2021 Trial Examination

THIS BOX IS FOR ILLUSTRATIVE PURPOSES ONLY

STUDENT NUMBER									Letter

PHYSICS

Unit 3 – Written examination

Reading time: 15 minutes
Writing time: 2 hours

Question and Answer Book

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	21	21	100
			Total 100

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners and rulers, one pre-written, A4 double-sided page of notes, one scientific calculator (not CAS or graphical) is permitted.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied

- Question and answer book of 30 pages. (Including formula sheet)

Instructions

- Print your name in the space provided on the top of this page.
- All written responses must be in English.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic communication devices into the examination room.

Instructions for Section A

Answer **all** questions in this section in the spaces provided. Write using black or blue pen.
Where an answer box has a unit printed in it, give your answer in that unit.
Unless otherwise stated, you should take the value of **g** to be 9.8 m s^{-2}.
Where answer boxes are provided, write your final answer in the box.
In questions worth more than 1 mark, appropriate working must be shown.
Unless otherwise indicated, diagrams are not to scale.

Question 1 (2 marks)

Patrick and Lucy are working with charged particles. Figure 1 below shows an electric field line pattern between two charged particles, X, on the left & Y, on the right.

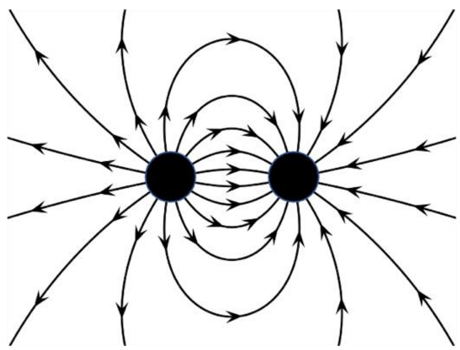


Figure 1

Based on the diagram, which **one or more** of the following statements is correct?
Answer in the box provided.

A. Both charges are positive.
B. Both charges are negative.
C. Either charge could be positive or negative.
D. X is positive, charge Y is negative.
E. X is negative, charge Y is positive.
F. X and Y are equal in magnitude.
G. Magnitude of X is greater than Y.
H. Magnitude of X is less than Y.
I. The field pattern is uniform.
J. The field pattern is non-uniform.

Question 2 (2 marks)

Keen astronomers, Lena and Hamish, are studying Saturn's moons. Tethys is Saturn's fifth largest moon, with a mass of 6.17×10^{20} kg and surface gravity of 0.146 N kg^{-1}.

Assuming a spherical shape, determine the radius of Tethys to the nearest km.

2 marks

km

Question 3 (3 marks)

Antonia and Gareth are investigating the behaviour of a fast-moving alpha particle in a magnetic field. Figure 2 shows the path of the alpha particle as it enters and leaves a magnetic field that is perpendicular to its velocity.

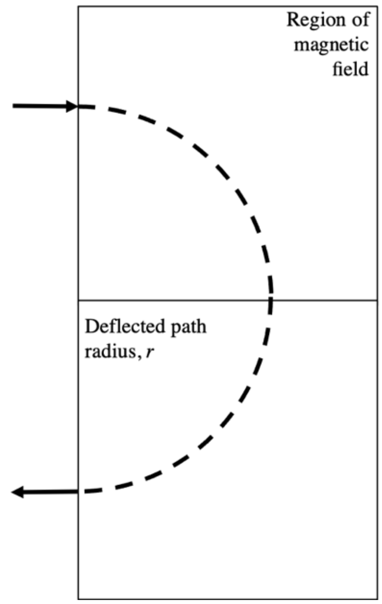


Figure 2

Data:

- Speed of alpha particle: 1.6×10^{7} m s^{-1}
- Mass of alpha particle: 6.64×10^{-27} kg
- Charge of alpha particle: $+3.20 \times 10^{-19}$ C
- Radius of curved path within magnetic field: 7.2×10^{-2} m

Determine the size and direction (**in** or **out of the page**) of the magnetic field that is deflecting the alpha particle.

