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SAHETI SCHOOL

PHYSICS PRELIM 2022

PHYSICAL SCIENCE

GRADE 12

PAPER 1 : PHYSICS

EXAMINER : C ORCHISON

DATE : 04 JUNE 2022

MODERATORS : M. RAMUTHAGA-MUSAMPA

HOURS : 3 HOURS

J. NAIDU

MARKS : 200

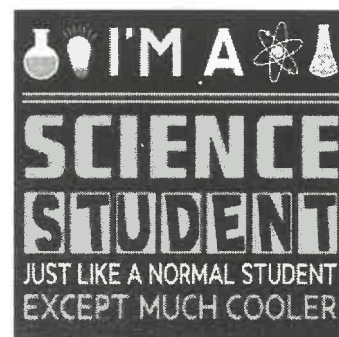
NAME : Orch memo

INSTRUCTIONS AND INFORMATION

1. This question paper consists of 31 pages with 9 questions.
2. A data sheet is provided.
3. Answer all questions on this paper and show all working out.
4. Extra space is provided at the end of the paper should you require it.
5. Use the mark allocation as guide to the maximum time you should spend on a question.
6. Use bullet points for all explanations.
7. Round all answers to 2 decimal places and include the correct SI unit.
8. Answers should be expressed in decimal format and not left as fractions.

In the inspiring words of the famous theoretical physicist Wolfgang Pauli...

"The best that most of us can hope to achieve in physics is simply to misunderstand it at a deeper level".

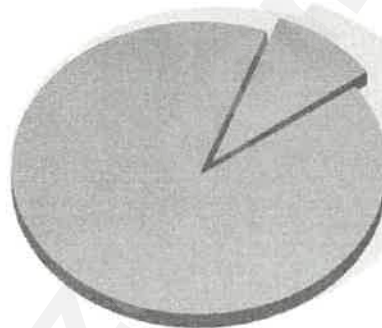


QUESTION 1

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.

1.1	A	B	☒ C	D	✓✓
1.2	A	B	☒ C	D	✓✓
1.3	☒ A		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	✓✓

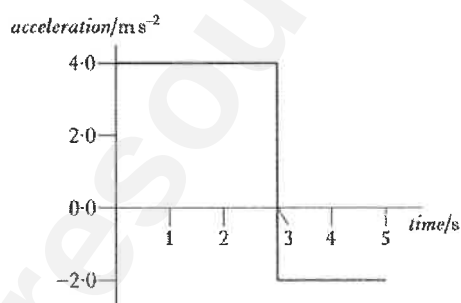
WHY I AM MAJORING IN PHYSICS



☒ To increase mankind's understanding of the universe

☐ To figure out how to build a lightsaber

- 1.1 The acceleration-time graph for an object starting from rest is given below.



$$V = \text{area} \\ = (4)(3) \\ = 12 \text{ m.s}^{-1}$$

$$V = (2)(-2) \\ = -4 \text{ m.s}^{-1}$$

What is the magnitude of the final velocity of the object after 5 seconds?

A 2 m.s^{-1}

B 4 m.s^{-1}

☒ C 8 m.s^{-1}

D 16 m.s^{-1}

- 1.2 A Casio calculator is dropped from the roof of a building which has a height of h . At the same instant another Casio calculator is thrown vertically upwards from the ground with velocity v . At what time do the calculators pass each other? Ignore air resistance.

A $\frac{1}{4} (h/v)$

B $\frac{1}{2} (h/v)$

☒ C h/v

D $2 (h/v)$

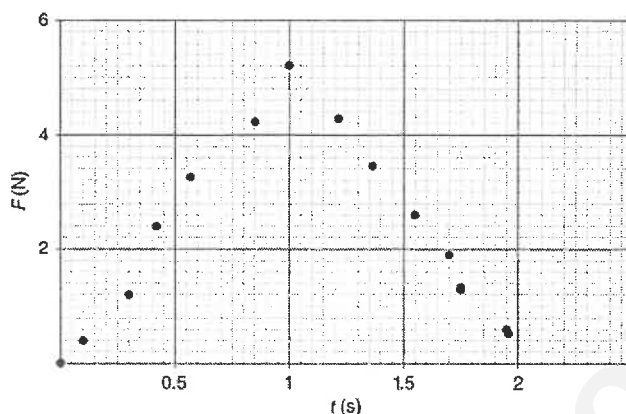
$$-s_1 + s_2 = h \quad \therefore -(0t + \frac{1}{2}gt^2) + (vt + \frac{1}{2}gt^2) = h$$

Page 2 of 31

$$\therefore vt = h \quad \therefore t = h/v$$

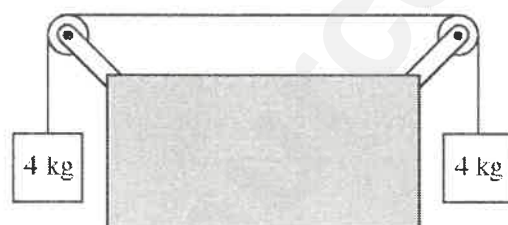
- 1.3 A PASCO cart experiences a changing net force acting on it over a period of 2 seconds as depicted in the graph below.

$$J = \text{area} \\ = \frac{1}{2}(5 \times 5,2) \\ = 5,2 \text{ N.s}$$



From the graph, the magnitude of the impulse experienced by the PASCO cart is approximately

- 1.4 Consider the following ideal pulley system in which the rollers are frictionless.



$$F_g = (4)(9,8) \\ = 39,2 \text{ N}$$

Which of the following statements are correct regarding the tension in the rope?

- I – the tension in the rope is 39,2 N when the system is at rest ✓
- II – the tension in the rope decreases when the block on the right is moving downwards at a constant velocity ✗ $a = 0 \therefore F_g = T$
- III – if one of the masses was replaced with an 8 kg mass the tension in the rope would double ✗

- A I and II B II and III C II only (D) I only

- 1.5 A car with a mass of 1000 kg travels at a constant velocity of 15 m.s^{-1} up a slope inclined at 8° to the horizontal. What is the rate of energy dissipation of the car's engine?

- A $1,47 \times 10^5 \text{ W}$
C $1,36 \times 10^3 \text{ W}$

- (B) $2,05 \times 10^4 \text{ W}$
D $1,5 \times 10^4 \text{ W}$

$$P = Fv = F_{g\parallel} \cdot v \\ = (1000)(9,8) \sin(8)(15)$$

1.6 A gravitational field is **defined** as ...

- A the force an object with mass experiences
- B the region in which an object with a mass experiences a force
- ☒ C the force acting per mass
- D the product of the mass and the acceleration due to gravity

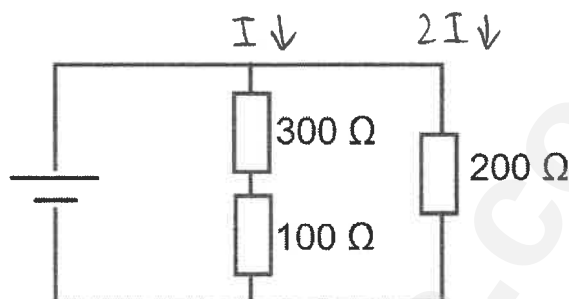
1.7 Consider the circuit shown below. Internal resistance of the battery is negligible.

$$W = I^2 R t$$

$$W = I^2 (300) t$$

$$W = I^2 (100) t$$

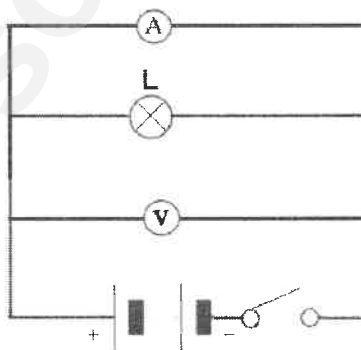
$$W = (2I)^2 (200) t$$



Which of the following options correctly ranks the energy dissipated by the resistors in a specific period of time?

