the **final** velocity of Object **B** to the initial velocity of Object **A**.

ratio = …………………….[2]

(ii) Object **C** has a velocity of u and moves horizontally towards Object **D** which is at rest. The collision between both objects is head-on and perfectly elastic.

The ratio of the mass of Object **C** to the mass of Object **D** is **2:1**.

Determine the ratio of the final velocity of Object **D** to the initial velocity of Object **C**.

ratio = …………………..[1]

(iii) Hence, if the **second and fourth spheres are replaced with steel spheres of mass 2*m*** of the executive toy in Fig. 7.1, determine the ratio of

$$\frac{\text{Maximum vertical displacement of the first sphere}}{\text{Maximum vertical displacement of the last sphere}}$$

Assume that the collision between both objects is head-on and perfectly elastic.

Ratio = …………….. [2]

(c) State and explain one significant difference to the motion observed if all the thin inextensible strings are replaced by springs of negligible mass.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

7 **(d)** A stream of positively charged alpha particles ${}^{4}_{2}He$ from a nuclear reaction is accelerated and sent into a mass spectrometer as shown in Fig. 7.2. The figure shows a mass spectrometer consisting of a velocity selector (Stage 1) and an ion separator (Stage 2), all in a vacuum.

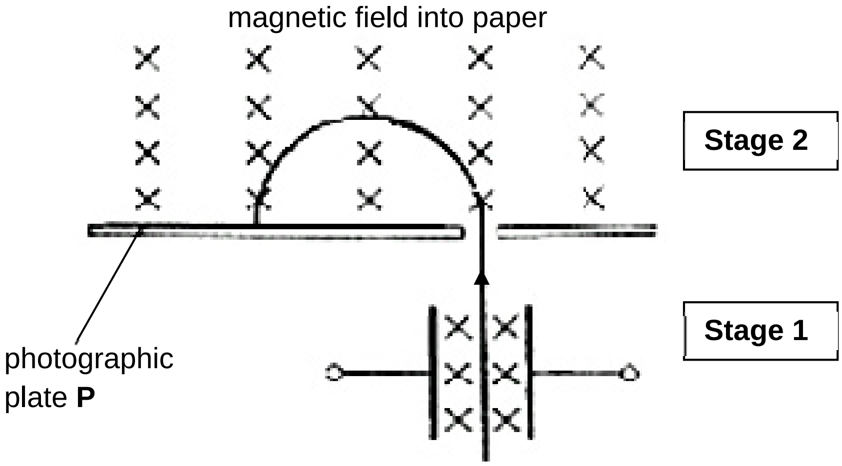
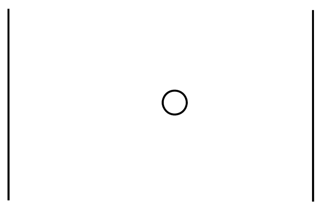


Fig. 7.2

Stage 1
The alpha particles produced in have a range of speeds after acceleration. A velocity selector is used to isolate the alpha particles with a particular speed. The plates producing the electric field have a separation of 1.0 cm. A uniform magnetic field is applied between the plates.

(i) Mark clearly in the diagram below, the direction of the electric force and magnetic force with arrows labelled F_E and F_B respectively. [2]



(ii) Describe and explain the path of alpha particles with speed less than *v*.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

7 (e) Stage 2

After velocity selection, alpha particles of speed 1.00×10^5 m s^{-1} are sent into a magnetic field as shown in the Fig. 7.2 in stage 2. The alpha particles are travelling at right angles to the field and are detected using a photographic plate P, placed at an appropriate position. Determine the distance between the point of incidence and the point of impact of the alpha particles on the photographic plate when a magnetic flux density of 0.050 T is used.

distance = ……………………m [2]

(f) A similar spectrometer can be used for detection of beta particles from beta decay. Beta particles typically travel more than 100 times faster than the alpha particles. State the necessary modifications to the spectrometer. Explain the reason.