3 marks

T	Direction:

Question 4 (2 marks)

Zac and Danielle use two bar magnets to generate and plot a magnetic field line pattern as shown in Figure 3.

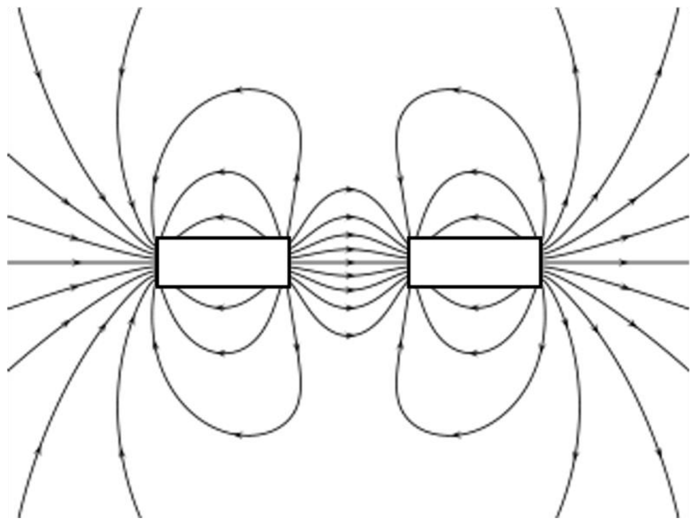


Figure 3

Label the missing poles of the bar magnets on Figure 3.

Question 5 (3 marks)

Luke and Charlie collate monopole and dipole properties of three different field types in Table 1 below, where Y refers to *Yes* and N refers to *No*.

Field Type	**Only Monopole**	**Only Dipole**	**Both Monopole and Dipole**
	N	Y	N
	N	N	Y
	Y	N	N

Table 1.

Complete the Field Type column by inserting **G** (Gravity), **M** (Magnetic) or **E** (Electrical) as applicable.

Question 6 (7 marks)

David and Jacqui have deconstructed an electron microscope and are investigating the properties of the velocity selector within it.

As shown in Figure 4, electrons enter the selector from the left, meeting an electric field (*E)* and perpendicular magnetic field (*B)*. Depending on their velocity, the electrons travel straight (to P) or are deflected up (towards Q) or down (towards R).

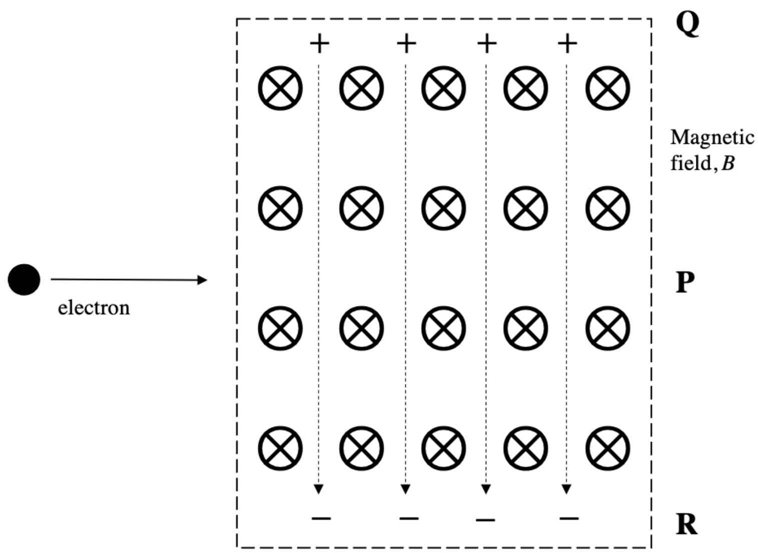


Figure 4

Data:

- Initial electron velocity: 1.8×10^{6} m s^{-1}
- Strength of electric field: 490 kV m^{-1}
- Charge on electron: 1.6×10^{-19} C

a. Determine the size of the electric force acting on an electron.