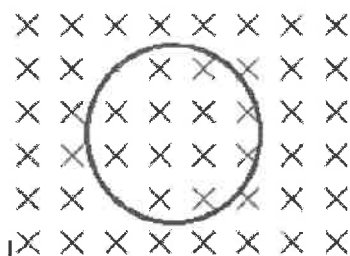
- A $E_{300\Omega} > E_{200\Omega} > E_{100\Omega}$
- B $E_{300\Omega} > E_{100\Omega} > E_{200\Omega}$
- ☒ C $E_{200\Omega} > E_{300\Omega} > E_{100\Omega}$
- D $E_{100\Omega} > E_{200\Omega} > E_{300\Omega}$

1.8 Which of the options correctly describes each of the following when the switch is **closed**?
The internal resistance of the battery is negligible.



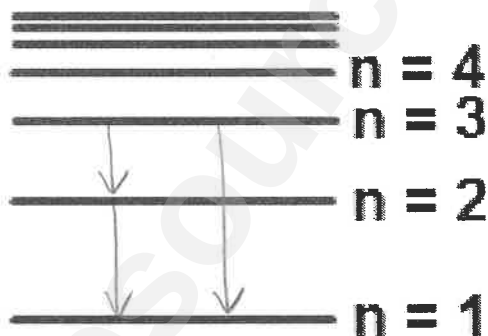
	Bulb L	Ammeter reading	Voltmeter reading
A	Glow ✗	Zero	Emf
B	Glow ✗	Maximum	Zero
C	Does not glow	Zero	Zero
☒ D	Does not glow	Maximum ✓	Emf ✓

- 1.9 A conducting loop of wire is placed as shown below in an increasing magnetic field which is directed into the page.



What is the direction of the induced current in the loop?

- A clockwise
 B anti-clockwise
 C into the page
 D out of the page
- 1.10 Consider the following representation of the energy levels in an atom. If an electron is excited to the 3rd energy level, how many possible emission lines could this produce?



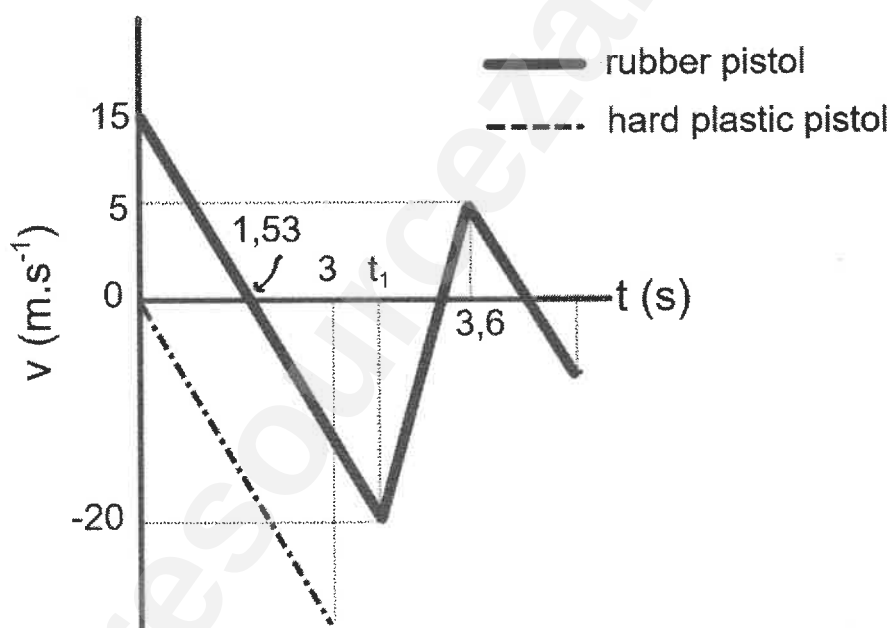
- A 1
 B 2
 C 3
 D 4

QUESTION 2

Jake loves Die Hard. LOVES it. He wants to be like his hero John McClane, so he heads up to the roof of a high building with two replica Beretta 92F pistols. One made from hard plastic and the other is made from rubber, each with a mass of 150 g.

In a dramatic move, he launches the rubber pistol vertically upwards at the edge of the roof and at the same instant he manages to drop the hard plastic replica. He fails to catch the rubber pistol as it passes him and it hits a ledge on the way down. The plastic pistol falls straight down. The graph below, not drawn to scale, shows the velocity of each pistol as a function of time.

Air resistance can be ignored.



- 2.1 Calculate the value of time t_1 . (3)

$$v = u + gt \quad \checkmark$$

$$-20 = 15 + (-9.8)t \quad \checkmark$$

$$t = 3.579 \quad \checkmark$$

- 2.2 Define displacement. (1)

change in position $\checkmark$

- 2.3 Calculate the height of the roof that Jake is standing on. (4)

$$V = U + gt$$

$$= 0 + (-9,8)(3)$$

$$= -29,4 \text{ m}$$

or

$$S = Ut + \frac{1}{2}gt^2$$

$$= 0 + \frac{1}{2}(-9,8)(3)^2$$

$$= -44,1$$

$$S = \frac{1}{2}bh = \frac{1}{2}(3)(29,4)$$

$$= 44,1 \text{ m}$$

$$\therefore \text{height} = 44,1 \text{ m}$$

- 2.4 Determine the acceleration the rubber pistol experiences while it is in contact with the ledge. (3)

$$a = \Delta y / \Delta x$$

$$= 5 - (-20) / 3,6 - 3,57$$

$$= 833,33 \text{ m} \cdot \text{s}^{-2} \text{ upwards}$$

- 2.5 Calculate the force the **ledge** exerts on the rubber pistol. (5)

$$F_{\text{net}} = ma$$

$$= (0,15)(833,33)$$

$$= 125 \text{ N}$$

$$F_{\text{net}} = F_{\text{ledge}} - F_g$$

$$125 = F_{\text{ledge}} - (0,15)(9,8)$$

$$\therefore F_{\text{ledge}} = 126,47 \text{ N upwards}$$

Rosa joins Jake on the roof and they decide to investigate the distances that the replica pistols fall as a function of time, because why not. They tabulate their very dodgy results as shown :