Stage 1:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Stage 2:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

[4]

8 **(a)** Describe how the alpha scattering experiment provides evidence for

(i) the small size of the nucleus,

…………………………………………………………………………………………

…………………………………………………………………………………………[1]

(ii) a charged nucleus.

…………………………………………………………………………………………

…………………………………………………………………………………………[1]

(b) In 1914, James Chadwick showed that the energies of the beta particles emitted for a radioactive source had a distribution of energies rather than with a distinct single value of energy.

Figure 8.1 shows the energy spectrum for beta particles emitted during the decay of Bismuth-210 ($^{210}_{83}Bi$). The intensity (vertical axis) indicates the number of beta particles emitted with each particular kinetic energy (horizontal axis).

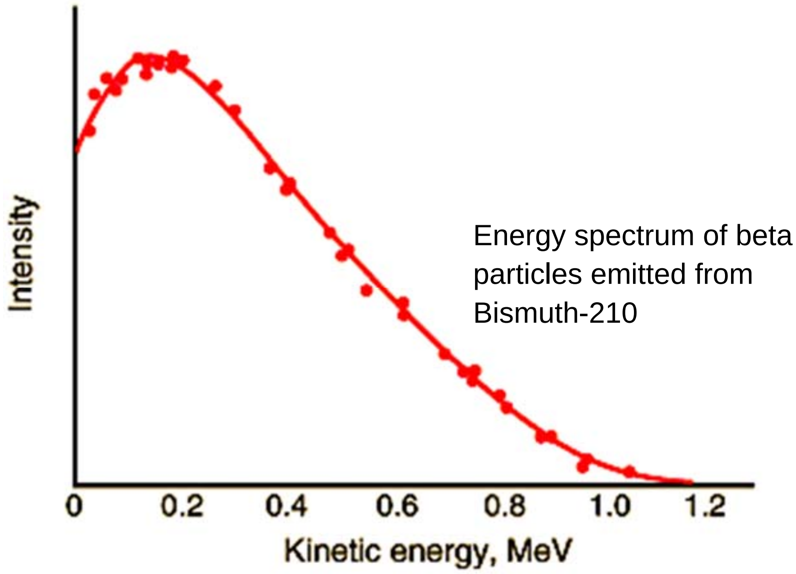


Fig. 8.1

(i) **1.** Determine, from Fig.8.1, *Q*, the maximum possible energy of the beta particle emitted.

Q =……………………… MeV [1]

2. Hence calculate the maximum speed of the beta particle.

Maximum speed =……………………… m s^{-1}

[Turn over

3. Comment on the value you obtained in **b(i)2**.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………[2]

8 (b) (ii) The radioactive isotope of Bismuth, $^{210}_{83}\mathrm{Bi}$, decays into Polonium (chemical symbol: Po) with the emission of a beta particle.

Determine the mass of the resultant Polonium nucleus, in terms of *u*, and express your answer to 3 decimal places. (mass of a $^{210}_{83}\mathrm{Bi}$ nucleus is 209.939 *u*; mass of proton m_p is 1.00729 *u*; mass of neutron m_n is 1.00867 *u*).

mass=……………………. *u* [3]

(iii) From Fig. 8.1, identify the most probable energy for the beta particle.

most probable energy value = ………………… MeV [1]

(iv) It is noted that the stable isotopes of heavy elements have an optimal neutron to proton ratio. Unstable isotopes will undergo transmutation into another element through radioactive decay such that product achieve the optimal ratio.

Suggest, with a reason, whether Bismuth-210 has an excess of neutrons or protons, as compared to the optimal ratio.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………[2]

8 **(a)** **(v)** The continuous spectrum of kinetic energy values of the beta particle presented a problem to physicists up to 1930s. If a stationary nucleus decayed into a beta particle and a stable daughter nucleus only, it should lead to a distinct single value of energy.

Explain, using conservation of linear momentum and energy, how the continuous spectrum of beta particle energies gave rise to this problem.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) **(vi)** Suggest what was proposed by physicists to resolve the problem in **(v)**.

