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Waldorf School

Grade 12 Physical Science Physics Preliminary Examination 2023

28 August 2023

200 Marks

3 hours

Full Name: Memo

INSTRUCTIONS:

1. This paper consists of 28 pages.
2. Write in dark blue or black pen.
3. Answer all questions in the spaces provided on the question paper.
4. You should show all your working on the question paper.
5. Where appropriate, express answers to TWO decimal places.
6. The number of marks is given in brackets () at the end of each question.
7. TWO blank pages (pages 27 to 28) are included at the end of the paper. If you run out of space for a question, use these pages. Clearly indicate the question number of your answer should you use this extra .

For Examiner's Use <i>Mr. K. Bennett</i>		For Moderators's Use <i>Mr. K. Hall</i>	
Question	Mark	Question	Mark
1	/20	1	/20
2	/14	2	/14
3	/30	3	/30
4	/13	4	/13
5	/7	5	/7
6	/18	6	/18
7	/21	7	/21
8	/18	8	/18
9	/28	9	/28
10	/18	10	/18
11	/13	11	/13
Total	/200	Total	/200
Initial		Initial	

Question 1 [20 Marks]

MULTIPLE CHOICE

Answer these questions on the multiple-choice answer sheet below.

Make a cross (X) in the box corresponding to the letter that you consider to be correct.

A	B	~~C~~	D
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1.1	A	B	C	~~D~~	✓✓
1.2	A	~~B~~	C	D	✓✓
1.3	A	B	~~C~~	D	✓✓
1.4	A	B	C	~~D~~	✓✓
1.5	~~A~~	B	C	D	✓✓
1.6	A	~~B~~	C	D	✓✓
1.7	A	~~B~~	C	D	✓✓
1.8	A	B	~~C~~	D	✓✓
1.9	A	B	C	~~D~~	✓✓
1.10	A	~~B~~	C	D	✓✓

1.1 Which of the following options contains both a **scalar** AND a **vector**?

- A Power and Work
- B Mass and Mechanical Energy
- C Weight and Electric Field
- ☒ D Electromotive Force and Impulse

(2)

1.2 An object initially at rest travels a distance d in a time t at a constant acceleration. What is the time taken for the object to travel $16d$ from rest at the same acceleration?

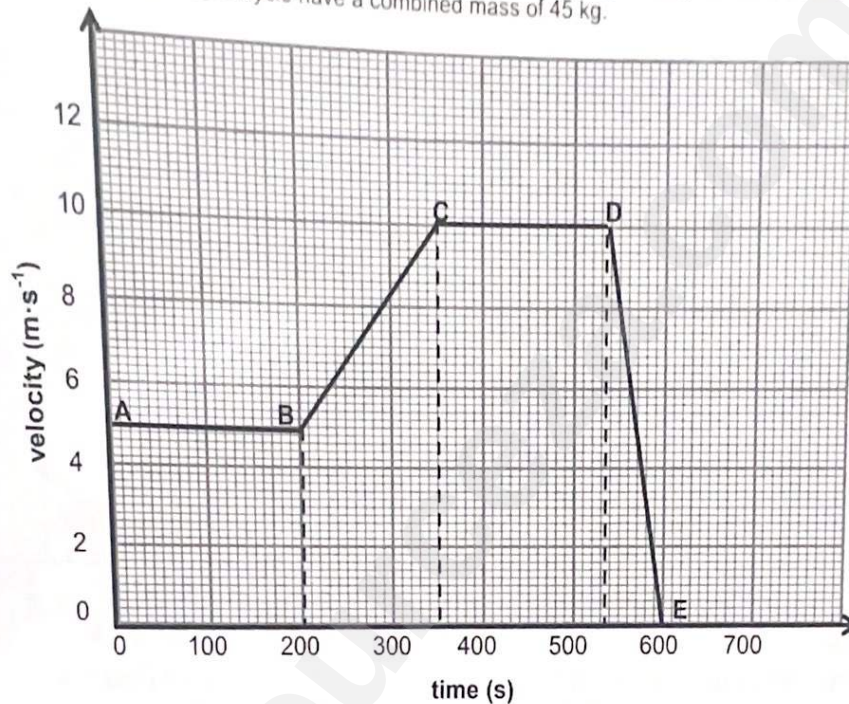
- A $2t$
- B $4t$
- C $8t$
- D $16t$

(2)

Question 2 [14 Marks]

ONE-DIMENSIONAL MOTION

The velocity-time graph below represents the motion of a girl riding her bicycle in a northerly direction. The girl and her bicycle have a combined mass of 45 kg.



2.1 Define velocity.

The rate of change of position OR the rate of displacement
OR the rate of change of displacement ✓✓ (2)