2 marks

N

Initially, electrons continue to travel in a straight line due to balanced electrical and magnetic forces.

b. Determine the size of the magnetic field, *B*.

2 marks

T

Jacqui would now like to see the electrons deflected upwards.

c. Complete the table below, indicating which modification (applied independently) would achieve Jacqui's aim. Use the terms: INCREASE or DECREASE in the table.

Electron velocity	**Magnetic field**	**Electric field**

3 marks

Question 7 (6 marks)

Alexis and Andrew have launched a new GPS satellite. The GPS satellite travels in a Medium Earth Orbit (MEO) at an altitude of 20,000 km. Assume the radius of the earth is 6.37×10^6 m.

a. State the radius of the satellite's orbit.

1 mark

m

b. Determine the period of the satellite's orbit.

3 marks

s

c. Determine the orbital speed of the satellite.

2 marks

m s^{-1}

Question 8 (5 marks)

Harriet and Lingming are attempting to reposition their own 30 kg satellite from a lower to higher orbit around a distant moon of Jupiter.

The gravitational field strength vs. altitude graph for the moon is shown below in Figure 5.

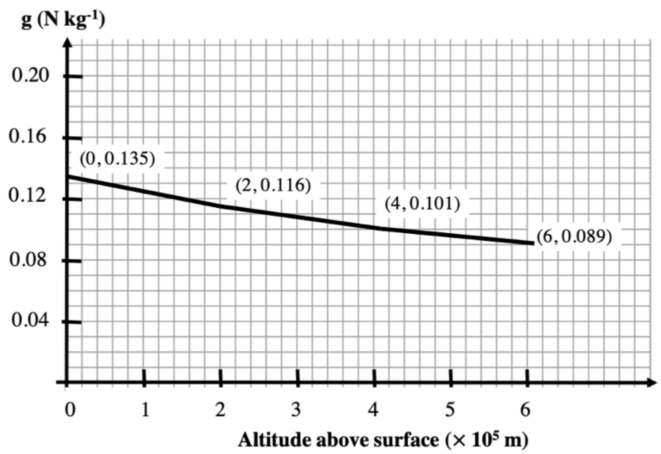


Figure 5

a. Determine the size of the change in gravitational potential energy (GPE) as Harrison and Lingming adjust its orbit from an altitude of 200 km to 600 km.

3 marks

J

With the manoeuvre complete, the satellite maintains a steady orbit at an altitude of 600 km.

b. Will the kinetic energy (E_k) of the satellite, be **constant, increasing** or **decreasing** during this orbit? Explain your answer.

2 marks

Question 9 (3 marks)

Isaac and Violet are demonstrating the functionality of a small generator. Key data for the device is listed below.

Data:

- Rectangular coil: 6 cm $\times$ 4 cm
- Turns: 12

Violet rotates the coil at a frequency of 20 Hz and Isaac observes an average voltage of 0.16 V for a quarter turn of the coil.

Determine the strength of the magnetic field that is surrounding the coil.

3 marks

T

Question 10 (8 marks)

Ethan and Justine move a small rectangular loop of copper wire into a magnetic field, *B*, at a constant speed as shown in Figure 6a. A graph of flux vs. time for the event is shown in Figure 6b.