Distance fallen (m)	t (s)
160	1,92
125	1,73
90	1,41
40	0,95

$$t^2$$

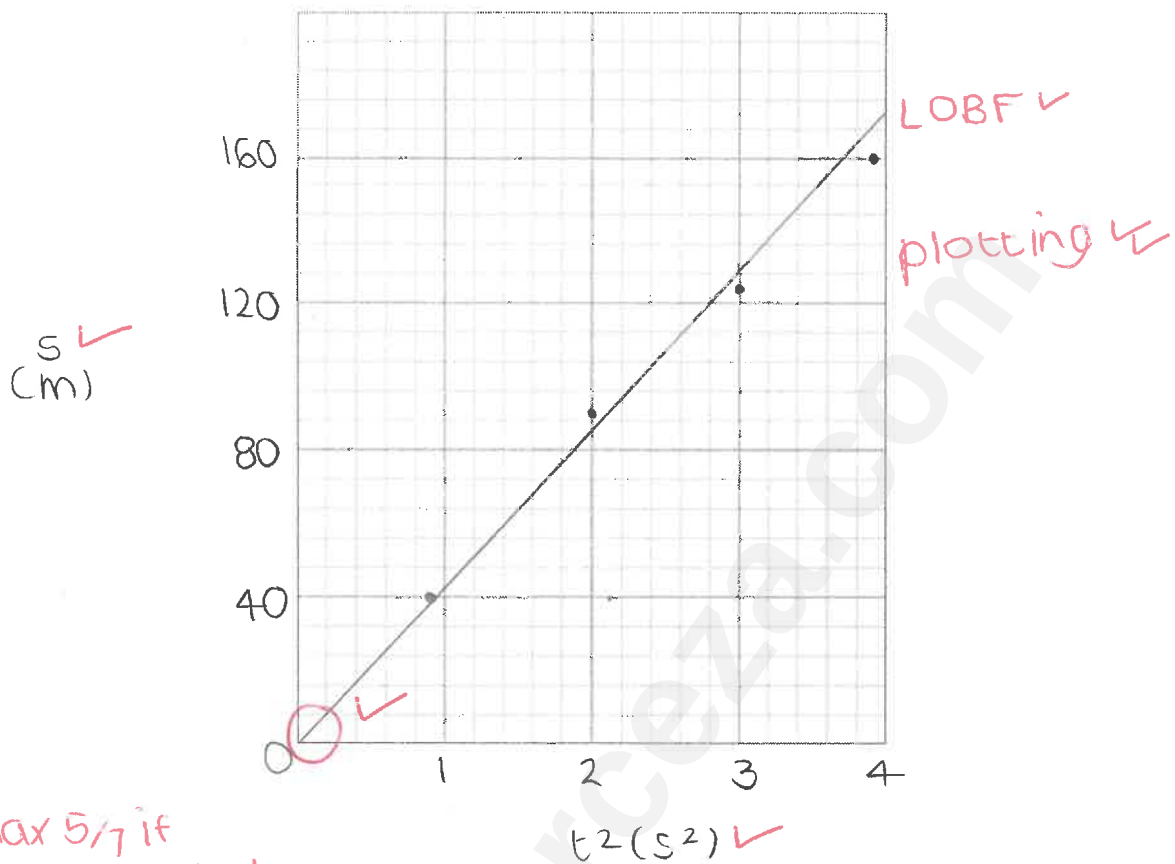
$$3,69$$

$$3$$

$$2$$

$$0,9$$

- 2.6 Use their results to plot a graph of displacement vs t^2 on the axes provided. (6)

Distance fallen by pistol vs time squared

- 2.7 Refer to an equation of motion to show how the gradient of the graph above is related to the pistol's acceleration. (3)

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

or

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

$\uparrow$ $\uparrow$ $\downarrow$ $\uparrow$
 $y =$ c m x

$$s = 0 + \frac{1}{2}gt^2$$

$$\frac{1}{2}g = s/t^2$$

$$s/t^2 = \Delta y / \Delta x$$

- 2.8 Hence show by calculation that their results are indeed incorrect. (2)

data from graph: $\frac{1}{2}g = \Delta y / \Delta x$

$$= \frac{128 - 0}{3 - 0}$$

$$= 42,67$$

$$\therefore g = 85,33 \text{ m s}^{-2}$$

In light of these two failures, Jake realises that he should probably steer clear of rooftops. He heads back out on the highway and cruises along heading East at 70 km.h^{-1} . His police scanner alerts him to a suspect in a red BMW on the same highway just as the car described overtakes him travelling at a constant 160 km.h^{-1} East. It takes Jake 1 second to react before he switches on his siren and starts accelerating at 3 m.s^{-2} in pursuit.



2.9 Define acceleration.

(1)

rate of change of velocity ✓

2.10 Calculate how far apart Jake and the suspect are the instance before Jake starts accelerating.

(4)

Jake : $s = ut = (70/3,6)(1) = 19,44 \text{ m}$ ✓

Susp : $s = ut = (160/3,6)(1) = 44,44 \text{ m}$ ✓

$\therefore 25 \text{ m apart}$ ✓

2.11 Calculate the time it takes for Jake to catch up to the suspect.

(4)



$$s_J = s_S + 25 \quad \checkmark$$

$$ut + \frac{1}{2}at^2 = ut + 25 \quad \checkmark$$

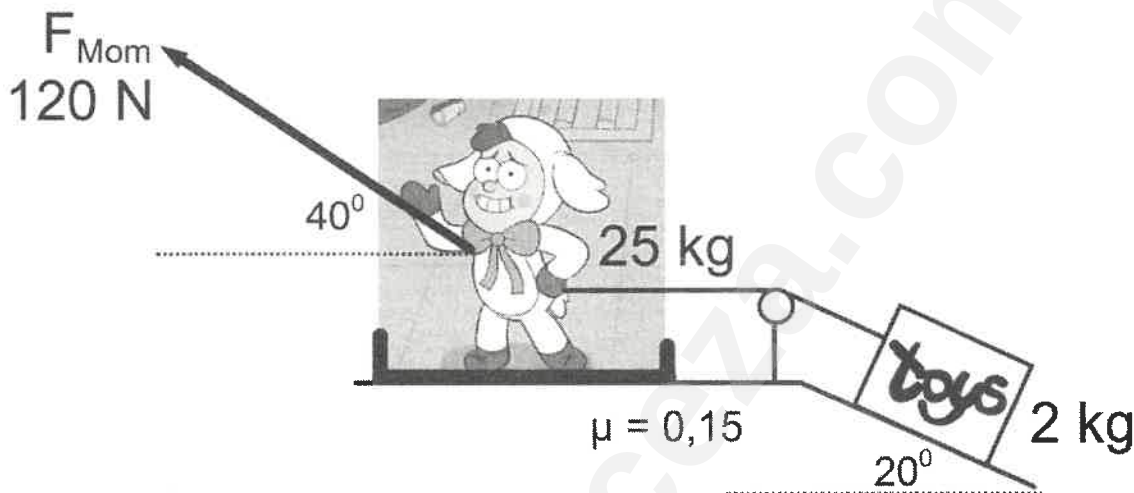
$$19,44t + \frac{1}{2}(3)t^2 = 44,44t + 25$$

$$\therefore t = 17,615 \quad \checkmark$$

36 MARKS

QUESTION 3

Before he moved to Gravity Falls, Dipper's mother would dress him up in a lamb costume and have him perform his signature song and dance, the "Lamby Lamby Dance." In this particular situation, Dipper found himself standing inside a little crate, dragging his toy box behind him using a rope over a frictionless pulley, while his mother dragged him across the carpet towards the lounge on the left to once again practice the dance. The kinetic coefficient of friction for both objects on the surface is 0,15.



3.1 Define *frictional force*.

force which opposes the motion of an object ✓ (1)

Dipper's sister Mabel shows you the following calculation she tried to do in order to work out the frictional force that the box of toys experiences. She got stuck when she couldn't figure out the value of T , so she stopped.

$$F_f = \mu F_N = (0,15)(F_{g\parallel} - T) = (0,15)(2)(9,8)(\cos 20^\circ - T)$$

3.2 Identify any two mistakes that Mabel has made in her working out.

(2)

- F_N should be $F_{g\perp} = F_g \cos \theta$ ✓
- T does not affect F_N ✓
- $F_{g\parallel}$ does not = $F_g \cos \theta$

- 3.3 Correctly calculate the kinetic frictional force that the box of toys experiences. (3)

$$\begin{aligned} F_{fk} &= \mu_k F_N = \mu F_{g\perp} = \mu F_g \cos \theta \\ &= (0,15)(2 \times 9,8) \cos 20^\circ \\ &= 2,76 \text{ N} \end{aligned}$$

- 3.4 Calculate the normal force experienced by Dipper and the crate if they have a combined mass of 25 kg. (3)

$$\begin{aligned} F_N &= F_g - F_{\text{mom. } v} \\ &= mg - F_{\text{mom. } \sin \theta} \\ &= (25 \times 9,8) - 120 \sin 40^\circ \\ &= 167,87 \text{ N} \end{aligned}$$

- 3.5 Calculate the magnitude of the kinetic frictional force that Dipper and the crate experience as they are being pulled to the left by his mother. (3)

$$\begin{aligned} F_{fk} &= \mu_k F_N \\ &= (0,15)(167,87) \\ &= 25,18 \text{ N} \end{aligned}$$

- 3.6 State Newton's second law of motion. (1)

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.