2.2 Write down the girl's initial velocity: 5 m.s^{-1} North ✓ (2)

2.3 What is the resultant force acting on the girl between C and D? ON ✓ (2)

2.4 Use the information on the graph to describe the motion of the girl:

2.4.1 From B to C: uniform acceleration ✓ (2)

2.4.2 From C to D: uniform velocity ✓ (2)

2.5 Use the graph to calculate the acceleration of the girl between D and E.

gradient = acceleration ✓

$$= \frac{\Delta v}{\Delta t}$$

$$= \frac{0 - 10}{600 - 535} \quad \checkmark$$

$$= -0.15 \text{ m.s}^{-2}$$

Acceleration: 0.15 m.s^{-2} South ✓✓

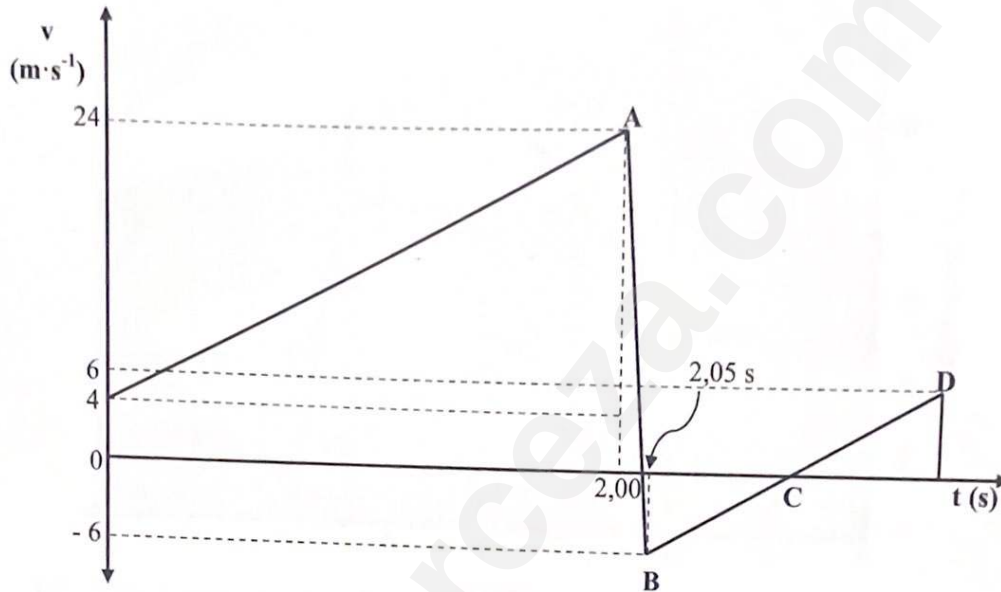
(4)

[14]

Question 3 [30 Marks]

FALLING BODIES

A child throws a golf ball vertically downwards from a 1st floor balcony.
The velocity versus time graph below represents the motion of the stone.
Air resistance can be ignored.



- 3.1 From the graph, was upwards or downwards taken as the positive direction?
Circle the correct option.

UPWARDS / DOWNWARDS ✓

(1)

- 3.2 The upward sloping lines on the graph are parallel with each other. Why?

The lines represent acceleration of the ball.

Acceleration is constant because the ball is in free fall (air resistance can be ignored).

(2)

- 3.3 At what speed was the golf ball thrown? 4 m·s⁻¹ ✓

(1)

- 3.4 At which point did the golf ball hit the ground for the first time?

Choose from A, B, C or D: A ✓✓

(2)

- 3.5 Where on the graph did the golf ball reach its maximum height after bouncing?

Choose from A, B, C or D: C ✓✓

(2)

- 3.6 Use the graph and not equations of motion to determine the height of the balcony above the ground.

$$\begin{aligned}\Delta x &= \text{area under } v-t \text{ graph} \\ &= 2(4) + \frac{1}{2}(2)(20) \\ &= 28 \text{ m}\end{aligned}$$

Height of balcony: 28 m above the ground (4)

- 3.7 If the golf ball has a mass of 150 g, what force does the ground exert on the golf ball between A and B?

Method 1

$$\begin{aligned}a &= \frac{-6-24}{2.05-2} \\ &= -600 \text{ m.s}^{-2} \\ &= 600 \text{ m.s}^{-2} \text{ upwards} \\ \text{Taking up as positive} \\ F_{\text{net}} &= ma \\ F_{\text{ground}} - F_{\text{gravity}} &= 0.15(600)\end{aligned}$$

Method 2

$$\begin{aligned}F_{\text{net}} &= \frac{\Delta p}{\Delta t} \\ F_{\text{gravity}} - F_{\text{ground}} &= \frac{m(v_f - v_i)}{\Delta t} \\ 0.15 \frac{600}{\text{net}} - F_{\text{ground}} &= \frac{0.15(-6-24)}{0.05}\end{aligned}$$

Force of ground on golf ball: 91.47 N upwards (5)

- 3.8 What is the momentum of the golf ball at point C? 0 kg.m.s⁻¹ (2)

- 3.9 Calculate the total time it took for the golf ball to reach point C.