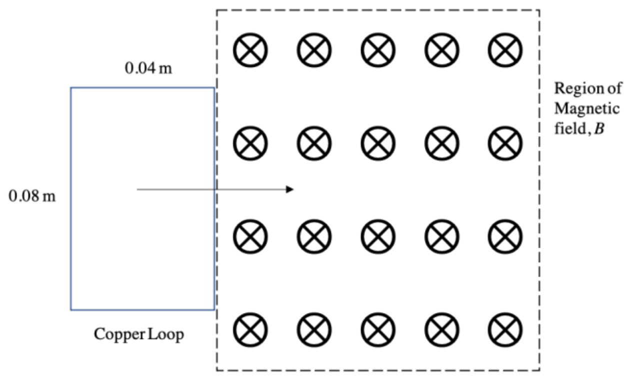


Figure 6a

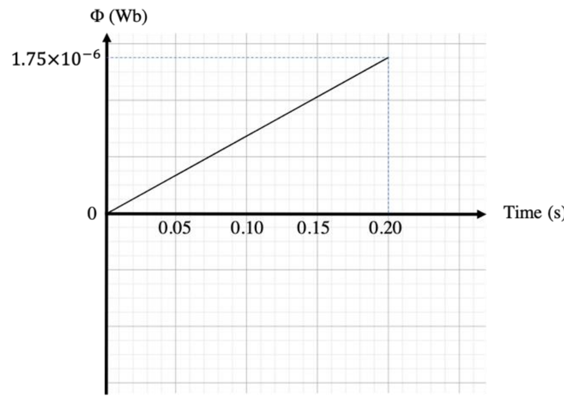


Figure 6b

a. Determine the speed of the loop.

1 mark

m s^{-1}

b. Determine the strength of the magnetic field, *B*.

2 marks

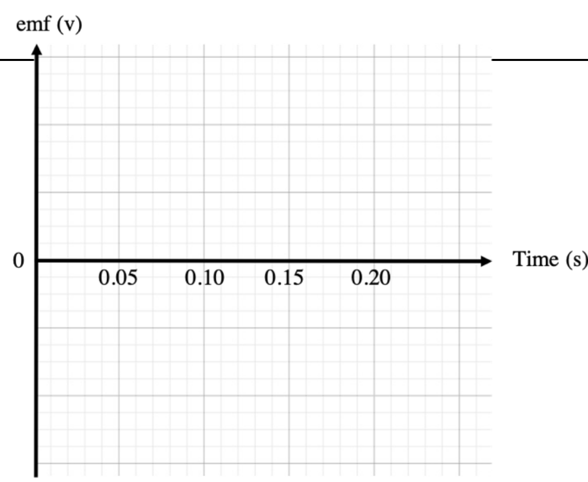
mT

c. Determine the direction of current in the loop as it moves into the magnetic field. Justify your choice with appropriate physics terminology.

Direction:

3 marks

d. On the axes provided below, sketch a graph of emf vs. time. Provide a vertical scale and use the convention: positive is clockwise.



2 marks

Question 11 (5 marks)

Tristan and Leanne have constructed a device that transforms 230 V_{RMS} to 12 V_{RMS} as shown in Figure 8. There are 60 turns on the secondary coil.

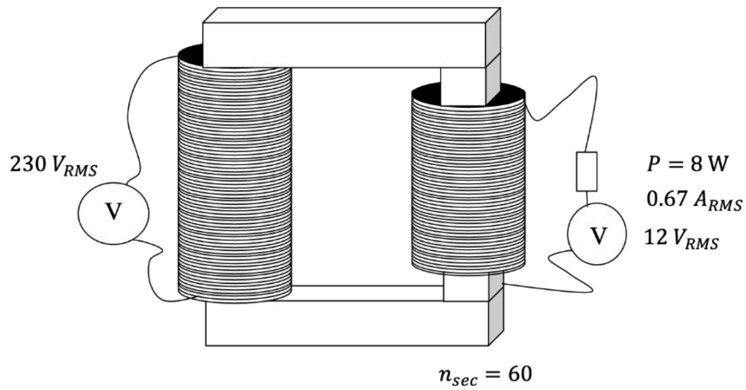


Figure 8

During testing, a light linked to the secondary operates at 8 W, with $I_{RMS} = 0.67$ A

a. Determine I_{PEAK} for the secondary coil.

2 marks

A

b. Determine the number of turns in the primary coil.

2 marks

turns

c. Assuming ideal transformer operation, determine I_{RMS} for the primary coil.