- 3.7 Prove by calculation that the force exerted by Dipper's mother is sufficient to accelerate the system towards the lounge at a rate greater than 2 m.s^{-2} . (6)

$$\text{Dipper: } F_{\text{momh}} - F_f - T = ma$$

$$\text{Toys: } T - F_{g\parallel} - F_f = ma$$

$$120 \cos 40^\circ - 25,18 - T = 25a$$

$$T - 6,70 - 2,76 = 2a$$

$$57,29 = 27a$$

$$\therefore a = 2,12 \text{ m.s}^{-2}$$

$$F_{g\parallel} = F_g \sin \theta$$

$$= (2)(9,8) \sin 20^\circ$$

$$= 6,70 \text{ N}$$

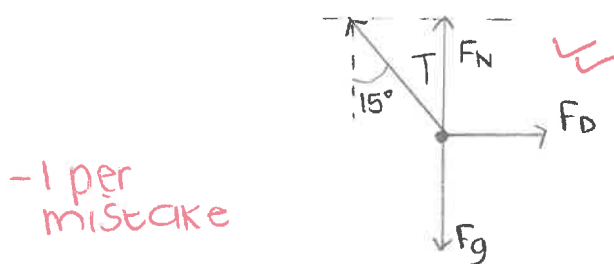
- 3.8 Dipper's mom is convinced that if she exerts the same force at an angle of 0° her applied force on the crate would be greater and the frictional force the crate experiences would be less, and therefore the system would experience a greater acceleration. Critically analyze her reasoning. (2)

- F_n would increase : correct ✓
- F_f would increase as no F_v to decrease F_n : incorrect ✓

Back in the present, Dipper is in the park with Candy. She asks him to pull her backwards with a horizontal force so that the swing she is sitting on makes an angle of 15° with the vertical before Dipper lets go. The combined mass of Candy and the swing is 40 kg .



- 3.8 Draw a fully-labelled free body diagram of all the forces acting on Candy when Dipper is exerting the horizontal force to hold her up. (3)



✓ { T - tension
F_g - weight
F_D - force of Dipper
F_N - normal

- 3.9 Calculate the magnitude the tension in the swing ropes when the swing is held at an angle of 15° to the vertical. (3)

$$F_g = T_v \quad \checkmark$$

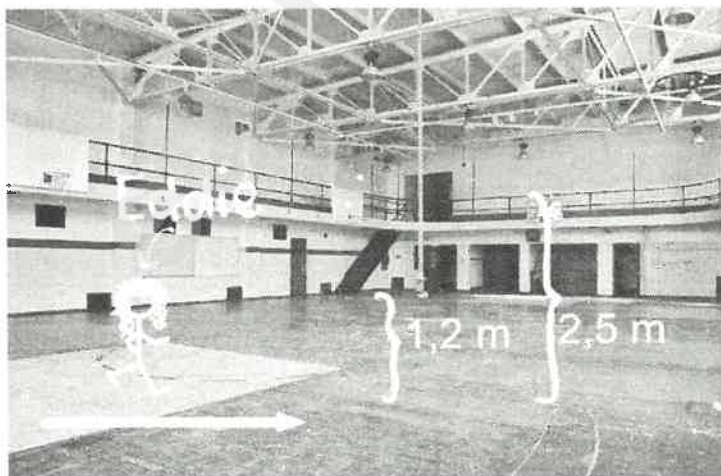
$$(40 \times 9,8) = T \sin 75^\circ \quad \checkmark$$

$$\therefore T = 405,83 \text{ N} \quad \checkmark$$

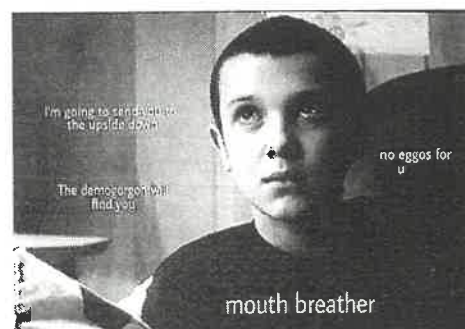
27 MARKS

QUESTION 4

A new monster from the Upside Down called Vecna, is on a murderous spree in the town of Hawkins. Eddie Munson becomes the prime suspect and is hunted down by Jason. In an attempt to escape from Jason (with a mass of 80 kg), Eddie (with a mass of 65 kg) runs towards the school gym where he sees one of the climbing ropes attached to the ceiling hanging in the middle of the room. His plan is to grab onto the bottom of the rope which is 1,2 m above the ground, and hopes to be able to swing up to the upper level of the gym 2,5 m above the floor as depicted in the sketch below:



When someone tells you they
don't like Stranger Things



- 4.1 Calculate the minimum velocity that Eddie needs to run at in order to be able to reach the upper level as planned. (5)

$$\begin{aligned}
 E_{p \text{ top}} &= E_{k \text{ bottom}} \\
 mgh &= \frac{1}{2}mv^2 \\
 (65)(9,8)(2,5-1,2) &= \frac{1}{2}(65)v^2 \\
 \therefore v &= 5,08 \text{ m.s}^{-1} \text{ right} \\
 &(5,05)
 \end{aligned}$$

- 4.2 State the law of conservation of linear momentum. (1)

the total linear momentum of an isolated system remains constant

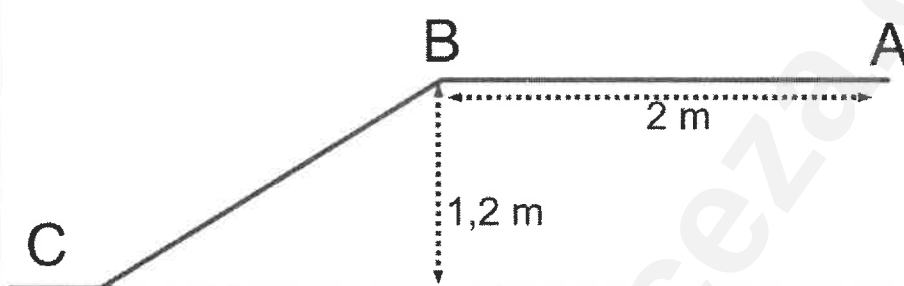
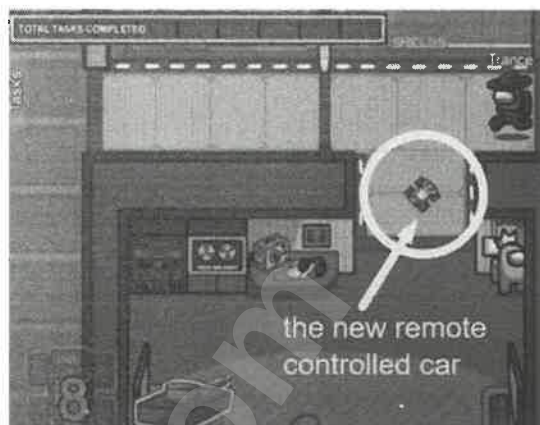
- 4.3 Eddie reaches the required velocity as calculated above, but just as he is about to grab the rope, he is tackled head-on by Jason (with a mass of 80 kg) who is running left towards him at 4 m.s^{-1} . Calculate the velocity with which they move off together immediately after the collision. (5)

$$\begin{aligned}
 p_i &= p_f \\
 m_1u_1 + m_2u_2 &= (m_1 + m_2)v \\
 (65)(5,08) + 80(-4) &= (65 + 80)v \\
 330,2 - 320 &= 145v \\
 \therefore v &= 0,073 \text{ m.s}^{-1} \text{ right} \\
 &(0,06)
 \end{aligned}$$