……………………………………………………………………………………………

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

(c) In an experiment, a detector is held a fixed distance from a sample of a radioactive material and the data provided is used to plot a graph of count-rate against time, as shown in Fig 8.2.

Fig. 8.2

(i) Explain why the data points on the graph do not lie on a smooth curve.

……………………………………………………………………………………………

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

(ii) Suggest two reasons why the count-rate recorded is not equal to the activity of the radioactive sample.

1. ……………………………………………………………………………………

……………………………………………………………………………………………

2. ……………………………………………………………………………………

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

(c) **(iii)** The count rate from a counter near a radioactive source is $7.6 \times 10^{8}\ s^{-1}$. The decay constant of the source is $4.6 \times 10^{-3}\ s^{-1}$.

1. Calculate the time taken for the count rate to fall to $8.3 \times 10^{3}\ s^{-1}$.

time = …………………… s [1]

2. When the detector is at a distance *y* from the radioactive source, the count rate is 234 counts per minute.

Calculate the count rate when the detector is at a distance 3*y* from the source.

average count rate = …………………… counts per minute [2]

End of Section B

Paper 2 Solutions

Question 1

1(a) Human reaction time. [1]

random error, as time taken for the student to react to the release of ball and ball hitting the ground fluctuates from measurement to measurement. [1]

(b) (i) $s = \frac{1}{2}gt^2$

$g = 13.06\ m\ s^{-2}$ [1]

(b)(ii) $s = ut + \frac{1}{2}at^2$

$s = \frac{1}{2}gt^2$

$\frac{\Delta g}{g} = \frac{\Delta s}{s} + 2\frac{\Delta t}{t}$

$\frac{\Delta g}{g} = 5.8\%$ [1]

$\Delta g = 13.06 \times 5.8\% = 0.8$ [1]

(b)(iii) $g = 13.1 \pm 0.8\ m\ s^{-2}$ [1]

(c) The time taken is very short (0.35s) compared to the expected human reaction time (0.2-0.7s).[1] Hence it's highly unreliable. [1]

Question 2

2 **(a)** Normal contact force much larger than weight in D. **[1]**

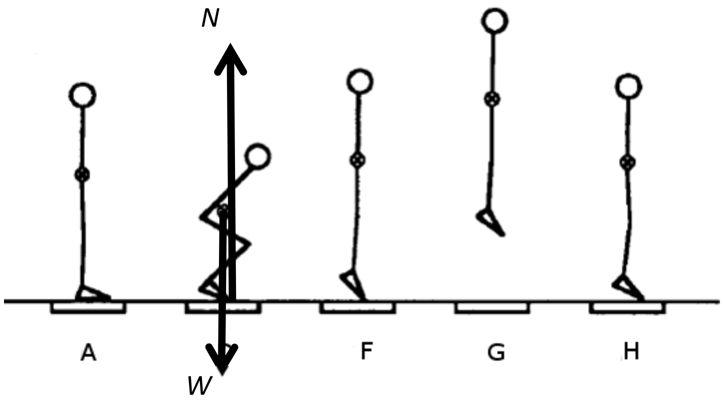


Fig. 2.1

W – Weight of Jumper

N – Normal reaction force due to platform on Jumper

(b) **(i)** An indication of the graph that t_a starts from t = 0.80 s till 1.35 s.