1 mark

A

Question 12 (7 marks)

Cameron and Riannon are analysing the motion of a carousel, where a 56 kg chair (shown here as a cube) is attached to a central pole and spun around at a constant speed. Riannon takes a snapshot of the setup and redraws it as shown below in Figure 9.

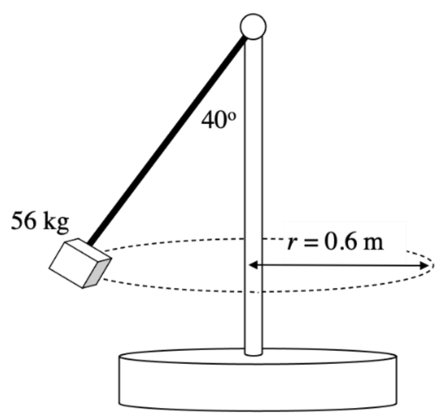


Figure 9

a. Based on the information shown in Figure 9, determine the speed of the chair.

3 marks

m s^{-1}

b. Based on the information shown in Figure 9, determine the tension in the cable joining the chair to the central pole.

2 marks

N

A rider now sits in the chair, increasing the mass to 86 kg. The operator maintains the same speed of the carousel.

c. Identify and explain the effect on the radius of the horizontal circle traced by the chair and the rider.

2 marks

Question 13 (3 marks)

William and Alexandra have devised a spring launching system that sends a 0.15 kg metal ball vertically into the air. It consists of a spring of natural length 0.6 m with a spring constant of 250 N m^{-1}. The spring is compressed by 0.2 m as shown in Figure 10 and then released, extending to its natural length and then releasing the ball.
[Note: All heights are measured relative to the horizontal bench upon which the spring is mounted.]

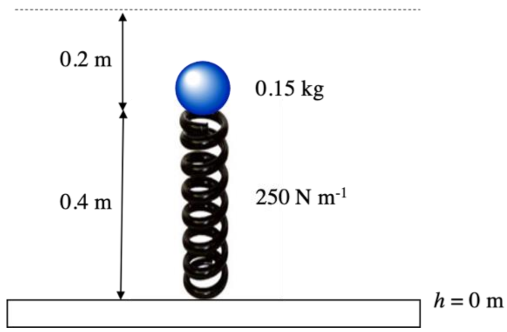


Figure 10

a. Determine the maximum height above the bench that is reached by the ball.

3 marks

m

Question 14 (5 marks)

Riley and Brandon are engaged in a mortar exercise that requires them to launch a projectile from ground level to the edge of a 53 m cliff which is 300 m from the launch point as shown in Figure 11. They set the launch velocity at 60 m s^{-1} and the launch angle at 40^o.
During your analysis of this question, you may ignore air resistance.

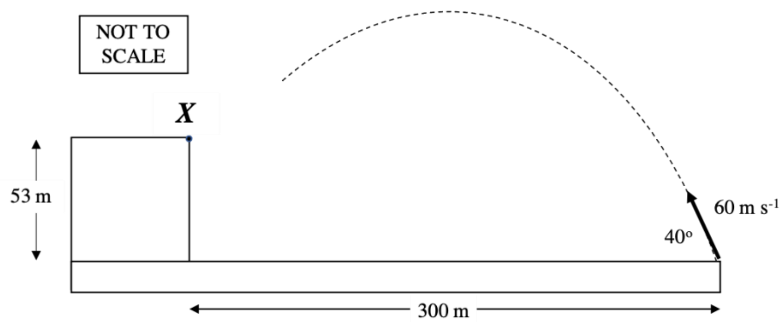


Figure 11

a. Determine the time take for the mortar projectile to travel a horizontal distance of 300 m (ie. level with the base of the cliff).

2 marks

s

Brandon is sceptical that the projectile will reach the intended target, *X*. He thinks that the projectile will fall short. Riley assures him that it will land accurately.

b. Who is correct? Determine whether the projectile is on target and, if not, explain whether it will fall too short or too long.