11 MARKS

QUESTION 5

In the game *Among Us*, you are either a Crewmate trying to complete a set of tasks, or a sneaky Imposter on a mission to sabotage the crewmates. Recently a prominent YouTuber named "Jelly" decided to test his skills and created a modification to the game. This new modification gives the Imposter a deadly weapon.. a remote controlled car which kills Crewmates as soon as they come into contact with it. The Imposter guides the car along the following path from A to C:



The car has a mass of 1,3 kg. Powered by a motor, it moves past point A with a velocity of $3 \text{ m}\cdot\text{s}^{-1}$ and reaches point B with a velocity of $5 \text{ m}\cdot\text{s}^{-1}$. A constant frictional force of 0,5 N acts against the car between points A and B.

- 5.1 State the *work-energy theorem*. (1)

the work done by a net force on an object is equal to the change in kinetic energy of the object ✓

- 5.2 Calculate the work done by the net force on the car between points A and B. (3)

$$\begin{aligned}
 W_{\text{net}} &= \Delta E_k = E_{kf} - E_{ki} \quad \checkmark \\
 &= \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \\
 &= \frac{1}{2}(1,3)(5)^2 - \frac{1}{2}(1,3)(3)^2 \quad \checkmark \\
 &= 16,25 - 5,85 \\
 &= 10,40 \text{ J} \quad \checkmark
 \end{aligned}$$

- 5.3 Hence calculate the force the motor exerted on the car between points A and B. (3)

$$W_{\text{net}} = F_{\text{net}} \cdot s$$

$$10,4 = (F_{\text{motor}} - F_f) s$$

$$10,4 = (F_{\text{motor}} - 0,5) 2$$

$$F_{\text{motor}} = 5,7 \text{ N}$$

- 5.4 Calculate the power of the car's **engine** if it took 6 seconds to travel between points A and B. (4)

$$W_{\text{motor}} = F_{\text{motor}} \cdot s$$

$$= (5,7)(2)$$

$$= 11,4 \text{ J}$$

$$P = W/t$$

$$= 11,4/6$$

$$= 1,9 \text{ W}$$

- 5.5 Define *mechanical energy*. (1)

the sum of the gravitational potential and kinetic energy at a point

- 5.6 Calculate the car's mechanical energy at point B. (4)

$$E_m = E_p + E_k$$

$$= mgh + \frac{1}{2}mv^2$$

$$= (1,3)(9,8)(1,2) + \frac{1}{2}(1,3)(5)^2$$

$$= 15,29 + 16,25$$

$$= 31,54 \text{ J}$$

- 5.7 If the car loses 10% of its mechanical energy as it moves from point B to point C, calculate the speed of the car at point C. (3)

$$\text{new } E_m = (0,9)(31,54) = 28,39 \text{ J}$$

$$E_k = \frac{1}{2}mv^2$$

$$28,39 = \frac{1}{2}(1,3)v^2$$

$$\therefore v = 6,61 \text{ m.s}^{-1}$$

19 MARKS

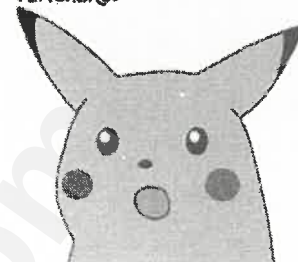
QUESTION 6

Perhaps the most famous of all Pokémon, is Pikachu. Despite being adorably cute, the static electricity in his body can render an enemy paralyzed. To date, there are only two known planets in the Pokémon universe. One is the Pokémon World, along with its moon, and the other is the unnamed world from which Deoxys came.

Pokémon World is similar to earth and therefore has been assigned a mass of 6×10^{24} kg and a diameter of 12 742 km. The unnamed world, which has a mass 20% greater than that of Pokémon World, exerts a gravitational force of 5×10^{20} N on Pokémon World.

STUDENTS: WE STUDIED OUR DEFINITIONS

TEACHERS:



6.1 State Newton's law of universal gravitation. (1)

Every particle with mass in the universe attracts every other particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres ✓

6.2 Calculate the distance between the centres of the two worlds. (4)

$$F = \frac{G m_1 m_2}{r^2} \quad \checkmark$$

$$5 \times 10^{20} = \frac{(6,7 \times 10^{-11}) (6 \times 10^{24}) (7,2 \times 10^{24})}{r^2} \quad \checkmark$$

$$r = 2,41 \times 10^9 \text{ m} \quad \checkmark$$

- 6.3 Pikachu has a mass of 6 kg. Determine the gravitational acceleration on the unnamed world, and hence calculate Pikachu's weight on the unnamed world. (5)

$$g' = \frac{G(1,2M)}{R^2} \quad \checkmark$$

$$= 1,2g$$

$$= 1,2(9,8) \quad \checkmark$$

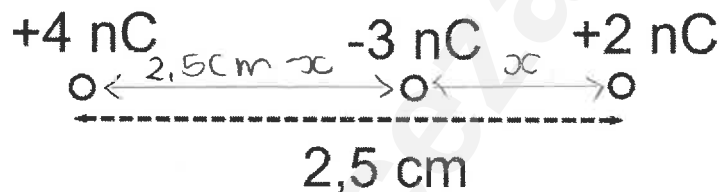
$$= 11,76 \text{ m.s}^{-2} \quad \checkmark$$

$$F_g' = mg' \quad \checkmark$$

$$= (6)(11,76)$$

$$= 70,56 \text{ N} \quad \checkmark$$

Pikachu uses his abilities to create three point charges and places them as shown in the diagram below:



- 6.4 Describe an *electric field*. (1)

a region of space in which an electric charge experiences a force $\checkmark$

- 6.5 Calculate the electric field the 4nC point charge experiences as a result of the +2nC point charge only. (3)

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

$$= \frac{(9 \times 10^9)(2 \times 10^{-9})}{(2,5 \times 10^{-2})^2} \quad \checkmark$$

$$= 2,88 \times 10^4 \text{ N.C}^{-1} \text{ left} \quad \checkmark$$

- 6.6 If the net electric force experienced by the -3nC charge is zero, calculate the distance the -3nC point charge is from the $+4\text{nC}$ charge. (5)

$$\frac{kq_1q_2}{r^2} = \frac{kq_1q_2}{r^2}$$

$$\frac{k(4 \times 10^{-9})(3 \times 10^{-9})}{(2,5 \times 10^{-2} - x)^2} = \frac{k(3 \times 10^{-9})(2 \times 10^{-9})}{x^2}$$

$$(4 \times 10^{-9})x^2 = (2 \times 10^{-9})(2,5 \times 10^{-2} - x)^2$$

[#insertmathshere]