Choose upwards as positive

$$v_i = 6 \text{ m.s}^{-1}$$

$$v_f = 0 \text{ m.s}^{-1}$$

$$v_f = v_i + a \Delta t$$

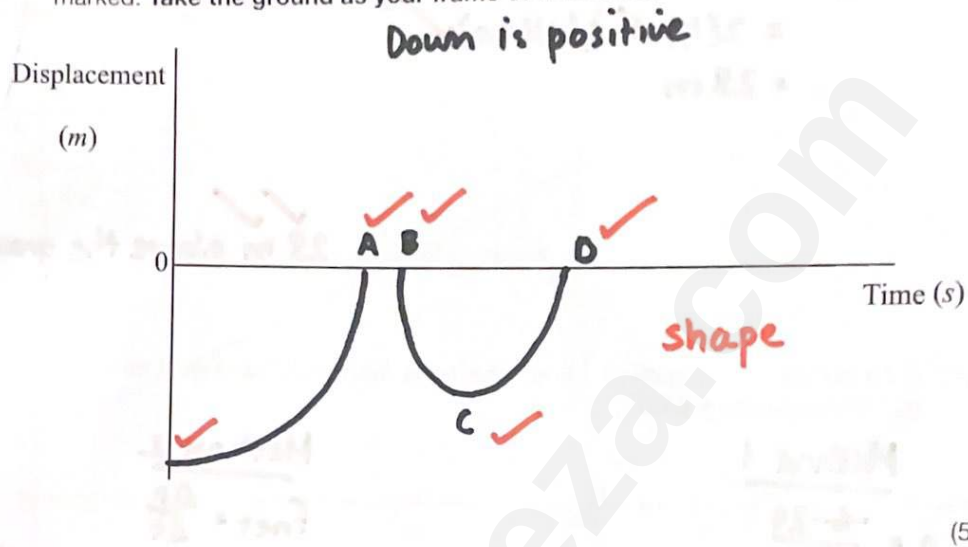
$$0 = 6 + (-9.8) \Delta t$$

$$\Delta t = 0.61 \text{ s}$$

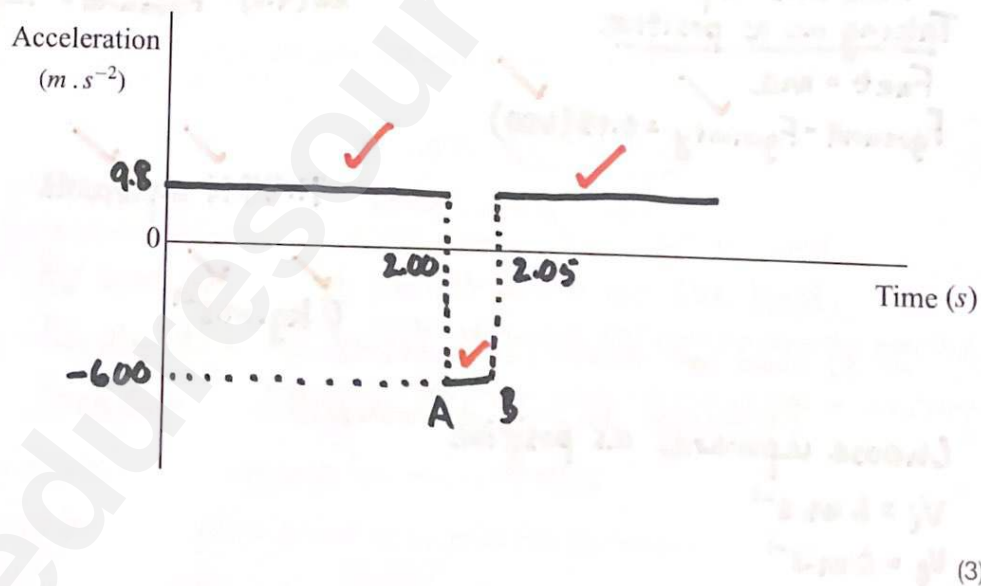
$$\text{Total time} = 2.05 \text{ s} + 0.61 \text{ s} = 2.66 \text{ s}$$

Time: 2.66 s (3)

- 3.10 Sketch a displacement-time sketch graph to represent the change in position of the golf ball for the same time period given in the velocity-time graph. No values need to be shown, but the positions A, B, C and D must be clearly marked. **Take the ground as your frame of reference.**



- 3.11 Draw an acceleration-time graph for the same period given in the velocity-time graph. Positions A and B must be clearly show. **Mark any significant values on the graph.**



[30]

Question 4 [13 Marks]

ROCKET SCIENCE

A model rocket is fired vertically upwards from rest at ground level.

The rocket accelerates upwards at 25 m.s^{-2} for 15 s and then runs out of fuel.

Air resistance is negligible. Take the ground as the reference point.



4.1 Calculate the rocket's maximum height above the ground.

While acceleration is 25 m.s^{-2}

$$\begin{aligned} \Delta x &= v_i \Delta t + \frac{1}{2} a \Delta t^2 \\ &= 0 + \frac{1}{2} (25)(15)^2 \\ &= 2812.5 \text{ m} \end{aligned}$$

Runs out of fuel

$$\begin{aligned} v_f &= v_i + a \Delta t \\ &= 0 + (25)(15) \\ &= 375 \text{ m.s}^{-1} \end{aligned}$$

$$\begin{aligned} v_f^2 &= v_i^2 + 2a\Delta x \\ (0)^2 &= (375)^2 + 2(-9.8)\Delta x \\ \Delta x &= 7174.74 \text{ m} \end{aligned}$$

$$9987.24 \text{ m}$$

Maximum height: ~~7174.74 m~~ (5)

4.2 Calculate the time the rocket is in the air from launch to crashing on the ground.



① 15 s ✓

$$\begin{aligned} \text{② } v_f &= v_i + a \Delta t \\ (0) &= 375 + (-9.8)\Delta t \\ \Delta t &= 38.26 \text{ s} \end{aligned}$$

$$\begin{aligned} \text{③ } \Delta x &= v_i \Delta t + \frac{1}{2} a (\Delta t)^2 \\ -9987.24 &= 0 + \frac{1}{2} (-9.8) \Delta t^2 \\ \Delta t &= 45.15 \text{ s} \end{aligned}$$

Time: 98.41 s (4)

4.3 Define displacement.

A change in position ✓✓ (2)

4.4 What is the rocket's displacement when it reaches its maximum velocity?

Displacement: 0 m ✓✓ (2)

[13]

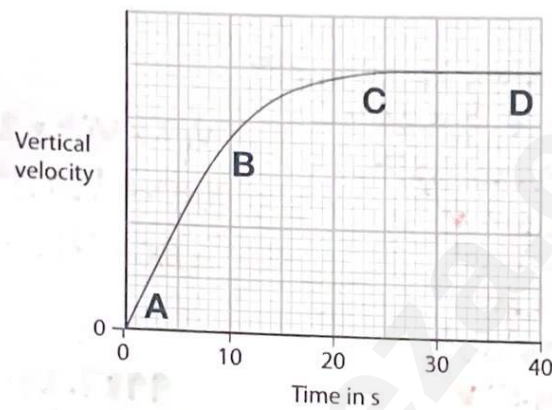
Question 5 [7 Marks]

SYKDIVING

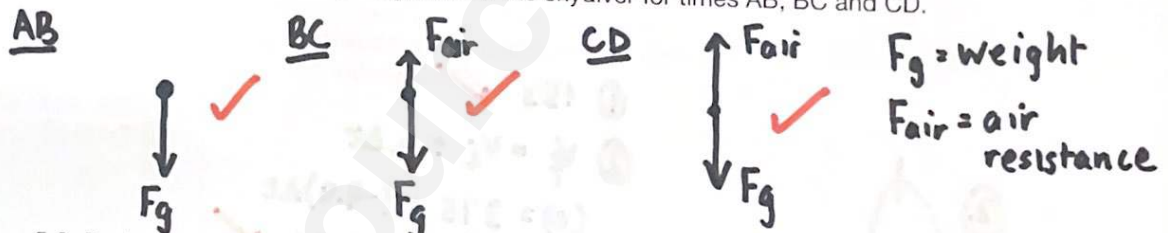
A skydiver jumps from an aircraft.