3 marks

Question 15 (6 marks)

Noah and Emily are using an air track to investigate a sticky collision. The air track enables frictionless motion of two gliders, which stick together with the aid of Velcro tabs upon contact. The "before and after" data is shown below in Figure 12.

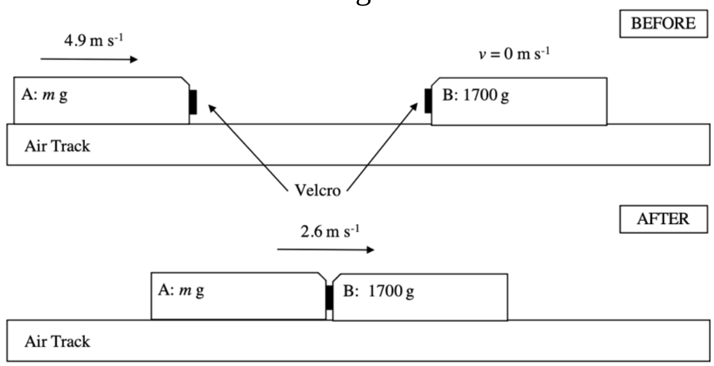


Figure 12

a. Determine the mass of Glider A.

2 marks

g

b. Given the collision takes 0.12 s, determine the magnitude and direction of the force of Glider B acting on Glider A during the collision.

2 marks

N

Direction:

c. Explain the difference between and an **elastic** and an **isolated** collision.

2 marks

Question 16 (5 marks)

Christina and Sam are attempting to analyse a coupled mass system on an inclined plane, as shown in Figure 13. A 2.0 kg mass falls vertically, pulling a 3.0 kg mass up a slope with an 8^{o} incline. A sliding friction force of 4 N impedes the motion of the 3 kg mass.

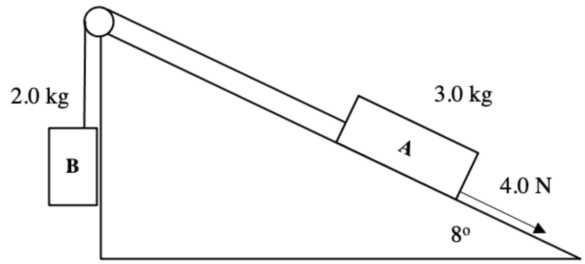


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Figure 13

a. Determine the acceleration of the coupled mass system.

3 marks

m s^{-2}

b. Determine the magnitude of the tension force in the coupling between the two masses.

2 marks

N

Question 17 (7 marks)
In a slightly controversial home experiment, Zander and Erica accelerate short-lived particles to a velocity of 0.98c before sending them through a 700 m long linear measuring station. At rest, the particles are known to have a half-life of 75 ns and a rest mass of 2×10^{-26} kg.

a. Determine the Lorentz factor for the particles from the reference frame of Zander, who stands at one end of the measuring station.

1 mark

b. Determine the half-life of the particles, as observed by the experimenters.

2 marks

ns

c. Determine the length of the measuring station from the reference frame of the particles themselves.

2 marks

m

d. Determine the relativistic kinetic energy of one of the particles.

2 marks

J

e. James and Benita are researching the power output of a nearby star. Benita estimates that the star converts 2.46×10^{11} kg of material into energy every minute. Determine the power output of the star.

2 marks

W

Question 19 (6 marks)

Rori and John construct a basic DC motor. The schematic drawing for their setup is shown below in Figure 14. Instead of using permanent magnets, John uses solenoids wrapped around an iron core to create the requisite magnetic field.

