PHYSICS
UNIT 3
2021

MARKING GUIDE

Name ___________________________________

Teacher ___________________________________

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Materials required/recommended for this paper

To be provides by the supervisor
This Question/Answer booklet
Formulae and Data booklet

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid, eraser, ruler, highlighters.

Special items: up to three non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor.

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Question 1 **(4 marks)**

(a) (i) Draw an arrow showing the direction of the magnetic field.

Description	Marks
Draws an arrow from left to right, from North (N) to South (S)	1
Total	1

(ii) Draw an arrow on the wire to show the direction of the force acting on it.

Description	Marks
Draws an arrow upwards from the wire.	1
Total	1

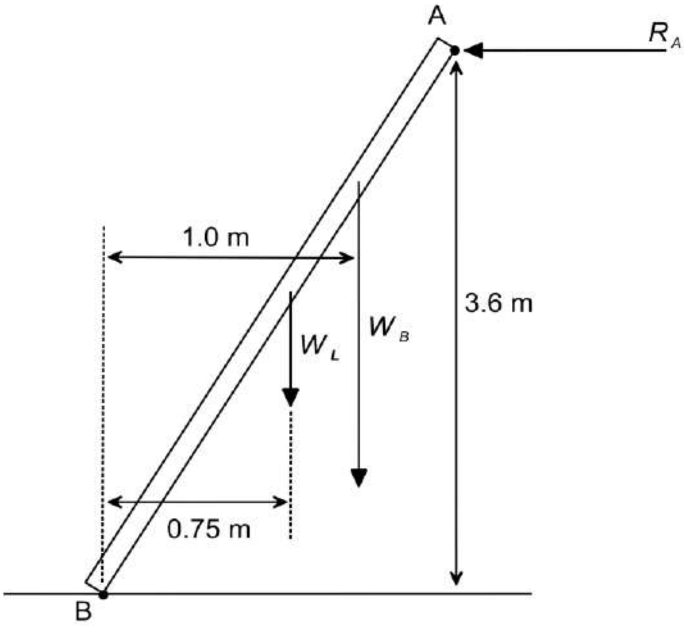
(a) Calculate the magnitude of the magnetic field (B) if the wire experiences a force of 2.7 mN.

Description	Marks
$B = \frac{F}{IL}$	
$B = \frac{F}{I \times L} = \frac{2.7 \times 10^{-3}}{1.2 \times 0.15}$	1
$B = 0.0150\ T$	1
Total	2

Question 2 **(5 marks)**

Description	Marks
M (Neptune) $= 17.3 \times (5.97 \times 10^{24}) = 1.03 \times 10^{26}$ kg	1
$T^2 = \frac{4\pi^2}{GM}r^3 = \frac{4\pi^2}{6.67 \times 10^{-11} \times 1.03 \times 10^{26}} \times (1.18 \times 10^8)^3$	1
$T^2 = 9.44 \times 10^9$ $\therefore\ T = 9.72 \times 10^4\ s$	1
$97026\ s = \frac{97026}{24 \times 3600}$ days $= 1.12$ days	1
Unknown moon (from table) is Proteus	1
Total	5

Question 3 (6 marks)



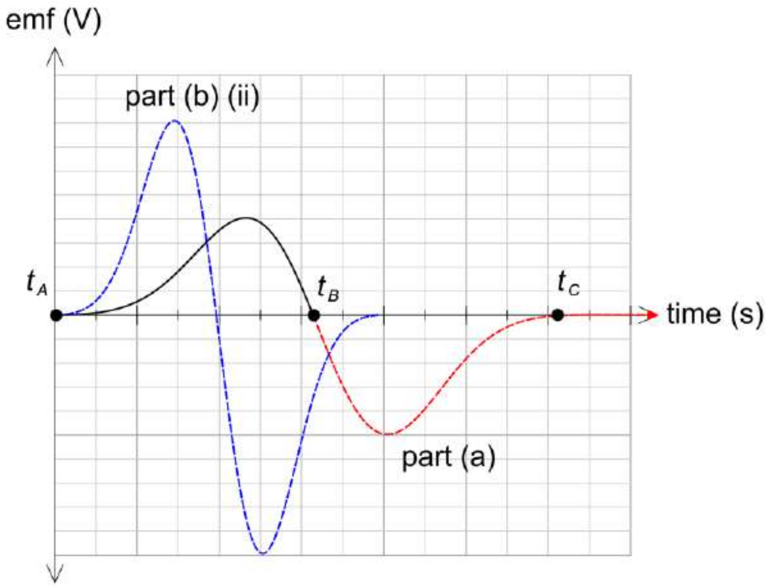
(a) Evaluate with calculations whether this situation is safe when the bricklayer is in the position described.

Description	Marks
Height of wall $h = \sqrt{3.9^2 - 1.5^2} = 3.6\ m$	1
Summing torques about point B $\tau_B = W_L \times 0.75 + W_B \times 1.0 - R_A \times h = 0$ $0 = (12 \times 9.8) \times 0.75 + (80 \times 9.8) \times 1.0 - 3.6R_A$	1
$R_A = 242$ N	1
Since the reaction force is less than 300 N, the situation is safe.	1
Total	4

(b) The bricklayer now moves to a position three-quarters up the length of the ladder. Explain how this makes the situation less safe.

Description	Marks
Moving 75% up ladder increases the CW torque from W_B about point B, thus also increasing the CCW torque required.	1
Thus, reaction force R_A will increase closer to 300 N, causing the situation to be less safe.	1
Total	2

Question 4 **(6 marks)**



(a) Complete the plot of the induced emf in the coil for the period the magnet moves between B and C. This will require you to mark and label t_C on the graph. Ignore any effects of the Earth's magnetic field.

Description	Marks
Larger maximum voltage for second half between B and C compared to between A and B.	1
Time between B and C slightly shorter (due to increased velocity) than between A and B.	1
Total	2

(b) The following changes are then made to this experiment:

(i) This equipment is now placed in an external vertical magnetic field. The external magnetic field is twice the strength of the magnetic field of the magnet. With reference to relevant Physics concepts, explain the effect on the output emf.