t_a = 0.55 s **[1]**

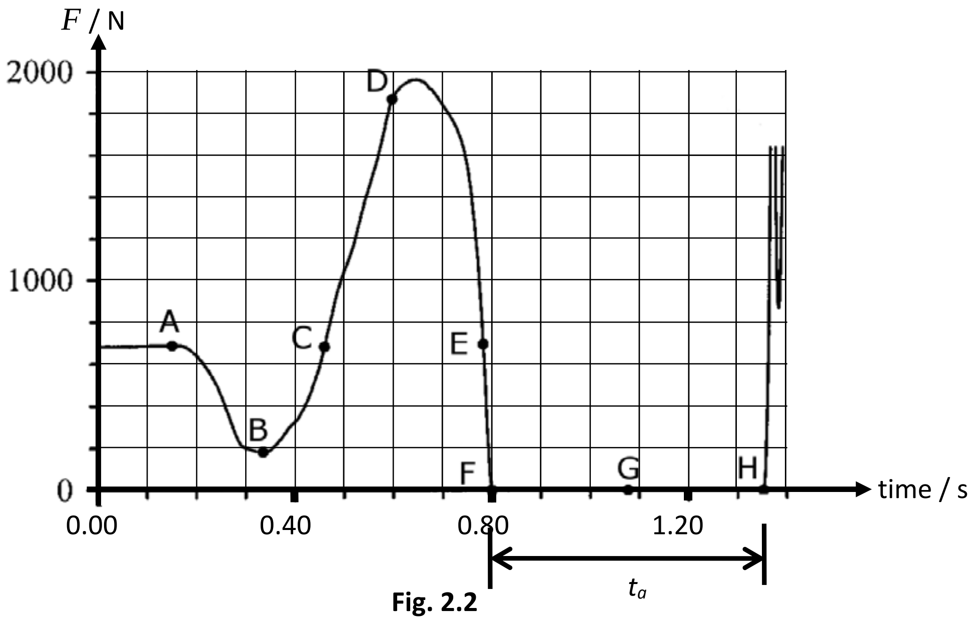


Fig. 2.2

(ii) Using $v = u + at$ and taking upwards as positive,

$$0 = v_0 + (-9.81)\frac{(0.55)}{2}$$ **[1]**

$v_0 = 2.7\ \mathrm{m\,s^{-1}}$ (Shown)

(iii) Using $v^2 = u^2 + 2as$ and taking upwards as positive,

$0 = 2.7^2 + 2(-9.81)h$ **[1]**

$h = 0.37\ \mathrm{m}$ **[1]**

(c) **(i)** Line W should be a horizontal straight line extended from the initial straight line from t = 0 s to point A. (i.e. W is about 650 N). **[1]**

(ii) Same shape as Fig. 2.2, just offset the y-axis to 0. Must cross x-axis at t = 0.45 s and t = 0.75 s. Note F_{net} = 0 up t t= 0.15 s. **[1]**

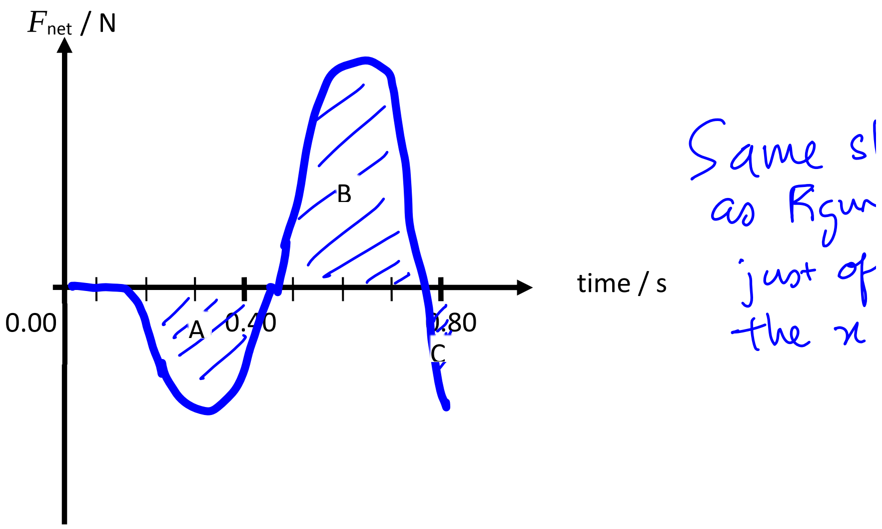


Fig. 2.3

(iii) By Newton's 2nd Law, the rate of change of linear momentum of the jumper is proportional to the net external force acting on him.

Therefore, the area under the force-time graph is equal to the change in momentum Δp of the jumper.