The graph shows the vertical velocity of the skydiver during the first 40 s of the fall.

His parachute is not open during this time.



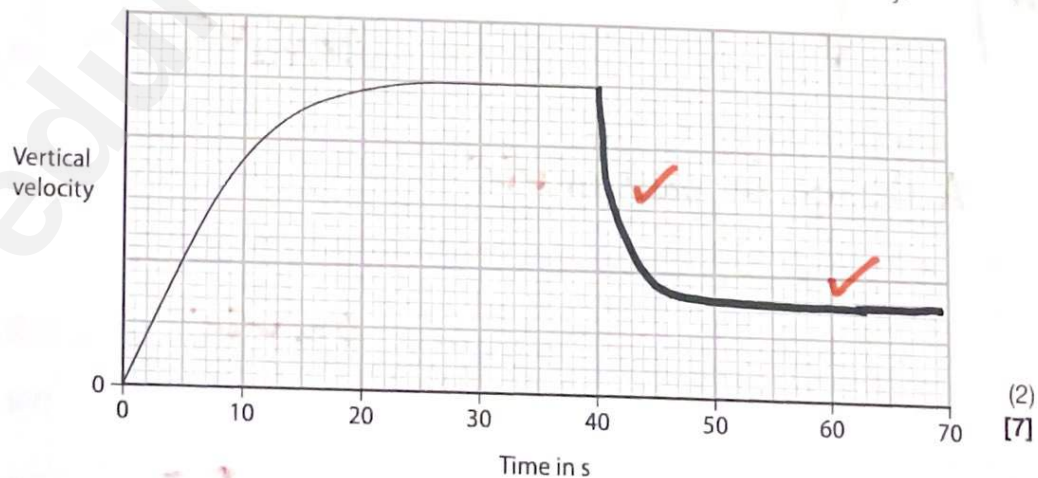
5.1 Draw THREE free-body diagrams for the skydiver for times AB, BC and CD.



5.2 During which portion of the skydiver's journey is mechanical energy conserved? (3)

Choose from AB, BC or CD: ... AB ✓✓ (2)

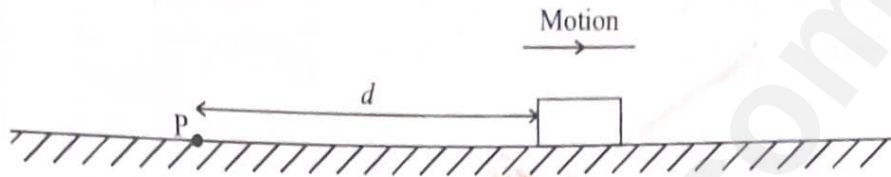
5.3 The skydiver opens his parachute after 40 s. Continue the line on the graph to show how the skydiver's vertical velocity changes and reaches terminal velocity.



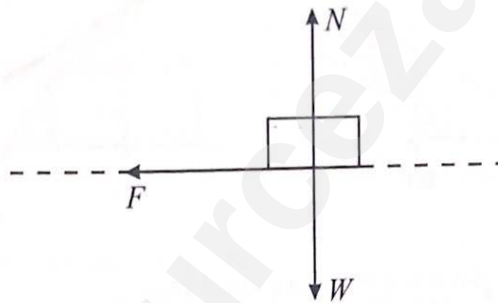
Question 6 [18 Marks]

SLIDING BLOCKS

A block is projected from a point P across a rough, horizontal surface.



The block slows down under the influence of a constant frictional force F and eventually comes to rest. Below is a free-body force diagram for the block whilst it is moving.



6.1 Define work.

The product of the displacement and the component of the force parallel to the displacement ✓✓ (2)

6.2 State, with a reason, the amount of work done by each of the forces W and N as the block moves across the surface.

0J

Forces perpendicular to motion (2)

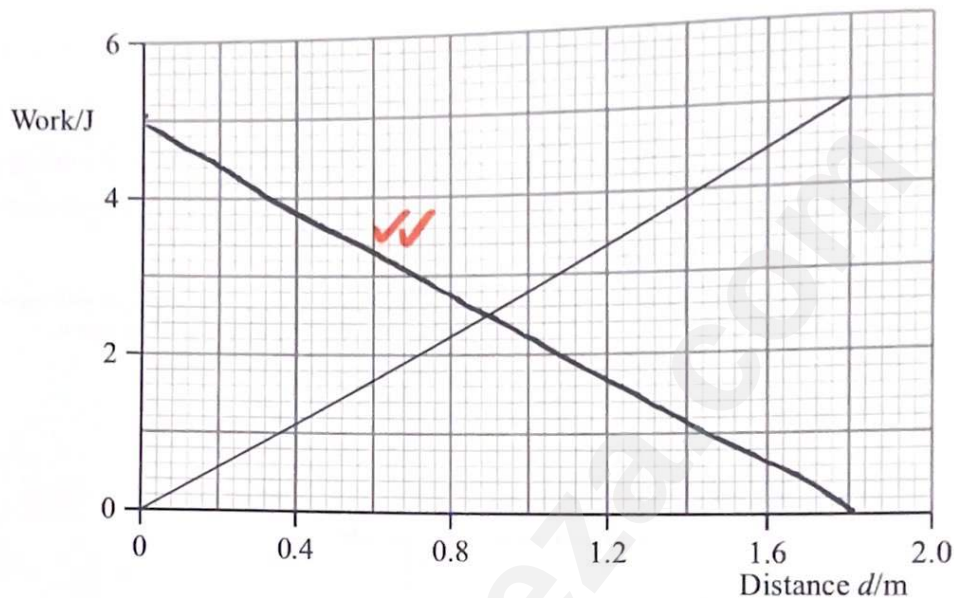
6.3 Does the frictional force F act to INCREASE or DECREASE the kinetic energy of the sliding block?