Description	Marks
The induced emf is proportional to the rate of change of flux due to the movement of the magnet through the coil (Faraday's law)	1
Since the field due to the external magnetic field is constant, the output emf will be unaffected.	1
Total	2

(i) This experiment is now performed on a planet where the acceleration due to gravity is 19.6 m s^{-2}. Draw the resulting emf output on the graph above for this location. (2 marks)

Description	Marks
On graph in blue – twice magnitude, second half larger than first half	1
On graph in blue – reduced time in the coil	1
Total	2

Question 5 (3 marks)

Description	Marks
Polarity of both charges is positive	1
$q_B > q_A$	1
Vector drawn horizontal to the left, equal in size to F_B	1
Total	3

Question 6 **(6 marks)**

Description	Marks
$T = \frac{1}{f} = \frac{1}{\left(\frac{54}{60}\right)} = 1.11\ s$	1
$v = \frac{2\pi r}{T} = \frac{2\pi \times 0.02}{1.11} = 0.113\ \text{m/s}$	1
$F_c = \frac{mv^2}{r} = \frac{185 \times 10^{-6} \times 0.113^2}{0.02} = 1.18 \times 10^{-4}\ \text{N}$	1
$F_c = F_e$ $\therefore F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = 0.000118 = \frac{1}{4\pi \times 8.85 \times 10^{-12}}\frac{q^2}{0.04^2}$ $q^2 = 2.11 \times 10^{-17}$	1 – 2
$q = 4.59 \times 10^{-9}\ C$ $q = 4.59\ \text{nC}$	1
Total	6

Question 7 **(3 marks)**

Description	Marks
$R_{bottom} = mg + \dfrac{mv^2}{r}$	1
$1075 = 75 \times 9.8 + \dfrac{75 \times v^2}{5.0}$ $v^2 = 22.7$	1
$v = 4.76 \text{ m s}^{-1}$	1
Total	3

Question 8 **(4 marks)**

Description	Marks
$R = 0.075\ \Omega \text{ km}^{-1} \times 2.50 \text{ km} = 0.1875\ \Omega$ $V_{drop} = 13.0 \text{ kV} - 11.5 \text{ kV} = 1.5 \text{ kV} = 1500 \text{ V}$	1
$P_{loss} = \dfrac{V_{drop}^{\ 2}}{R} = \dfrac{1500^2}{0.1875} = 12 \times 10^6 \text{ W} = 12 \text{ MW}$	1
$P_{out} = P_{delivered} + P_{loss} = 231 + 12 = 243 \text{ MW}$	1
$e = \dfrac{P_{out}}{P_{in}} \times 100 = \left(\dfrac{243}{270}\right) \times 100 = 0.900$ $\therefore$ efficiency = 90.0%	1
Total	4

Question 9 **(7 marks)**

(a) Show that the trolley accelerates up the slope at exactly 1.00 m s^{-2}.

Description	Marks
Container: $\Sigma F_c = W_c - T = m\,a$ $\therefore 588 - T = 60\,a$	1 – 2
Trolley: $\Sigma F_T = T - F_f - W_T = ma$ $\therefore 163a = T - 60 - 163 \times 9.8 \times \sin 11°$ $\therefore 163a = T - 364.8$	1 – 2
Combining: $\therefore (588 - 60a) - 364.8 = 163a$ $\therefore \quad 223.2 = 223a$ $\therefore \quad a = 1.00 \text{ m s}^{-2}$	1 – 2
Total	6

(b) Unfortunately, two of the bags of cement were not attached securely and dropped off the counterweight shortly after the trolley began moving. Which of the following graphs best describes the entire journey of the trolley on the slope? Circle your answer.

Description	Marks
Graph A	1
Total	1

Question 10 **(7 marks)**

(a) Indicate on the diagram above the direction of the current flowing in the coil.

Description	Marks
Current is anticlockwise (D-C-B-A)	1
Total	1

(a) Calculate the magnitude of the torque on the coil when it is in the position shown.

Description	Marks
$\tau = 2N(BIL)r = 2NBIL.\left(\frac{L}{2}\right)$ $\therefore \tau = NBIL^2$	1
$\tau = 15 \times 0.55 \times 1.50 \times 0.1^2$	1
$\tau = 0.124$ Nm	1
Total	3

(b) The student notices that once the motor is turned on for a short period, it quickly maintains a constant rotational speed. Explain this observation, using relevant Physics concepts. Ignore mechanical friction.

Description	Marks
As the speed of the coil increases, there is an induced emf ("back emf") in the opposite direction to the coil voltage, proportional to the speed of the coil (Faraday's law)	1
As the coil speeds up, the "back emf" increases and the net coil voltage decreases, thus decreasing the current drawn.	1
When the torque produced by the coil current is sufficient to overcome the frictional forces and drag forces, the coil will stop accelerating and rotate at a constant speed.	1
Total	3

Question 11 **(3 marks)**

Description	Marks
From graph: estimate of period = 13 ms (note: not 6.5 ms) $\therefore$ estimate of frequency = $\frac{1}{13 \times 10^{-3}} = 77$ Hz	1
$\varepsilon_{max} = 2\pi NBAf$ $\therefore \quad N = \frac{\varepsilon_{max}}{2\pi BAf} = \frac{3.18 \times 10^3}{2\pi \times 0.09 \times \pi \times 0.13^2 \times 77} = 1377$	1
Number of turns is 1400 (max 2 sf)	1
Total	3

Question 12 **(14 marks)**

(a) Calculate the orbital speed that the spacecraft should have at the location indicated by X for it to maintain a stable orbit at an altitude of 4000 km.