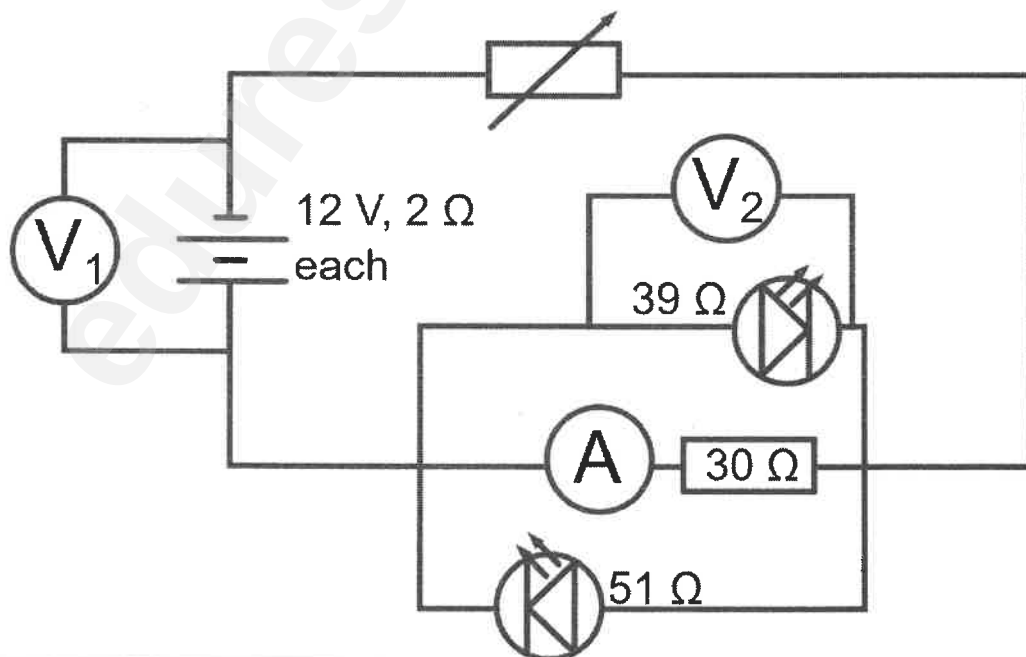
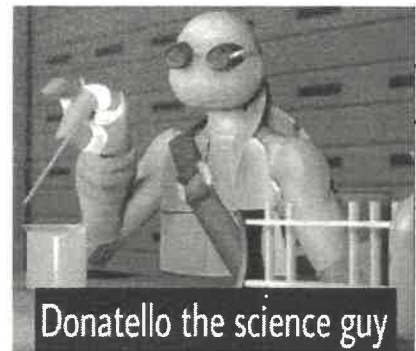
$$x = 1,04 \times 10^{-2} \text{ m}$$

$$\therefore 2,5 \times 10^{-2} - 1,04 \times 10^{-2}$$

$$= 1,46 \times 10^{-2} \text{ m}$$

QUESTION 7

Leonardo and Donatello have decided that they need a little more colour in their sewer home, so they set up the circuit below containing different coloured LED bulbs and a rheostat. Each cell in the battery has an emf of 12 V and internal resistance of $2\ \Omega$. The $39\ \Omega$ LED produces green light when a current of 20 mA passes through it, and the $51\ \Omega$ LED is designed to produce red light.



- 7.6 Calculate the resistance that Leonardo needs to set the rheostat to in order for the required 20 mA to pass through the green LED.

(5)

$$\text{emf} = I(R + r)$$

$$24 = 0,046(R + 4)$$

$$\therefore R = 517,74 \Omega$$

$$R_{\text{ext}} = R_s + R_p$$

$$517,74 = R_s + 16,96$$

$$\therefore R_s = 500,78 \Omega$$

COE

$$R_p = 12,73 \Omega$$

$$I_t = 0,061 \text{ A (3 branches)}$$

$$\therefore R_{\text{ext}} = 389,44 \Omega$$

$$\therefore R_s = 376,71 \Omega$$

- 7.7 Calculate the amount of charge passing through the battery in a time of 3 minutes.

(3)

$$Q = It$$

$$= (0,046)(3 \times 60)$$

$$= 8,28 \text{ C}$$

- 7.8 Define power.

(1)

rate at which work is done

- 7.9 Calculate the power dissipated by the green LED.

(3)

$$P = I^2 R$$

$$= (20 \times 10^{-3})^2 (39)$$

$$= 1,56 \times 10^{-2} \text{ W}$$

SA: "Hi, can I get some electricity please?"
Eskom: "Sorry, the machine is broken"



7.1 Define *potential difference*. (1)

work done per unit positive charge ✓

7.2 Calculate the reading on voltmeter V_2 . (3)

$$\begin{aligned} V &= IR \quad \checkmark \\ &= (20 \times 10^{-3})(39) \quad \checkmark \\ &= 0.78 \text{ V} \quad \checkmark \end{aligned}$$

7.3 Calculate the reading on the ammeter, A. (3)

$$\begin{aligned} I &= V/R \quad \checkmark \\ &= 0.78/30 \quad \checkmark \\ &= 0.026 \text{ A} \quad \checkmark \end{aligned}$$

7.4 Explain why the total current passing through the circuit is calculated by only adding the current through the 30Ω resistor and the current through the green LED. (1)

the red LED is reverse biased ✓

7.5 Calculate the effective resistance in parallel. (3)

$$\begin{aligned} \frac{1}{R_p} &= \frac{1}{R_1} + \frac{1}{R_2} \quad \checkmark \\ &= \frac{1}{39} + \frac{1}{30} \quad \checkmark \\ \therefore R_p &= 16.96 \Omega \quad \checkmark \end{aligned}$$

- 7.10 Michaelangelo says that the reading on voltmeter V_1 would decrease if Raphael corrects the red LED. Is he correct? Explain your answer fully using bullet points. (4)

R_t : decreases ✓
 I_t : increases ✓
 V_{lost} : increases ✓
 V_1 : decreases $\therefore$ correct ✓

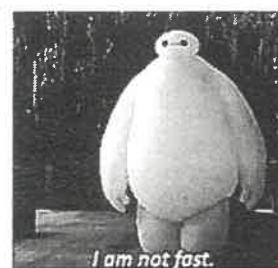
27 MARKS

QUESTION 8

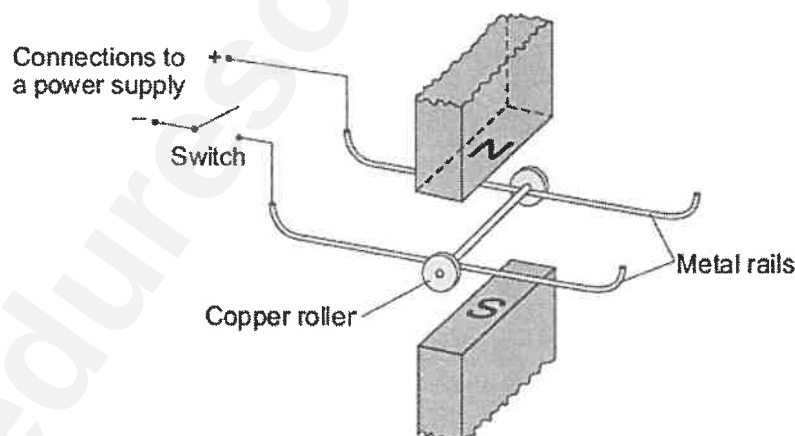
Hiro Hamada is a 14-year-old high school graduate and robotics genius. His older brother Tadashi takes Hiro to the research lab at his university, where he meets Tadashi's creation, Baymax, an inflatable healthcare robot. Baymax and Hiro spend some time walking through the lab and are especially fascinated by the area containing magnets, motors and transformers.

Teacher: Why are you always late?

Me:



Hiro notices a copper roller balancing on metal rails connected to a DC power supply as shown below. The roller starts between the poles of the two magnets.