Decrease (1)

6.4 Hence, does the frictional force F do POSITIVE or NEGATIVE work on the sliding block?

Negative (1)

The graph shows how the total work done varies with the distance d which the block has travelled from the projection point P.



6.5 Use the graph to determine the magnitude of force F .

$$\text{gradient} = \text{Force} \checkmark$$

$$= \frac{5-0}{1.8-0} \checkmark$$

$$= 2.78 \text{ N} \checkmark$$

$$\text{Force } F: 2.78 \text{ N}$$

(3)

6.6 The block comes to rest 1.80 m from P.

Draw a line on the graph above to show how the kinetic energy of the block varied during the motion.

Straight line finishing at (1.8, 0)
Starting at (0, 5)

(2)

6.7 The mass of the block was 820 g.

Use the work-energy theorem to calculate the speed with which it was projected from P.

$$W_{\text{net}} = \Delta E_k \checkmark$$

$$F_{\text{net}} \Delta x = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \checkmark$$

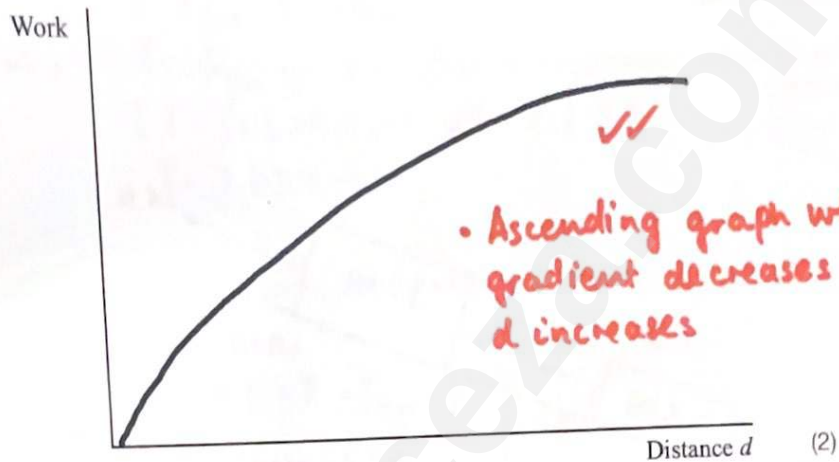
$$(2.78)(1.8) = \frac{1}{2} (0.82) (0)^2 - \frac{1}{2} (0.82) v_i^2 \quad \text{Speed: } 3.49 \text{ m.s}^{-1}$$

$$v_i = 3.49 \text{ m.s}^{-1} \checkmark$$

(3)

6.8 Suppose that, instead of a constant friction force, the block had been brought to rest by a drag force (air resistance) which depends on speed.

6.8.1 On the axes below sketch a graph to show qualitatively how you would expect the total work done against air resistance to vary with the distance d .



6.8.2 Explain the shape of your graph.

- Force greater at higher speed
- Gradient is the force
- Force decreases with distance because speed decreases $\therefore$ gradient decreases

[18]

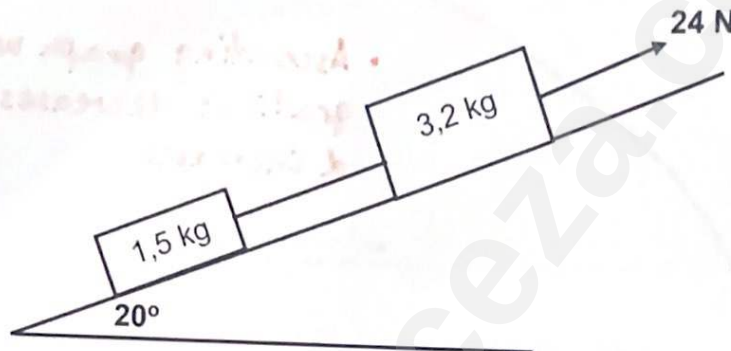
Question 7 [21 Marks]

INCLINED PLANES

Two blocks of masses 1,5 kg and 3,2 kg are connected by a light inextensible string.

A 24 N force is applied on a system of blocks by a motor to move them up an inclined surface which is 20° to the horizontal at a CONSTANT VELOCITY as shown on the diagram below.

The 1,5 kg box experiences a constant frictional force of 2 N as it moves up the incline.



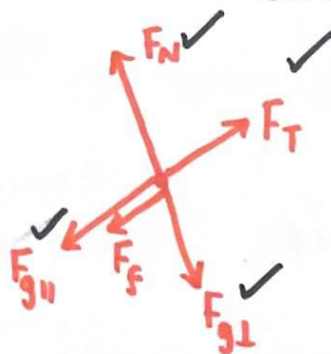
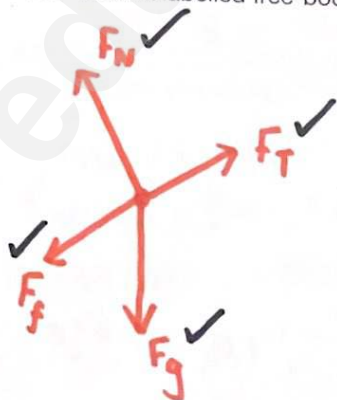
7.1 State Newton's Second Law of Motion in words.