Description	Marks
$\frac{mv^2}{r} = \frac{GmM}{r^2} \quad \therefore v = \sqrt{\frac{GM}{r}}$	1
Uses distance of 4000 km + 3390 km = 7390 km	1
$v = \sqrt{\frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23}}{(4000 + 3390) \times 10^{3}}}$	1
$\therefore v = 2.40$ km/s	1
Total	4

(b) Using your answer to part (a), given data and relevant physics concepts, explain why the Mars2021 will continue to descend from an altitude of 4000 km.

Description	Marks
$v = \sqrt{\frac{GM}{r}} \quad \rightarrow \quad v^2 \propto \frac{1}{r}$ For a satellite, as r increases, the stable orbit velocity v decreases.	1
A satellite travelling slower than the stable orbital speed will fall to a lower orbit.	1
The actual speed of the spacecraft (1.95 km/s) is slower than the stable orbital speed (2.40 km/s), thus it will “fall”.	1
Total	3

(c) Use the area under the graph to estimate the change in potential energy of the spacecraft as it descends from an altitude of 4000 km to an altitude of 500 km. Show working.

Description	Marks
Each square represents $(0.5 \times 10^6 \text{ m}) \times (0.5 \text{ N/kg}) = 2.5 \times 10^5$ J/kg	1
Squares $\approx$ 22 (21 – 23)	1
ΔPE = mass $\times$ squares $\times$ energy per square per kg $\therefore \Delta PE = 1025 \times 22 \times 2.5 \times 10^5 = 5.64 \times 10^9$ J $\therefore \Delta PE = 5.6 \times 10^9$ J (2 sf) (accept 5.4 - 5.9 GJ)	1
Total	3

(d) Using your answer to part (c), determine the final speed of the spacecraft as it reaches an altitude of 500 km altitude. [Note: if you did not get an answer to part (c) use 5 GJ for the change in potential energy]

Description	Marks
$E_{total} = KE_i + PE_i = KE_f + PE_f =$ constant $\therefore KE_f = KE_i + PE_i - PE_f$ $\therefore KE_f = KE_i +$ Work	1
$KE_i = \frac{1}{2}mv^2 = \frac{1}{2} \times 1025 \times 1950^2 = 1.95 \times 10^9$ J	1
$KE_f = 1.95$ GJ $+ 5.64$ GJ $= 7.59 \times 10^9$ J [6.95×10^9 J]	1
$KE_f = \frac{1}{2}mv^2 = 7.59 \times 10^9$ J $\therefore v = 3.85 \times 10^3$ m/s $= 3.85$ km/s [3.68 km/s] (accept 3.79 – 3.91 km/s)	1
Total	4

Question 13 **(15 marks)**

(a) Determine the ratio $N_p : N_s$ in its simplest form.

Description	Marks
$P_p = V_p I_p$ $9000 = V_p \times 25$ $V_p = 360\ \text{V}$	1
$N_p : N_s = V_p : V_s$ $N_p : N_s = 360 : 5400$	1
$N_p : N_s = 1 : 15$	1
Total	3

(b) Determine the number of turns of wire in the primary coil.

Description	Marks
$N_p = \frac{555}{15} = 37$	1
Total	1

(c) Determine the RMS current on the secondary side of the transformer.

Description	Marks
$P_s = V_s I_s = P_p = 9.0\ \text{kW}$	1
$9000 = 5400 \times I_s$ $I_s = 1.67\ \text{A}$	1
$I_s\ (\text{rms}) = \frac{I_{\text{peak}}}{\sqrt{2}} = \frac{1.67}{\sqrt{2}} = 1.18\ \text{A}$	1
Total	3

(d) State and explain one (1) possible source of power loss within non-ideal transformers.

Description	Marks
Either Eddy currents in the iron core OR Resistive heat loss in wires of secondary coil	1
Eddy currents in the iron core The alternating magnetic field experienced by the iron core results in the formation of eddy currents. These eddy currents create heat losses due to the resistance in the iron core.	1 – 2
Resistive heat-loss in wires of secondary coil Wires, no matter which property or dimension all have some sort of resistance. Effectively they act as a resistor and therefore have some amount of power loss (voltage drop) across them.	1 – 2
Total	3

(e) With reference to the principles of electromagnetic induction and/or Faraday's Law, explain how the voltage in the primary coil of this transformer is transformed to the stated voltage in the secondary coil.

Description	Marks
Transformers use AC current.	1
AC implies that the associated magnetic field/flux is also continually changing (alternating)	1
This alternating magnetic field (or changing flux) occurs in both coils (since they are both connected by the iron core)	1
According to Faraday's Law, the emf is proportional to the number of turns (N): $\varepsilon = -\frac{N\Delta\Phi}{\Delta t}$ $\therefore \varepsilon \propto N$	1
Therefore, increasing N on the secondary side will increase the induced emf (voltage) in the secondary coil.	1
Total	5

Question 14 **(18 marks)**

(a) Calculate the vertical and horizontal components of the initial speed of the water as it exits the hose. (2 marks)

Description	Marks
$u_h = u \cos \theta = 12.2 \times \cos 36° = 9.87$ m/s	1
$u_v = u \sin \theta = 12.2 \times \sin 36° = 7.17$ m/s	1
Total	2