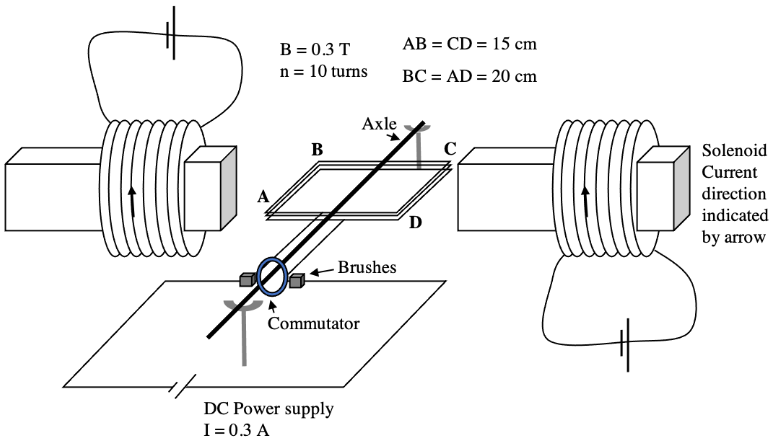

Figure 14

a. Based on the information shown in Figure 13, label the direction of the magnetic field in the vicinity of the coil.

1 mark

b. Determine the magnitude of the force acting on side AB of the coil and indicate whether the coil will initially rotate clockwise or anticlockwise.

3 marks

N	Direction:

The coil rotates an angle of 10^o from the horizontal.

c. Explain whether the size of the of the force acting on side AB will be **larger/smaller/same** in size. Justify your answer with an appropriate physical formula.

2 marks

Question 20 (7 marks)

Oscar and Erica are designing a rollercoaster and are attempting to determine the appropriateness of forces acting on riders in the carts that travel on the ride. A 300 kg cart and 60 kg rider start from rest at the top of a 26 m slope (Point A). As the cart descends to ground level, over 47 m of track, there is an average of 80 N of friction acting on the cart.

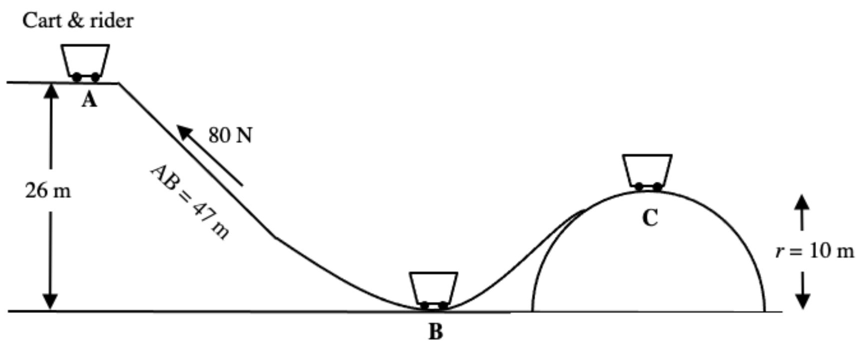

Figure 15

a. Determine the total kinetic energy of the cart and rider at the base (Point B).

3 marks

J

Point B can be considered to be at the bottom of a circular curved section of track.

b. Will the rider feel heavier or lighter at Point B? Explain your answer. You may refer to appropriate formulae, but there is no need for a specific calculation.

2 marks

A short time later, the cart and rider reach Point C with a velocity of 8 m s^{-1} over a crest with radius 10 m.

c. Determine the apparent weight of the rider at Point C.

2 marks

N

Question 21 (3 marks)

Leo and Siobhan are experimenting with two charged spheres, $Q_1 = 1.6$ µC and $Q_2 = -0.8$ µC. Leo places the charges 3 cm apart, with Q_2 positioned to the right of Q_1.

Determine the size and direction of the force of Q_1 acting on Q_2.

3 marks

N

Direction:

Question 22 (3 marks)

Blair and Weihan are designing a power transmission system for a shed on Blair's farm. Weihan has found access to a 50 kW, 230 V generator located some distance from the shed. Transmission lines of total resistance 0.6 Ω link the generator and shed. A step-up transformer (ratio 1:5) is located adjacent to the shed, whilst a step-down transformer (ratio 10:1) is located at the shed site, as shown in Figure 16.