- 8.1 When Baymax closes the switch the copper roller moves. Does it move to the left or to the right? (1)

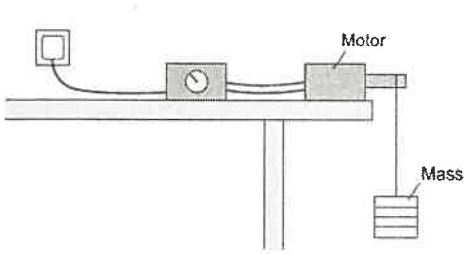
right ✓

- 8.2 Hiro wants the same roller to move quicker. Suggest two changes he could make in order to achieve this. (2)

- increase current ✓
- stronger magnets ✓

* not decrease mass

They then find a **motor** being used to lift a mass and some tabulated results as shown:



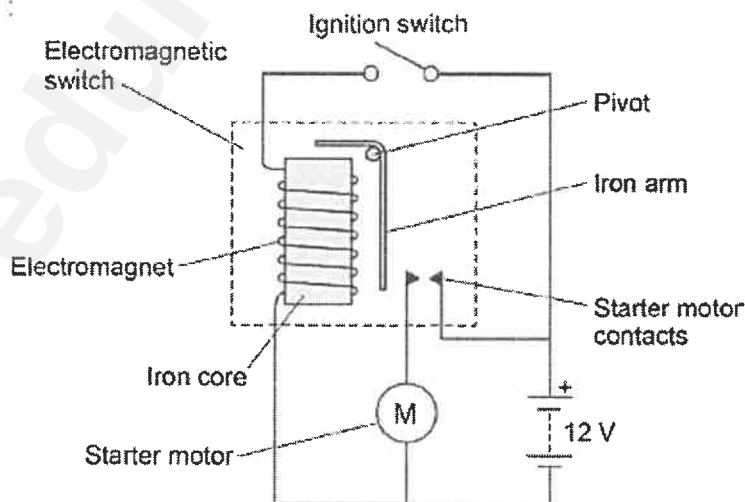
Test	Electrical input power in watts	Work done lifting the mass in joules	Time taken to lift the mass in seconds	Output power in watts
A	20	24	2.4	10
B	40	24	1.2	20
C	60	24	0.8	30
D	80	24	0.2	120

- 8.3 Hiro thinks that one of the results is somewhat suspicious. By calculating efficiency, show which result is anomalous. (3)

$$\begin{aligned} \% \text{ efficiency} &= P_{\text{out}} / P_{\text{in}} \times 100 \\ &= 120 / 80 \times 100 \\ &= 150\% \end{aligned}$$

∴ D is dodgy ✓

Baymax excitedly points to a diagram showing the ignition circuit used to switch on the starter motor in a car:



PLEASE TURN OVER

8.4 Define magnetic flux linkage.

(1)

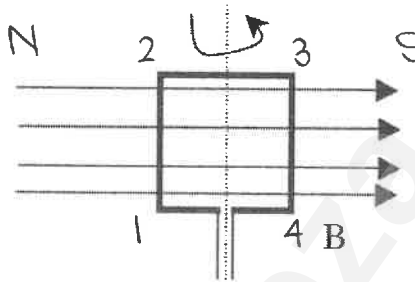
the product of the number of turns on the coil and the flux through the coil ✓

8.5 Determine the polarity at the **top** of the electromagnet when the current is flowing in the circuit.

(1)

north ✓

Hiro sketches the following diagram of an armature and tells Baymax that it represents an **AC generator**:



8.6 State Faraday's law.

(1)

the induced emf is directly proportional to the rate of change of magnetic flux ✓

8.7 If Hiro rotates the armature in the diagram as shown, does the induced current flow in the direction 1-2-3-4 or 4-3-2-1 through the loop?

(1)

1-2-3-4 ✓

8.8 What component is missing from this generator in order to produce alternating current? (1)

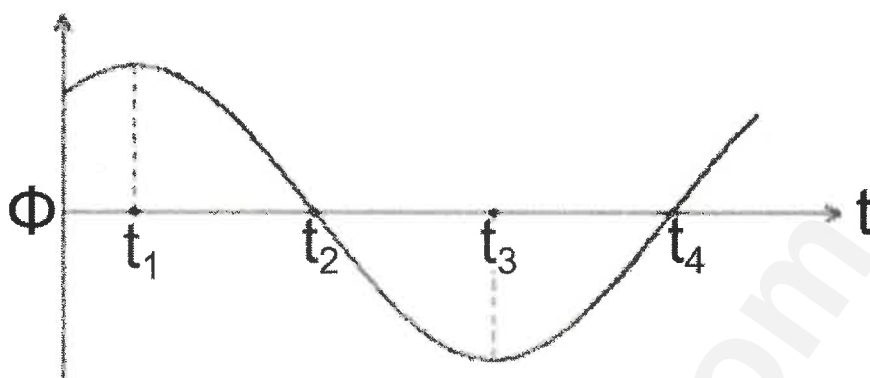
slip rings ✓

8.9 Aside from changing this component, what would Hiro need to do in order to change this into a DC motor?

(1)

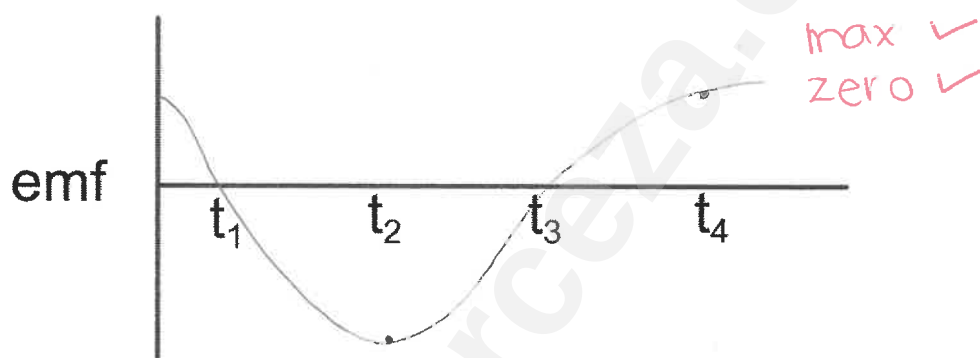
replace the mechanical input with a DC power supply ✓

Hiro draws a graph to show the variation of magnetic flux through the coil of his generator:

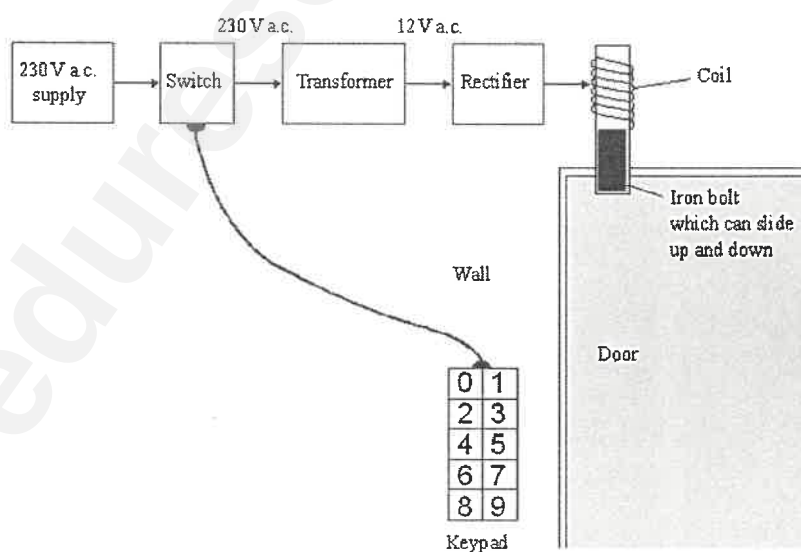


8.10 Sketch the corresponding induced emf graph on the axes below:

(2)



Lastly they discover a remote controlled door bolt. When the correct numbers are entered into the keypad, the transformer is activated in order to step the voltage down from 230 V to 12 V, and the door can be opened.