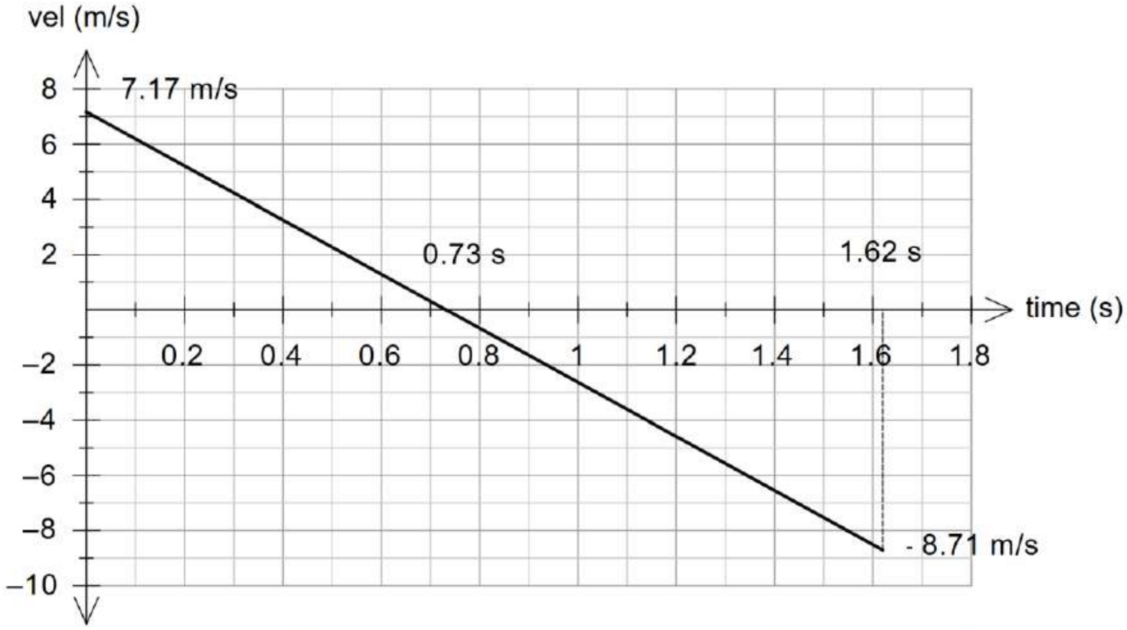
(b) Determine the height above the ground the water is being released from if the water travels a horizontal distance of 16.0 m to the far edge of the lawn.

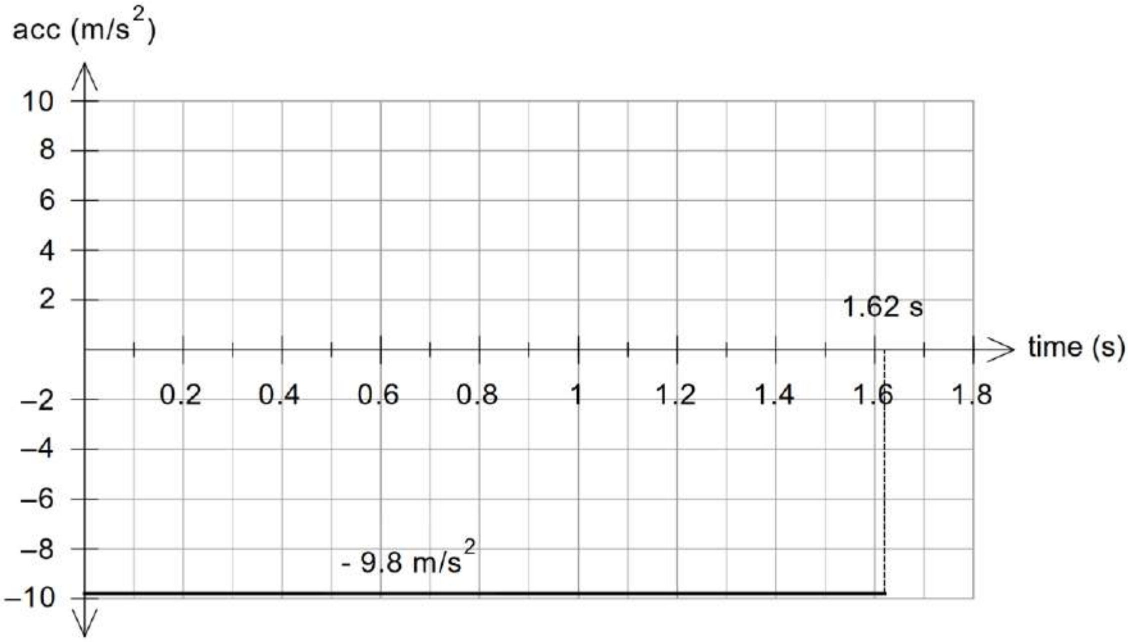
Description	Marks
horizontally: $s_h = u_h \times t$ $16.0 = 9.87 \times t$ $\therefore \quad t = 1.62$ s	1 – 2
vertically: $h = ut + \frac{1}{2}at^2$ $h = 7.17 \times 1.62 + \frac{1}{2} \times (-9.8) \times 1.62^2 = -1.25$ $\therefore$ height off ground = 1.25 m	1 – 2
Total	4

(c) Determine the maximum height the water reaches above the end of the hose.

Description	Marks
Vertically: Max height occurs when vertical velocity is zero I.e. $v = 0$	1
Use: $v^2 = u^2 + 2as$ $0^2 = 7.17^2 + 2 \times (-9.8) \times s$	1
$s = 2.62$ m	1
Total	3

(d) Using the information in the question, draw a velocity-time graph and an acceleration-time graph for the water droplet for the period between leaving the hose and hitting the grass. Assume that upwards is a positive frame of reference. Indicate and label all key features of each graph. Ignore the effects of air resistance for this question.





Description	Marks
Inidcates correct initial velocity on graph (~7.2 m/s)	1
Indicates correct final velocity on graph (~8.7 m/s)	1
Indicates correct final time on graph (1.62 s)	1
Indicates correct time at which v = 0, 0.73 s (i.e. time of max height)	1
Velocity-time graph is linear with gradient of –9.8 m/s^2	1
Acceleration-time graph is constant at –9.8 m/s^2	1
Total	6

(e) State three (3) ways in which the motion of a water droplet exiting the hose is affected by drag force due to air resistance.

Description	Marks
Three of the following:	
Reduced range	1
Reduced maximum height	1
Decreased time of flight	1
Asymmetrical nature of motion (i.e. – no longer a perfectly parabolic path)	1
The horizontal velocity component decreases – no longer constant – hence reduced range	1
The vertical velocity component decreases at a greater rate – hence reduced height	1
The vertical velocity component downwards still increases but at a slower rate	1
Total	3

Question 15 **(15 marks)**

(a) On the diagram above, draw and label the electric field *E* in the region between the two plates. Draw at least four (4) field lines.