Δp = Area B – Area A – Area C (an indication of which areas on the graph to calculate for)

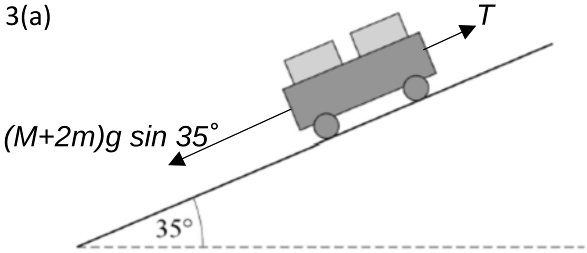
= $mv - mu$

= mv_0 - 0

v_0 = $\dfrac{\Delta p}{m}$ **[1]**

Question 3

3(a)



[1]

[Ignore arrows not parallel to ground e.g. weight, Ignore friction, W not acceptable for (M+2m)g]

3(b) T – Mg sin35˚ = Ma --- (1)

AND (M+2m)g sin35˚ - T = (M+2m)a ---(2) [1m]

(1) + (2):

(M+2m)g sin35˚ - Mg sin35˚ = Ma + (M + 2m)a [1m]

Hence a = mg sin 35˚/(M+m)

OR

(M + 2m)g sin35˚ - Mg sin35˚ = (2M+2m)a [1m]

a = 2mg sin35˚/(2M + 2m) [1m]

Hence a = mg sin 35˚/(M+m)

3(c) (i)

Friction provides for the resultant force on the blocks which cause it to accelerate together with the trolley. [1] If the acceleration is too large, friction will be insufficient so the blocks will slip off the trolley. [1]

3(c)(ii)

Acceleration = $0.25 \times \frac{30 \times 9.81 \times sin35°}{(30+95)}$ = 0.338 [1m]

(use of $v^2 = 2as$)

$v = \sqrt{(2 \times 0.338 \times 9.0)}$ = 2.47

$t = \frac{2.47}{0.338}$ = 7.3 s [1m]

OR

(use of s = ½ at^2)

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 9}{0.338}}$ = 7.3 s [1m]

Question 4

(a) Gravitational potential energy of an object is the energy it possesses by virtue of its position in a gravitational field while elastic potential energy is the energy that is stored when a spring is stretched or compressed. [1]

(b)(i) Taking the child and the pogo stick as a system.

At **A**, the gravitational potential energy is at a minimum while the elastic potential energy is at a maximum, since it is at rest, kinetic energy is zero. [B1]
From **A** to **B**, the gravitational potential energy has increased while the elastic potential energy is now zero since the spring is relaxed. Kinetic energy is non-zero at this point. [B1]
From **B** to **C**, the gravitational potential energy reaches its maximum, elastic potential energy is still zero while the kinetic energy is zero since it comes to rest. [B1]

(b)(ii) By conservation of energy,

Total energy at point A = Total energy at point C
$\frac{1}{2}kx_A{}^2 = mg(x_A + x_C)$
$x_A + x_C = 1.22\ m$ [C1]
$x_C = 1.02\ m$ [A1]

(b)(iii) Point of maximum speed is where the system is in equilibrium, net force = 0.

Mg – kx = 0
x = 0.01635 m [1]

By conservation of energy,
Loss in EPE = Gain in KE + Gain in GPE
$\frac{1}{2}kx_A{}^2 - \frac{1}{2}k(0.01635)^2 = Gain\ in\ KE + mg(x_A - 0.01635)$

Gain in KE = 252.95 J [1]

Maximum speed = 4.50 ms^{-1} [1]

(b)(iv) Just below B, since x = 0.01635m. At B there is only weight OR at maximum speed elastic force upwards is equal to the weight downwards. [B1]

Question 5

(a) Decay constant, λ = ln2/5730 = 1.210 × 10^{-4} yr^{-1} [1]

$$C = C_0 e^{-\lambda t}$$
$$5.2 = 6.5 e^{-\lambda t}$$ [1]

t = 1845 yrs [1]

(b) (i) Energy required to break Uranium into its individual constituent nucleons = 235 × 7.6 MeV [1]

Energy released by La formation from individual constituent nucleons = 146 × 8.2 MeV

Energy released by Br formation from individual constituent nucleons = 87 × 8.6 MeV [1]

Net energy released = 159.4 MeV [1]

(b)(ii) Binding energy of neutron = 0 since it is free from any nuclear force. [1]

Question 6

(a) (i) Vertical axis: 10 small squares represent 25 mA $\Rightarrow$ 1 small square represent 2.5 mA.