When a net force, F_{net} , is applied to an object of mass, m , it accelerates in the direction of the net force. The acceleration, a , is directly proportional to the net force and inversely proportional to the mass. (2)

7.2 What is the resultant force acting on the 3.2 kg block?

0 N

7.3 Draw a labelled free-body diagram of all forces acting on the 1,5 kg block.



Key

F_N = normal force
 F_f = kinetic friction
 F_g = weight
 F_T = Tension (4)

7.4 Show that tension in the string connecting the blocks is approximately 7.0 N.

$$\begin{aligned}
 F_{\text{net}} &= ma \\
 F_{\text{net}} &= T - F_{g\parallel} - f \\
 T - F_{g\parallel} - f &= ma \\
 T - F_{g\parallel} - f &= 0 \\
 [T - (1.5 \times 9.8 \sin 20^\circ) - 2] &= 0 \\
 T &= 7.03 \text{ N}
 \end{aligned}$$

Any one ✓ ✓ ✓ ✓ ✓

(5)

7.5 Calculate the coefficient of kinetic frictional force between the 3.2 kg block and the surface.

$$\begin{aligned}
 F_{\text{net}} &= ma \\
 F_{\text{net}} &= F - T - F_{g\parallel} - f \\
 F - T - F_{g\parallel} - f &= 0 \\
 [24 - 7.03 - (3.2 \times 9.8 \sin 20^\circ) - f_k] &= 0 \\
 f_k &= 6.22 \text{ N} \\
 f_k &= \mu_k F_N \\
 [6.22 = \mu_k \times 3.2 \times 9.8 \cos 20^\circ] \\
 \mu_k &= 0.21
 \end{aligned}$$

Any one ✓ ✓ ✓ ✓ ✓

Coefficient of kinetic friction: 0.21

(5)

7.6 Calculate the average power developed by the motor in pulling the the system of blocks 11 m in 4.9 seconds.

Method 1

$$\begin{aligned}
 W &= F \Delta x \\
 &= (24)(11) \\
 &= 264 \text{ J}
 \end{aligned}$$

$$P = \frac{W}{\Delta t}$$

$$= \frac{264}{4.9}$$

$$= 53.87 \text{ W}$$

Method 2

$$\begin{aligned}
 v &= \frac{\Delta x}{\Delta t} = \frac{11}{4.9} = 2.24 \text{ m.s}^{-1} \\
 P &= Fv \\
 &= (24)(2.24) = 53.87 \text{ W}
 \end{aligned}$$

Power: 53.87 W

(3)

[21]

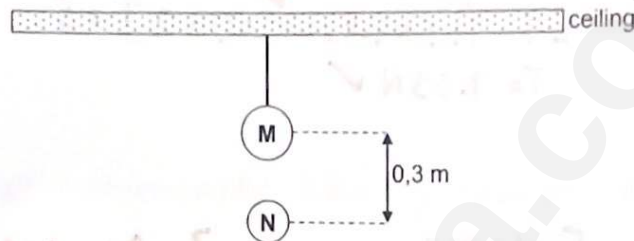
Question 8 [18 Marks]

ELECTRIC FIELDS

A charged sphere **M** is suspended from a ceiling by a light inextensible, insulated string.

Another charged sphere **N**, of mass $2,04 \times 10^{-3} \text{ kg}$ and carrying a charge of $+8,6 \times 10^{-8} \text{ C}$, hangs STATIONARY vertically below sphere **M**.

The centres of the spheres are $0,3 \text{ m}$ apart, as shown in the diagram below.



8.1 State Coulomb's law in words.

Two point charges in free space or air exert forces on each other. The force is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. ✓✓ (2)

8.2 State whether the charge on sphere **M** is POSITIVE or NEGATIVE.

Negative ✓✓ (2)

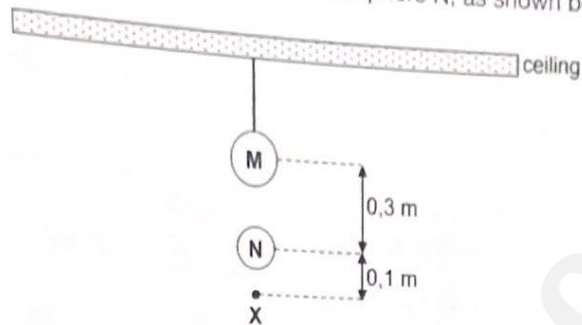
8.3 Calculate the magnitude of the charge on sphere **M**.

$F_g = mg$
 $= (2,04 \times 10^{-3})(9,8)$ ✓
 $= 0,02 \text{ N}$
 $F = \frac{kQ_M Q_N}{r^2}$ ✓
 $F_{\text{net}} = mg - \frac{kQ_M Q_N}{r^2}$
 $0 = 0,02 - \frac{(9 \times 10^9)(Q_M)(8,6 \times 10^{-8})}{(0,3)^2}$ ✓
 $Q_M = 2,33 \times 10^{-6} \text{ C}$ ✓

Charge on **M**: $2,33 \times 10^{-6} \text{ C}$

(5)

Point X is 0,1 m vertically below the centre of sphere N, as shown below.



- 8.4 Calculate the net electric field at point X.