Description	Marks
Electric field lines directed from bottom plate to top plate	1
Electric field lines should be uniform (4 or more lines shown)	1
Total	2

(b) Using convention for the direction shown in the diagram above, indicate the direction of the forces acting on the proton, due to the magnetic and electric field when the proton is first released. The first one has been done for you.

Description	Marks
Magnetic force = INTO PAGE	1
Electric force = UP	1
Total	2

(c) Determine the magnitude and direction of the net force on the proton when it is released in the region. You may ignore gravity.

Description	Marks
$F_e = Eq = \dfrac{Vq}{d} = \dfrac{1600}{0.50} \times 1.6 \times 10^{-19} = 5.12 \times 10^{-16}$ N	1
$F_m = qvB = (1.6 \times 10^{-19}) \times (150 \times 10^{3}) \times (8.8 \times 10^{-3}) = 2.11 \times 10^{-16}$ N	1
$F = \sqrt{F_e^{\,2} + F_m^{\,2}} = \sqrt{(5.12 \times 10^{-16})^2 + (2.11 \times 10^{-16})^2}$	1
$F = 5.54 \times 10^{-16}$	1
$\tan\theta = \dfrac{F_m}{F_e} = 0.413 \rightarrow \theta = 22.4°$ to vertical	1
Total	5

(d) Calculate the work done by the electric field as it moves through the entire region.

Description	Marks
$V = 3.00 \times 10^3 - 1.40 \times 10^3 = 1.60 \times 10^3$ V	1
$W = qV = 1.6 \times 10^{-19} \times 1600 = 2.56 \times 10^{-16}$ J	1
Or: $W = Fs = 5.12 \times 10^{-19} \times 1600 = 2.56 \times 10^{-16}$ J	2
Total	2

(d) An observer watching the proton being released notices that the proton begins to move upward in a spiral. It is observed that the spiral has a constant radius but an ever-increasing distance vertically between rotations. Account for this motion.

Description	Marks
The electric field accelerates the proton vertically ($F = Eq = ma$)	1
Since it is being accelerated vertically, the distance between rotations increases for every period of rotation.	1
The magnetic force $F = qvB$ acts perpendicular to its velocity and magnetic field ($\therefore F$ is horizontal), providing a centripetal force, causing circular motion.	1
Since $r = \frac{mv}{qB}$, and m, v, q and B are constant, the radius is constant.	1
Total	4

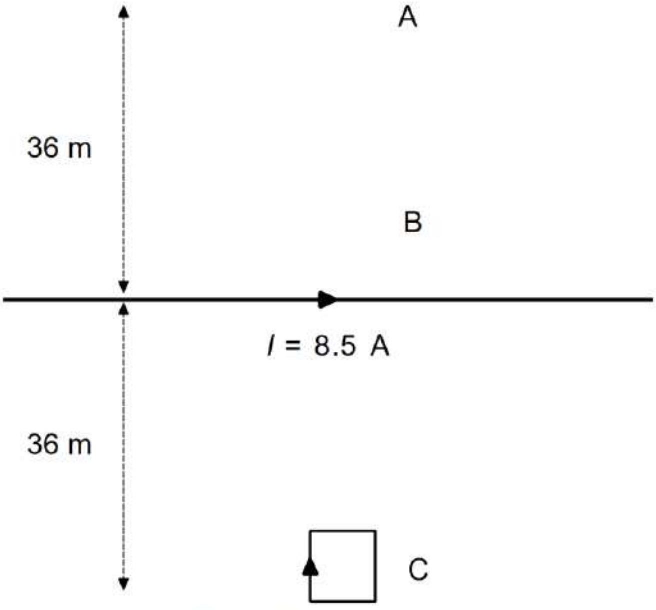
Question 16 **(12 marks)**

(a) As the centre of the coil moves from point A to B, it experiences an average induced EMF equal to 2.50×10^{-6} V. Determine the speed of the coil.

Description	Marks
$\varepsilon = -\dfrac{\Delta\Phi}{\Delta t} = \dfrac{A}{t}(B_i - B_f)$	1
$B_i = \dfrac{\mu_0 I}{2\pi r_i} = \dfrac{4\pi \times 10^{-7} \times 8.5}{2\pi \times 36} = 4.72 \times 10^{-8}$ T	1
$B_f = \dfrac{\mu_0 I}{2\pi r_i} = \dfrac{4\pi \times 10^{-7} \times 8.5}{2\pi \times 9} = 1.89 \times 10^{-7}$ T	1
$\varepsilon = 2.50 \times 10^{-6} = \dfrac{6.0^2}{t}\left(1.89 \times 10^{-7} - 4.72 \times 10^{-8}\right)$	1
$t = 2.04$ s	1
$v = \dfrac{d}{t} = \dfrac{27}{2.04} = 13.2$ m/s	1
Total	6

(b) Will the induced EMF in the coil be greater at point A or point B? Justify your choice. No calculations are needed.