Please read to half a smallest division. When V = 400 mV, I = 130 mA.

(a)(ii) When there is no current drawn from the cell, the terminal potential difference (measured by the voltmeter) is equal to the emf. From the graph, when I = 0, emf = V = 550 mV.

(a)(iii) Let the internal resistance be r.

$$V_{Th} = E - Ir$$

When V_{Th} = 400 mV, I = 130 mA, and E = 550 mV

therefore $r = \dfrac{E - V_{Th}}{I}$ = 1.15 Ω.

(b) (i) Use P = VI where V = 520 mV and I = 75 mA

= 0.039 W

(ii) Since power = V x I (*this formula looks like length x breadth)*

The shaded area is a rectangle of sides 75 mA and 520 mV.

(c) (i) 1. Increases

(*double check by considering two points on the graph and find the power using VI).*

2. Decreases

(ii) (460, 120) M is slightly above the midpoint between I = 100 mA to 125 mA. (Estimate)

(d) (i) V = IR $\Rightarrow$ $I = \dfrac{V}{R}$ The line should have a gradient of $\dfrac{1}{R}$ passing through the origin and the point V = 420 mV and I = 100 mA

(ii) Since the current through the solar cell is the same as that through the 4.2 Ω resistor and pd across the terminal of the solar cell = pd across 4.2 Ω resistor, find the solution to the following pair of simultaneous equations:

V = IR --------- (1)

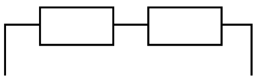
V = f(I) --------- (2) f(I) means some function of current I (ie curve given in fig 8.3).

Solution to the above is the intersection point, I = 113 mA, V = 475 mV. Use P = VI = 0.054 W (where V and I are coordinates of the intersection point) to find power dissipated.

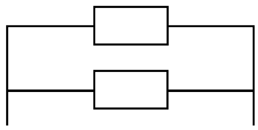
(e) Main concepts:

(1) When connected in series, pd add up. When connected in parallel the pd does not add up.
(2) Power always add up. So work on the required pd first.

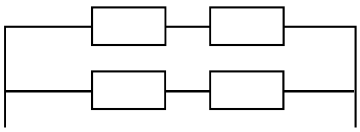
(i)



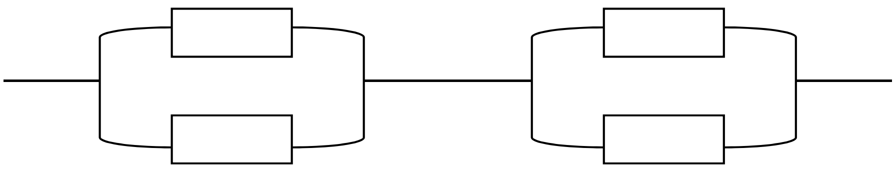
(ii)



(iii)



Or



Question 7

(a)

By conservation of energy, the first sphere will accelerate as it loses gravitational potential energy and gains kinetic energy achieving maximum velocity, v, at the lowest position just before it with the second sphere. [B1]

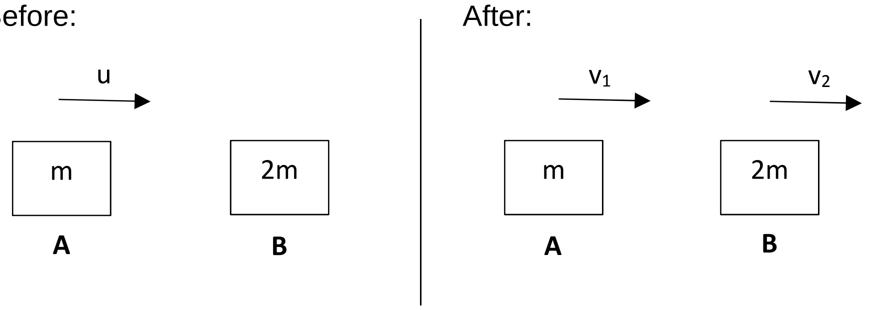
Since the spheres are identical, they have the same mass. By conservation of linear momentum, the first sphere with a velocity of v will collide with the next sphere which is at rest. After collision, the second sphere will move off with a velocity v, while the first sphere comes to rest. This continues on till the last sphere moves off with a velocity v. [B1]