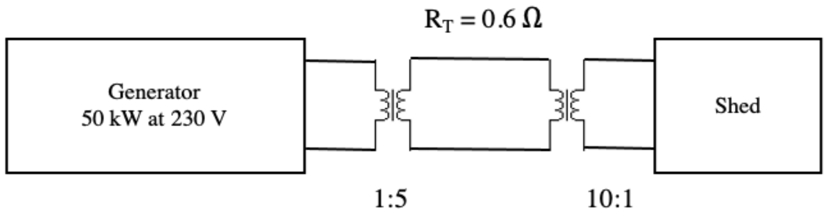

Figure 16

Determine the voltage at the shed site.

V

3 marks

END OF QUESTION AND ANSWER BOOKLET

Formula and Data Sheet

Prefixes

n = nano = 10^{-9}	m = milli = 10^{-3}	M = mega = 10^{6}
μ = micro = 10^{-6}	k = kilo = 10^{3}	G = giga = 10^{9}

General constants

Universal gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Mass of Earth	$M_E = 5.98 \times 10^{24}$ kg
Radius of Earth	$R_E = 6.37 \times 10^{6}$ m
Mass of the electron	$m_e = 9.1 \times 10^{-31}$ kg
Charge on the electron	$q = -1.6 \times 10^{-19}$ C
Speed of light	$c = 3.0 \times 10^{8}$ m s^{-1}
Planck's constant	$h = 6.63 \times 10^{-34}$ J s $h = 4.14 \times 10^{-15}$ eV s
Tonne	t = tonne = 10^{3} kg
Gravitational field strength at surface of Earth	9.8 N kg^{-1}
Coulomb constant	$k = 8.99 \times 10^{9}\ \mathrm{N\ m^2\ C^{-2}}$

Area of Study 1 – How do things move without contact?

Electric field	$E = k\frac{Q}{r^2}$
Electric force	$F = \frac{kq_1q_2}{r^2}$
Uniform electric field	$E = \frac{V}{d}$
Potential energy changes in a uniform field	$W = qV$
Force on a charged particle due to uniform electric field	$F = qE$
Force on moving charged particle in magnetic field	$F = qvB$
Radius of path followed by charged particle in magnetic field	$qvB = \frac{mv^2}{r}$
Gravitational field and force	$g = \frac{GM}{r^2}, F = \frac{GMm}{r^2}$
Potential energy changes in uniform gravitational field	$E_g = mg\Delta h$
Satellite motion	$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
Force on a current carrying conductor	$F = nIlB$

Area of Study 2 – How are fields used to move electrical energy?

Magnetic flux	$\phi = B_{\perp}A$
Electromagnetic induction	$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$
Transformer action	$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$
AC voltage, RMS	$V_{RMS} = \frac{V_{PEAK}}{\sqrt{2}}, I_{RMS} = \frac{I_{PEAK}}{\sqrt{2}}$
Voltage, Power	$V = IR,\ P = VI = I^2R$

Area of Study 3 – How fast can things go?

Velocity, acceleration	$v = \frac{\Delta x}{\Delta t}, a = \frac{\Delta v}{\Delta t}$
Equations for constant acceleration	$v = u + at$ $x = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $x = \frac{1}{2}(v + u)t$
Newton's second law	$\Sigma F = ma$
Circular motion	$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
Hooke's law	$F = -kx$
Elastic potential energy	$E_s = \frac{1}{2}kx^2$
Kinetic energy	$E_k = \frac{1}{2}mv^2$
Gravitational potential energy near Earth's surface	$E_g = mgh$
Time dilation	$t = t_o\gamma$
Length contraction	$L = \frac{L_o}{\gamma}$
Lorentz factor	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
Momentum and impulse	$\Delta p = m\Delta v = F_{av}\Delta t$
Mass-Energy	$E_{tot} = E_k + E_0 = \gamma m_o c^2$, where $E_0 = m_o c^2$ $E_k = (\gamma - 1)m_o c^2$