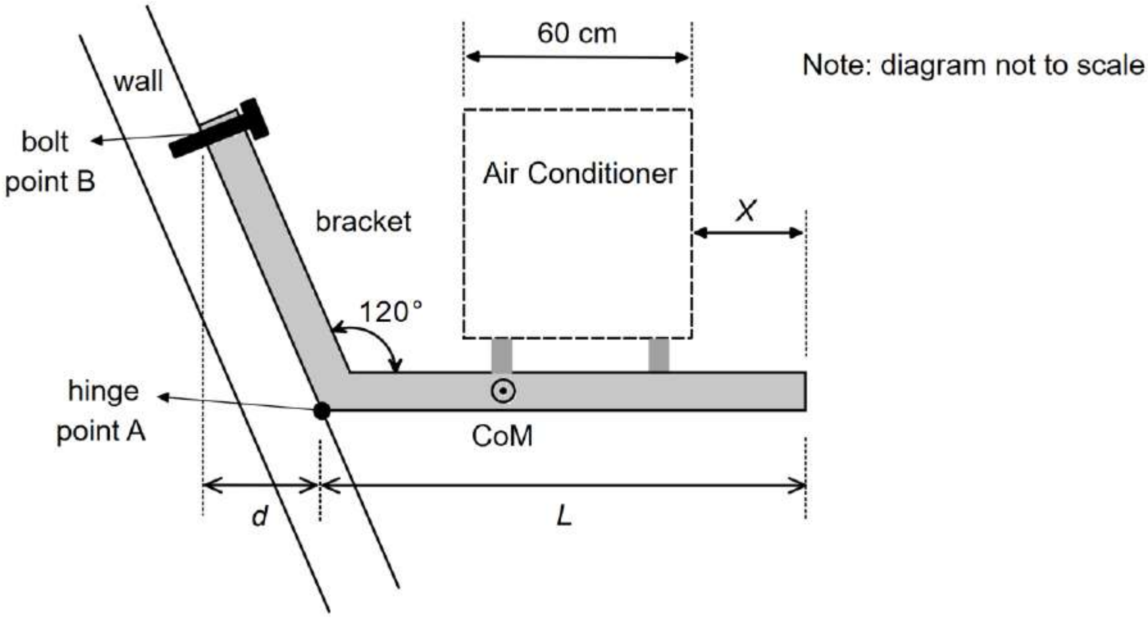
Description	Marks
Flux $\varphi = BA$ and magnetic field $B \propto \dfrac{1}{r}$	1
At a smaller distance (r) from the wire, the rate at which the magnetic field strength (B) changes (and, hence, the rate of change of flux experienced by the coil) is greater than at a further distance, even if the speed remains constant.	1
Although the coil is cutting through the same are of magnetic flux in the same amount of time, the strength of the magnetic flux is greater nearer the wire becuase the magnitude of the B field is greater." Therefore, the induced emf is greater at point B.	1
Total	3



(c) On the diagram above, draw the coil at point C and indicate the direction of the induced current in the coil at this location. With reference to a relevant physics concept, explain the reason you drew the current in the direction you did.

Description	Marks
The current will be clockwise.	1
Due to the increasing distance, the B field is getting smaller into the page in the coil at point C. According to Lenz's law the induced current will oppose the change (i.e. increase into the page in the coil).	1
A clockwise current will produce a B field increasing into the coil.	1
Total	3

Question 17 **(7 marks)**



Description	Marks
$\Sigma\tau_{acw} = \Sigma\tau_{cw}$	1
$F_{bolt} \times r_{bolt} = W_{brack} \times r_{brack} + W_{AC} \times r_{AC}$	1
$r_{brack} = 0.45$ m $r_{AC} = 1.10 - X - 0.3 = 0.80 - X$ $r_{bolt} = \dfrac{0.2}{\sin 30°} = 0.4$ m	1 – 2
$2290 \times 0.4 = (20 \times 9.8) \times 0.45 + (130 \times 9.8) \times (0.80 - X)$ $916 = 88.2 + 1274 \times (0.80 - X)$ $\therefore \quad 191.4 = 1274X$	1 – 2
$X = 0.150$ m $X = 15.0$ cm	1
Total	7

Question 18 **(9 marks)**

(a) With reference to specific forces, explain why the string always makes an angle dipped below the horizontal when the ball is twirling horizontally?

Description	Marks
For the net force to be exactly horizontal the vertical weight force needs to be balanced by another force – in this case the vertical component of the tension.	1
The tension force obviously also needs to provide a horizontal force, in this case, the centripetal force, causing circular motion.	1
Since both components are non-zero, the string will always be at some angle below horizontal	1
Total	3

Alternate Solution

Description	Marks
For perfect horizontal motion, there would be no vertical component of the tension	1
However, there must be a vertical weight force, which is therefore unbalanced	1
So perfect horizontal motion is not possible, and the string will always be dipped	1
Total	3

(b) Calculate θ if the mass of the ball is 1.00×10^2 grams, the ball traces a circle of 1.0 m radius and the ball passes around the teacher's head once every second.

Description	Marks
$\tan\theta = \frac{W}{F_c} = \frac{mg}{\frac{mv^2}{r}} = \frac{rg}{v^2}$ **Note:** θ is the angle to the horizontal, not vertical	1
$v = \frac{2\pi r}{T} = \frac{2\pi \times 1}{1} = 6.28 \text{ m/s}$ $\tan\theta = \frac{rg}{v^2} = \frac{1 \times 9.8}{6.28^2} = 0.248$	1
$\theta = 13.9°$	1
Total	3

(c) How would the tension in the string change if the ball were made to move faster? No calculations are necessary. Use a relevant formula to justify your response.

Description	Marks
If the velocity increases, centripetal force will increase, Since $F_c \propto v^2$	1
Thus, the horizontal component of the tension also increases	1
Since the vertical component of the tension remains unchanged (weight force), the tension will increase.	1
Total	3

Question 19 **(18 marks)**

(a) Briefly explain why a "crown elevation" road profile is not suitable for the design of a road surface where cars are travelling around a corner.

Description	Marks
The outside lane of a "crown elevation" road will have the horizontal component of the normal force pushing away from the cricle centre.	1
Therefore, a car will need to rely much more on friction for F_c $\therefore$ not suitable.	1
Total	2

(b) Determine the angle θ for a "super elevated" road with a slope of 2.5%.