- 8.11 If there are 250 turns on the primary coil of the transformer, calculate the number of turns on the secondary coil of the transformer rounded to the nearest whole number. (3)

$$N_s/N_p = V_s/V_p \quad \checkmark$$

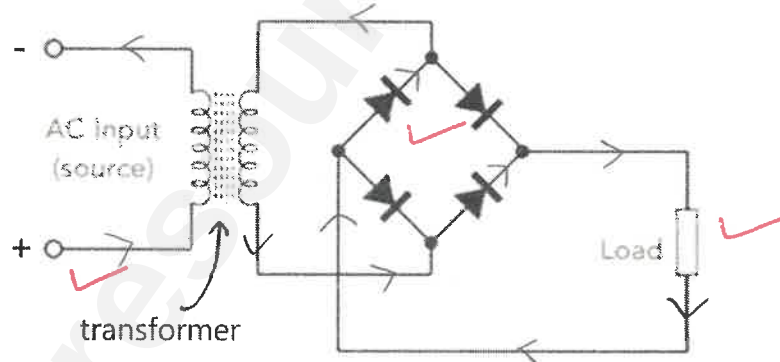
$$N_s/250 = 12/230 \quad \checkmark$$

$$\therefore N_s = 13,04 (\approx 13) \quad \checkmark$$

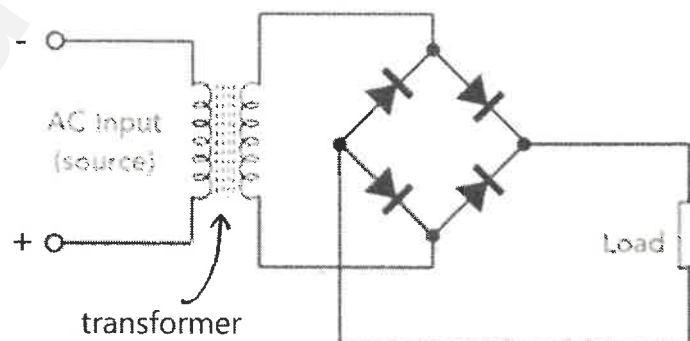
- 8.12 Why will a transformer not work on direct current? (1)

no change in magnetic flux ✓

- 8.13 Baymax knows that a bridge rectifier is used to change the current from the transformer into direct current. On the circuit diagram below, clearly indicate the path that conventional current would follow in the relevant wires using a highlighter and arrows, starting from the indicated positive terminal. **Assume that current does not change direction across the transformer.** (3)



Extra one in case you make a mess... #iknowyoudguys



21 MARKS

QUESTION 9

Mando and Grogu are on their way to apprehend a fugitive when their spacecraft, the Razor Crest, encounters enemy fire and they have to make an emergency landing on a remote outer rim planet. Mando is unfamiliar with the planet and so they run an emission spectrum before stepping out of the Razor Crest to see if the gases in the atmosphere are dangerous.



- 9.1 Explain how an emission spectrum is able to determine the gases present. (1)
- each element has a unique spectrum due to a unique electron configuration ✓

The energy levels shown below belong to one of the gases they detect.

E_4	_____	$-0.871 \times 10^{-19} \text{ J}$
E_3	_____	$-1.36 \times 10^{-19} \text{ J}$
E_2	_____	$-2.42 \times 10^{-19} \text{ J}$
E_1	_____	$-5.45 \times 10^{-19} \text{ J}$
E_0	_____	$-21.8 \times 10^{-19} \text{ J}$

- 9.2 Why are the given energy values negative? (1)
- they represent the amount of energy the electron would need to have added to it in order to reach ionized state ✓
- 9.3 Define a *photon*. (1)
- packet of light energy ✓

- 9.4 Grogu notices a blue band of light in the spectrum. If the photon is emitted when the electron transitions from excited level E_4 to excited level E_1 , calculate the wavelength of blue light. Give your final answer in nanometers. (4)

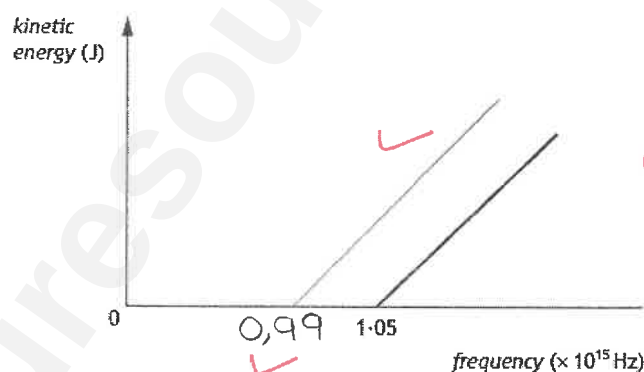
$$\Delta E = 5,45 \times 10^{-19} - 0,871 \times 10^{-19} \\ = 4,58 \times 10^{-19} \text{ J} \checkmark$$

$$E = hc/\lambda \\ 4,58 \times 10^{-19} = \frac{(6,6 \times 10^{-34})(3 \times 10^8)}{\lambda} \checkmark$$

$$\lambda = 4,32 \times 10^{-7} \text{ m} \checkmark \\ = 432 \text{ nm} \checkmark$$

As a bounty hunter, Mando is familiar with alarm systems that use laser beams based on the photoelectric effect. He sees that an unknown metal plate is being used and measures the speed of the ejected electrons as the frequency of incoming light varies.

The graph below shows his results:



- 9.5 Define threshold frequency. (1)

minimum frequency of incident radiation at which electrons will be emitted from a particular metal $\checkmark$



Groggu, who is known for getting his little green hands on things he should leave alone, replaces the unknown metal with aluminium, which has a threshold frequency of $9,9 \times 10^{14}$ Hz.

9.6 Add a line to the diagram to show how the kinetic energy of the ejected electrons would vary for aluminium compared to the unknown metal. (2)

9.7 If the velocity of the photoelectrons is measured to be $5,7 \times 10^6$ m.s⁻¹, calculate the frequency of the incoming radiation striking the aluminium surface. (6)

$$\begin{aligned}
 E &= W_0 + E_k \\
 &= (6,6 \times 10^{-34}) (9,9 \times 10^{14}) + \frac{1}{2} (9,1 \times 10^{-31}) (5,7 \times 10^6)^2 \\
 &= 6,53 \times 10^{-19} + 1,48 \times 10^{-17} \\
 &= 1,48 \times 10^{-17} \text{ J}
 \end{aligned}$$

$$\begin{aligned}
 E &= hf \\
 1,48 \times 10^{-17} &= (6,6 \times 10^{-34}) f \\
 f &= 2,34 \times 10^{16} \text{ Hz}
 \end{aligned}$$

9.8 Mando and Groggu compare the speed and number of photoelectrons ejected by both the unknown metal plate and the aluminium plate when they are irradiated with light of the same frequency and intensity. The work function of both metals is met by this frequency, so Mando says he thinks that both the speed and number of photoelectrons will be greater using the aluminium plate. Is he correct? Explain your answer fully using bullet points. (4)

Speed: increases;
due to a lower work function

number: stays the same;
intensity (number of photons)
has not changed

20 MARKS