Since the last sphere has the same velocity as the first sphere, it will rise to the same height as the first sphere where it was released by conservation of energy as the last sphere loses kinetic energy and gains gravitational potential energy.

The last sphere then reaches the same maximum height and comes to rest momentarily. Due to the tension of the string and weight of the sphere, the net force causes the last sphere to accelerate in the opposite direction before colliding with the neighbouring sphere. This motion then repeats itself in an oscillatory manner. [B1]

(b)(i)

Before: After:



By PCLM,

$mu = mv_1 + 2mv_2$ --- (1)

Since collision is elastic, applying relative speed relation,

$u - 0 = v_2 - v_1$ --- (2)

Sub (2) into (1)

$m(v_2 - v_1) = mv_1 + 2mv_2$

$(v_2 - v_1) = v_1 + 2v_2$

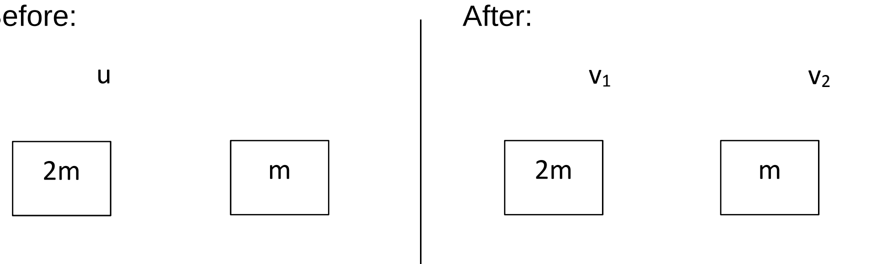
$v_2 = -2v_1$

Hence $v_1 = -\frac{u}{3}$ and $v_2 = \frac{2u}{3}$

$Ratio = \frac{2}{3}$ = 0.67

(c)(ii)

Before: After:



By PCLM,

$2mu = 2mv_1 + mv_2$ --- (1)

Since collision is elastic, applying relative speed relation,

$u - 0 = v_2 - v_1$ --- (2)

Sub (2) into (1)

$2m(v_2 - v_1) = 2mv_1 + mv_2$

$(2v_2 - 2v_1) = 2v_1 + v_2$

$v_2 = 4v_1$

Hence $v_1 = \frac{u}{3}$ and $v_2 = \frac{4u}{3}$

$Ratio = \frac{4}{3}$ = 1.3

(c)(iii)

Collision (i) occurs twice.

Collision (ii) occurs twice.

$$\frac{Max\ vert\ displacement\ of\ first\ ball}{Max\ vert\ displacement\ of\ last\ ball} = \frac{Change\ in\ GPE\ of\ first\ ball}{Change\ in\ GPE\ of\ last\ ball}$$

By CoE, since the ball comes to rest at max GPE,

$$\frac{Change\ in\ GPE\ of\ first\ ball}{Change\ in\ GPE\ of\ last\ ball} = \frac{Max\ KE\ of\ first\ ball}{Max\ KE\ of\ last\ ball} = \frac{0.5\ mv_i^2}{0.5\ mv_f^2}$$

Hence

$$\frac{Max\ vert\ displacement\ of\ first\ ball}{Max\ vert\ displacement\ of\ last\ ball} = \frac{v_i^2}{v_f^2} = \frac{u^2}{(\left(\frac{2}{3}\right)\left(\frac{4}{3}\right)\left(\frac{2}{3}\right)\left(\frac{4}{3}\right)u)^2}$$