Upwards as positive

$$E = \frac{kQ}{r^2}$$

$$E_{\text{net}} = \frac{(9 \times 10^9)(2.33 \times 10^{-6})}{(0.4)^2} - \frac{(9 \times 10^9)(8.6 \times 10^{-8})}{(0.1)^2}$$

$$E_{\text{net}} = 131062.5 - 77400 \\ = 53662.5 \text{ N}\cdot\text{C}^{-1}$$

Net electric field: $5.36 \times 10^4 \text{ N}\cdot\text{C}^{-1}$ upwards (5)

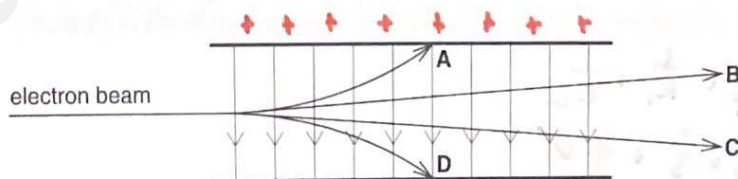
- 8.5 An electron is fired through a uniform electric field.

- 8.5.1 Draw the electric field pattern surrounding an electron.



- arrows pointing towards charge
- field lines are radial
- must meet charge at 90°

- 8.5.2 Which path shows a possible movement of an electron in the electric field shown?



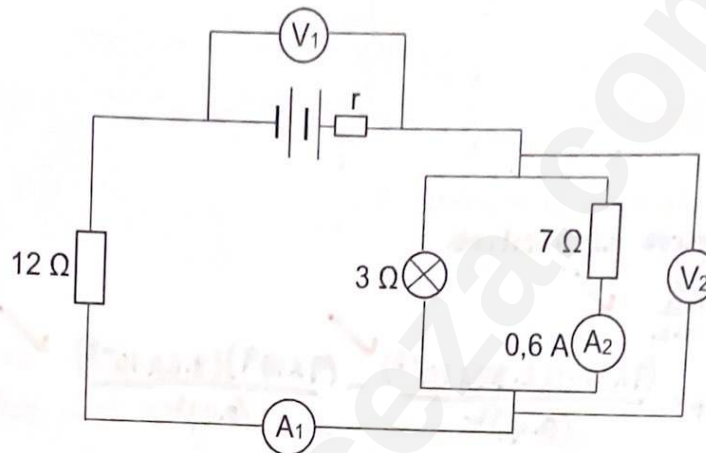
Choose from A, B, C or D: **A** (2)

[18]

Question 9 [28 Marks]

ELECTRIC CIRCUITS

In the circuit represented below, the battery has an emf of 30 V and an unknown internal resistance. Ammeter A₂ reads 0,6 A. The ammeters have zero resistance and the voltmeters have infinite resistance.



9.1 State Ohm's Law.

Current through a conductor is directly proportional to the potential difference across the conductor at constant temperature. ✓✓

(2)

9.2 Calculate the reading on V₂.

$$V = IR \quad \checkmark$$

$$= (0.6)(7) \quad \checkmark$$

$$= 4.2V \quad \checkmark$$

$$V_2: 4.2V$$

(3)

9.3 What is the effective resistance of the bulb and resistor connected in parallel?

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{7} \quad \checkmark$$

$$R_p = 2.10\Omega \quad \checkmark$$

$$\text{Effective resistance: } 2.10\Omega$$

(2)

9.4 Define current.

The rate of flow of charge ✓✓

(2)

9.5 Calculate the current reading on ammeter A_1 .

$$I_{\text{bulb}} = \frac{V_{\text{bulb}}}{R_{\text{bulb}}} = \frac{4.2}{3} = 1.4 \text{ A} \quad \checkmark$$

$$\begin{aligned} I_{\text{total}} &= I_{\text{bulb}} + I_{10\Omega} \\ &= 1.4 + 0.6 \quad \checkmark \\ &= 2.0 \text{ A} \quad \checkmark \end{aligned}$$

A_1 : 2.0 A

(4)

9.6 Calculate the power dissipated by the 12Ω resistor.

$$\begin{aligned} P &= I^2 R \quad \checkmark \\ &= 2^2 \cdot 12 \quad \checkmark \\ &= 48 \text{ W} \quad \checkmark \end{aligned}$$

Power: 48 W

(3)

9.7 Determine the internal resistance of the battery.

$$\begin{aligned} \text{emf} &= I(R+r) \quad \checkmark \\ 30 &= 2(2.1 + 12 + r) \quad \checkmark \\ r &= 0.9 \Omega \quad \checkmark \end{aligned}$$

Internal resistance: 0.9 Ω

(4)

- 9.8 Calculate the amount of energy emitted by the $3\ \Omega$ bulb in 3 minutes.

$$W = \frac{V^2 t}{R} = \frac{4.2^2}{3} (3 \times 60) = 1058.4\text{ J}$$

$$W = VIt = (4.2)(1.4)(3 \times 60) = 1058.4\text{ J}$$

$$W = I^2 R t = (1.4)^2 (3) (3 \times 60) = 1058.4\text{ J}$$

Energy: 1058.4 J

(4)

- 9.9 If the voltmeter V_2 is replaced by a conducting wire, what would happen to the reading on V_1 ?

Decrease

(1)

- 9.10 Explain your answer to Question 9.9. Use an appropriate equation to aid you in your explanation.

The total resistance decreases, so the current increases ($V = IR$), so lost volts increase and so V_{term} decreases ($V_{\text{term}} = \text{emf} - Ir$) equation used in context.

(3)

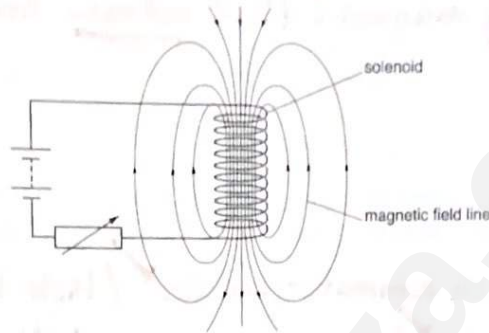
[28]

Question 10 [18 Marks]

ELECTROMAGNETIC EFFECTS

A circuit contains a battery, a variable resistor and a solenoid.