Description	Marks
$\tan\theta = \frac{2.5}{100} = 0.025$ $\theta = 1.43°$	1
Total	1

(c) Without using equation 2, show that the maximum speed of a car navigating a corner on flat ground, with friction, is given by the expression:

Description	Marks
$F_c = \frac{mv^2}{r} = F_f = \mu N$	1
$\mu N = \mu mg = \frac{mv^2}{r}$ $\therefore \mu rg = v^2$	1
$\therefore v = \sqrt{\mu rg}$	1
Total	3

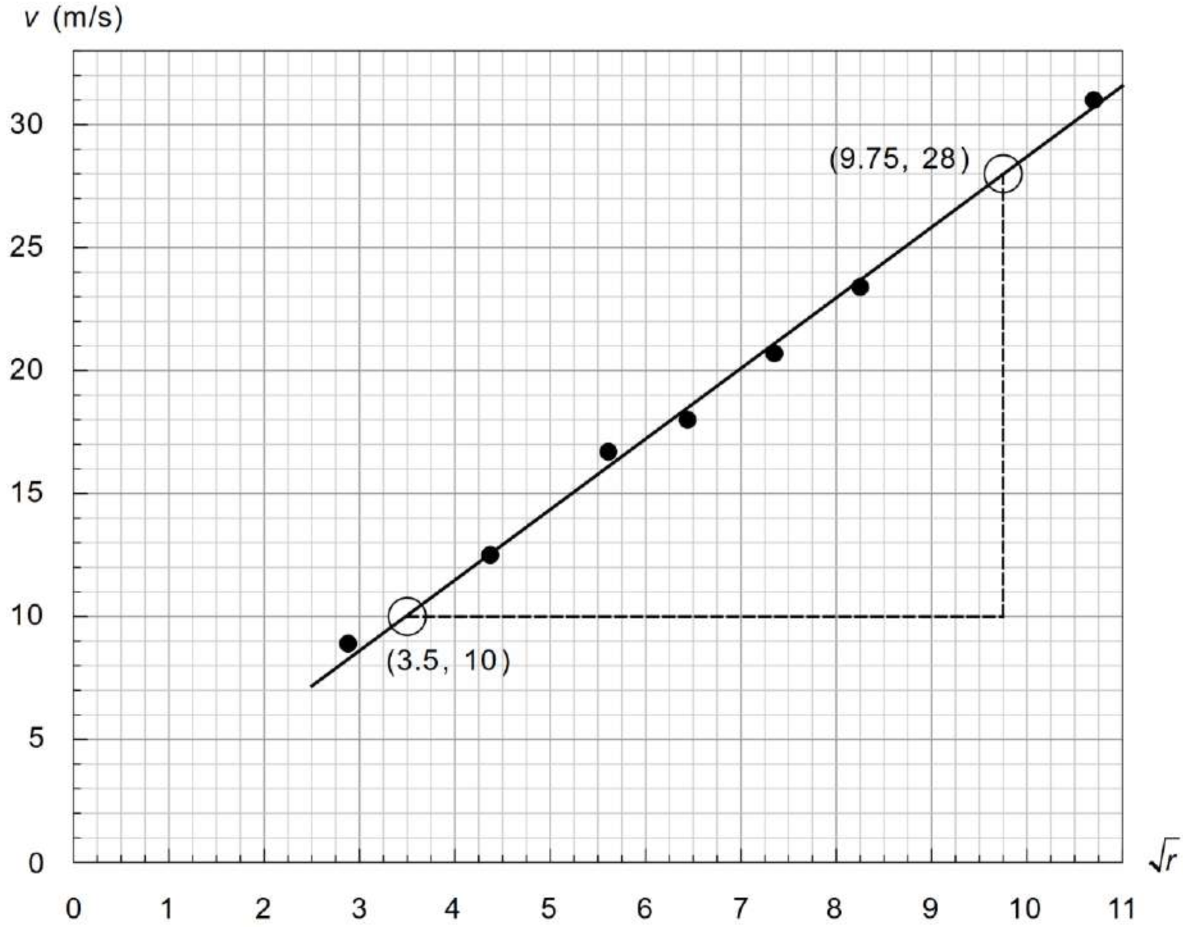
(d) Calculate the three (3) possible maximum speeds that a car could navigate a bend on a road with a radius 46 m on a normal, dry day under the three following conditions (note: if you could not determine θ for part (b) then use θ = 2.0°):

Description	Marks
$\mu = 0.7$	1
Condition 1 $v_{max} = \sqrt{0.7 \times 46 \times 9.8} = 17.8 \text{ m s}^{-1}$	1
Condition 2 $v_{max} = \sqrt{46 \times 9.8 \times \dfrac{\sin 1.43° + 0.7 \times \cos 1.43°}{\cos 1.43° - 0.7 \times \sin 1.43°}} = 18.2 \text{ m s}^{-1}$ [18.4 m/s]	1
Condition 3 $v_{max} = \sqrt{46 \times 9.8 \times \tan 1.43°} = 3.36 \text{ m s}^{-1}$ [3.97 m/s]	1
Total	4

(e) A sports car is navigating a racecourse with seven bends which are all on flat ground. The driver of the sports car drives as fast as possible without their car skidding around each corner. For each bend, the radius; the maximum velocity; and the square root of radius are listed in the table below.

Corner	Radius r (m)	Velocity v (m s^{-1})	$\sqrt{r}$
1	19.1	12.5	4.37
2	8.30	8.90	2.88
3	41.5	18.0	6.44
4	68.0	23.4	8.25
5	31.5	16.7	5.61
6	114	31.0	10.7
7	54.0	20.7	7.35

(i) Use the information in the table to graph the velocity v versus the square root of radius $\sqrt{r}$ on the set of axes provided below. Draw a line of best fit.