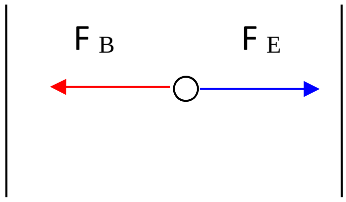
Ratio = 1.60

(c)

The tension of the spring for all the spheres except for the first sphere is equal to the weight of the sphere since net force = 0. The first sphere will have a greater tension since it undergoes centripetal acceleration, T = mg + mv^2/r. Hence extension for the first sphere is greater than that of the rest. [B1]

The first sphere and the second sphere no longer collide head-on. [B1]

(d) (i)



[2]

(ii) The alpha particle would be deflected to the right along a parabolic path.

As the speed of the particle is less than v, the magnetic force experienced is less than the electric force. Hence the particles experience a constant acceleration to the right.

(e) <u>Stage 2</u>

$Bqv = mv^2/r$

➔ $r = mv/Bq$

$= (4 \times 1.67 \times 10^{-27} \times 1.00 \times 10^5) / (0.050 \times 2 \times 1.6 \times 10^{-19})$

$= 4.175 \times 10^{-2}$ m

Point of impact = 2 r = $2 \times 4.175 \times 10^{-2}$ m = 8.35×10^{-2} m [3]

(f) Stage 1: as the velocity is much higher, the ratio of E/B needs to be much higher. Hence a much stronger electric field needs to be used.

Stage 2: while the speed of beta particles is 100 times faster, its mass is more than 1000 times smaller. Hence the position of photographic plate needs to be much closer to the entrance

Question 8

8 (a) (i) most alphas have small deflection
so nucleus is small target
(ii) deflection too large to be gravitational
so must be electrostatic i.e. charged

(b) (i) 1. from the graph, Q = 1.2 MeV

2. $v = \sqrt{(E/(\frac{1}{2} m_e)}$
$= 6.5 \times 10^8 \text{ ms}^{-1}$ [1]
The calculated value of v is more than c, the speed of light. [1]

(This suggests that the classical formula for kinetic energy ½ mv^2, is not valid in calculating the speed of the beta particle.)

3. $m(Po) = m(Bi) – m_e – Q/c^2$
$= [(209.939u) – (9.11 \times 10^{-31}/1.66 \times 10^{-27}) – (1.2\times10^6\times1.60\times10^{-19}/c^2)]/(1.66 \times 10^{-27} \text{ kg})$
$= 209.937$ u

(ii) Range of values accepted : 0.16 - 0.18 MeV

(iii) Since ^{210}Bi undergoes spontaneous beta decay, a process in which it increases its proton number by one
while decreasing its neutron number by one, it suggests that ^{210}Bi must have an excess of neutrons as compared to the optimal ratio.

(iv) For a stationary nucleus decaying into the beta particle and daughter nucleus, the conservation of linear momentum requires that $\underline{p_1} = -\underline{p_2}$.
The sum of kinetic energies will thus be $(p_1)^2/2m_1 + (p_2)^2/2m_2 = E$, which ought to equal the energy released in the reaction, which, if equal to the increase in the total binding energy/decrease in total mass, ought to be constant.

The range of beta particle energies and thus the supposed energy released E, seem to suggest that the energy released was not constant, in contradiction to the principle of conservation of energy.

(v)
- Energy was not conserved in a beta decay**.** (proven false)
- **The existence of another undetected particle.**
- (The actual reason. The undetected particle was the neutrino, and a 3 body interaction allowed for the beta particle to carry away a varying amount of KE whilst still ensuring COE)

(c) (i) random nature of emissions
(ii) e.g. self-absorption, detector not 100% efficient,
detector not surrounding source, background radiation

c(iii)
1.
$R = R_o e^{-\lambda t}$ so $8.3 \times 10^3 = 7.6\times10^8 \times e^{-4.6\times10\text{-}3t}$ t = 2480 s

2. Using inverse square law, answer is 26 counts per minute.