The figure below shows the magnetic field pattern produced by the current in the solenoid.



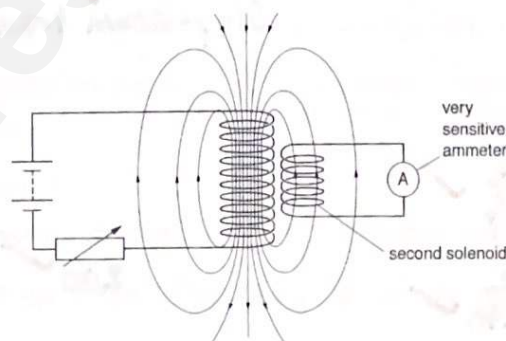
- 10.1 State how the magnetic field pattern indicates regions where the magnetic field is stronger.

(magnetic field) lines closer together / denser / more lines (2)

- 10.2 State what happens to the magnetic field when the current in the circuit is reversed.

(magnetic field (lines) direction reversed. (2)

A second solenoid is placed next to the first solenoid. The shows the second solenoid connected to a very sensitive ammeter.



- 10.3 State Faraday's law of electromagnetic induction.

The emf induced is directly proportional to the rate of change of magnetic flux. (2)

The variable resistor is adjusted so that its resistance changes **quickly**.

10.4 State and explain what is seen to happen in the circuit of the second solenoid.

Ammeter needle deflects / reading on ammeter

Changing magnetic field induces an emf

(3)

10.5 The variable is then adjusted much more **slowly** than in 10.3. State and explain the difference in what is seen to happen in the circuit of the second solenoid.

Reading on ammeter smaller / lasts longer

Slower rate of changing magnetic field induces a smaller emf.

(2)

The figure below shows two separate solenoids wound around an iron core. The primary coil P is connected to an a.c. supply. A 6.0 V lamp is connected across the secondary coil S.



10.6 Name the device in the figure above: Step-down transformer (2)

10.7 The e.m.f. of the a.c. supply is 240 V. The primary coil has 8000 turns. Calculate the number of turns on the secondary coil.

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\frac{N_s}{8000} = \frac{6}{240}$$

Turns: 200

(3)

10.8 A 240 d.c. supply is used instead of the 240 a.c. supply.

Tick **one** box to indicate what happens to the lamp.

☐

glows more brightly

☐

glows less brightly

☐

glows with the same brightness

☒

does not glow

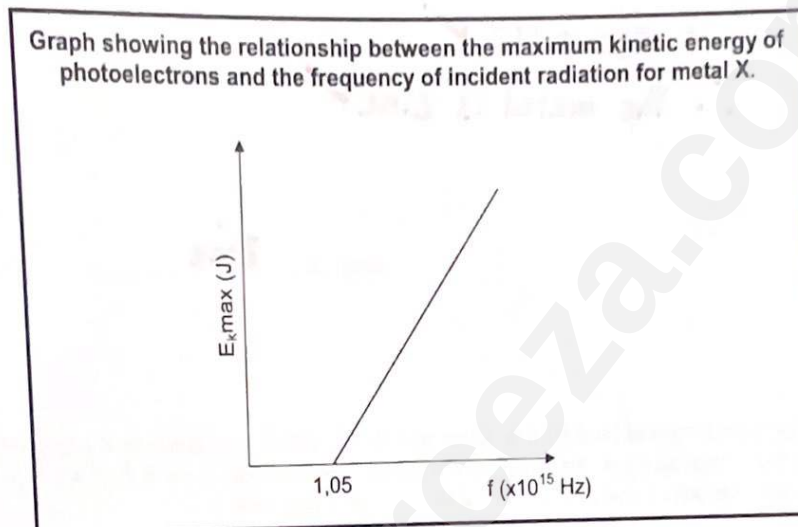
(2)

[18]

Question 11 [13 Marks]

QUANTUM PHYSICS

A Physics student measures the maximum kinetic energy of photoelectrons emitted from the surface of metal X, using different frequencies of the incident radiation. The student uses his data to plot the graph shown below.



The following table shows the work function of a variety of metals:

Metal	Work Function (J)
Sodium	$3,82 \times 10^{-19}$
Zinc	$6,97 \times 10^{-19}$
Copper	$7,52 \times 10^{-19}$
Platinum	$1,02 \times 10^{-18}$
Calcium	$4,78 \times 10^{-19}$

11.1 Define *work function*.

The minimum amount of energy needed to emit an electron from the surface of a metal ✓✓

(2)

11.2 What is represented by the gradient of the graph above?

Planck's constant ✓✓

(2)

11.3 Use the information from the graph and table to determine the identity of metal X.

$$\begin{aligned}
 W_0 &= hf_0 \\
 &= (6.64 \times 10^{-34})(1.05 \times 10^{15}) \\
 &= 6.93 \times 10^{-19} \text{ J} \\
 \therefore \text{The metal is Zinc}
 \end{aligned}$$

Metal X: Zinc

(4)

11.4 The wavelength of blue light is given as 475 nm. When this blue light is shone onto a certain metal surface, the maximum velocity of emitted electrons is $2.77 \times 10^5 \text{ m s}^{-1}$. Determine which metal from the table above is being used.

$$\begin{aligned}
 \frac{hc}{\lambda} &= W_0 + \frac{1}{2} m_e v^2 \\
 \frac{(6.6 \times 10^{-34})(3 \times 10^8)}{475 \times 10^{-9}} &= W_0 + \frac{1}{2} (9.1 \times 10^{-31})(2.77 \times 10^5)^2 \\
 W_0 &= 3.82 \times 10^{-19} \text{ J} \\
 \therefore \text{The metal is sodium}
 \end{aligned}$$

Metal: Sodium

(5)

[13]

TOTAL: 200 Marks