Description	Marks
Plotting velocity v versus $\sqrt{r}$ (i.e. on correct axes)	1
Accurately plotting of points	1
Draws an accurate LOBF	1
Total	3

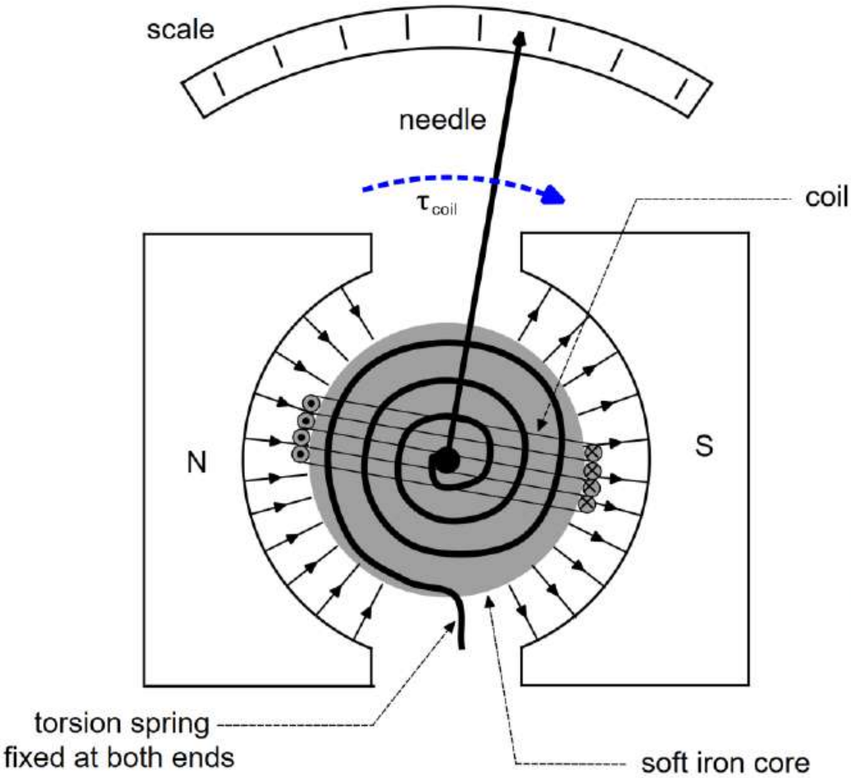
(ii) Determine the gradient for your line of best fit and use it to estimate a value for the coefficient of friction μ on the racecourse. Indicate clearly how you used your graph to calculate the gradient. Give your answer to an appropriate number of significant figures. Based on your result, explain the likely conditions of the road that day.

Description	Marks
Indicates construction lines on graph. Uses points from LOBF: (3.5, 10) and (9.75, 28).	1
$m = \dfrac{28 - 10}{9.75 - 3.5} = 2.88$	1
$m = \sqrt{\mu g} = 2.88$ $\therefore \mu = \dfrac{m^2}{g} = \dfrac{2.88^2}{9.8}$	1
$\mu = 0.85$ (max 2 sf) (allow $\mu = 0.80 \rightarrow \mu = 0.90$)	1
The road conditions are very dry and hot!	1
Total	5

Question 20 **(18 marks)**

Galvanometers

(a) On Figure 4 indicate the direction of the torque provided by the coil.



Description	Marks
Torque acting in a clockwise direction on diagram.	1
Total	1

(b) Explain the importance of the circular shape of the permanent magnets.

Description	Marks
The circular shape means the magnetic field always enters or exits the metal core at 90° to the current in the wire.	1
This means that the $B_{\perp}$ is constant, no matter the rotation angle of the needle.	1
$\therefore F = BIL$ is only dependent on current I (since the product BL is constant), hence F is always constant	1
Total	3

(c) State two (2) likely sources of an inaccurate reading when using a galvanometer.

Description	Marks
Stiffness of the spring is not constant	1
The magnetic field between the poles and core is not uniform (or not circular in shape)	1
Total	2

(d) With reference to relevant physics concepts, explain how eddy currents in the metal core help the needle of DC galvanometer to quickly come to a reading without vibrating back and forth?

Description	Marks
The induced eddy currents generate a braking force on the needle/core/coil	1
This braking force is proportional to velocity ($I \propto v$) – Faraday's law	1
As the needle moves, the total torque decreases and the needle slows down	1
∴ as the needle slows due to reducing torque, the braking force due to eddy currents also dampen the motion, reducing extra vibration.	1
Total	4

(e) Ideally, the angle of deviation of the needle of a galvanometer should be directly proportional to the current in the coil. In other words: $\theta = CI$ where C is some constant. Use equation 3 to determine an expression for the constant *C*.

Description	Marks
$\tau_s = k\theta = \tau_c = NBIA$ $\therefore \theta = \dfrac{NBIA}{k}$	1
$\therefore C = \dfrac{NBA}{k}$	1
Total	2

(f) A certain galvanometer has a rectangular 3.0 cm by 4.0 cm coil wrapped around a soft iron metal core. The core is attached to a torsion spring with stiffness $k = 3.50 \times 10^{-3}$ Nm per °. The coil and core arrangement sit in the region between two circular magnetic poles with a magnetic field strength of 550 mT. The coil has 38 turns of wire.

(i) Determine the angle the needle deviates when a known current of 1.76 A passes through the coil.

Description	Marks
$\theta = \dfrac{NBIA}{k}$	1
$\theta = \dfrac{38 \times (550 \times 10^{-3}) \times 1.76 \times (0.03 \times 0.04)}{3.5 \times 10^{-3}}$	1
$\theta = 12.6°$	1
Total	3

(ii) Unfortunately, the scale on the galvanometer is no longer legible. An unknown current is passed through the device such that the needle deviates exactly three divisions, through an angle of 21.5°. How much current (A) is represented by each division on the scale?

Description	Marks
$I = \dfrac{k\theta}{NBA}$	1
$I = \dfrac{3.5 \times 10^{-3} \times 21.5}{38 \times (550 \times 10^{-3}) \times (0.03 \times 0.04)} = 3.00\ \text{A}$	1
Each division should be 1.00 A.	1
Total	3

Alternatively:

Description	Marks
Using previous answer a current of 1.76 A gives an angle of 12.6° so 1° would be produced by a current = $\dfrac{1.76}{12.6} = 0.1397\ \text{A}$	1
So 21.5° would required a current of $21.5 \times 0.1397 = 3.003\ \text{A}$ spanning 3 divisions	1
$\therefore$ each division = $\dfrac{3.003}{3} = 1.00\ \text{A}$	1
Total	3

END OF EXAMINATION