Mark schemes

Q1.

(a) Max 2 from one route ✓✓

Alternative 1

- $\Phi = BA \cos\theta = 4.9 \times 10^{-5} \times (2 \times 8.0) \times \cos 68° = 2.9(4) \times 10^{-4}$ (Wb)

  OR

  $\Phi = BA = 4.9 \times 10^{-5} \times (2 \times 8.0) = 7.84 \times 10^{-4}$ (Wb)
- Time to fall to the ground = 1.3 (1.28) (s)
- $\varepsilon = \frac{\Delta\Phi}{\Delta t}$ with their $\Delta\Phi$ and t

  Marks can only be awarded from one route.

  mp1 and 2 the mark can be awarded from seeing a substitution.

  For mp1 condone sin 68° in both routes

  $$t = \left(\frac{2s}{a}\right)^{\frac{1}{2}} = \left(\frac{2\times 8.0}{9.81}\right)^{\frac{1}{2}} = 1.28$$

  *In 3rd bullet do **not** allow* $\varepsilon = \frac{\Delta B}{\Delta t}$ *or* $\varepsilon = \frac{\Delta B \cos\theta}{\Delta t}$ *but condone any value for A.*

Alternative 2

- $\varepsilon = Blv$ or $\varepsilon = Blv \cos\theta$ seen
- $v = \sqrt{2g\Delta h}$ OR $\sqrt{2as} = 12.5$ (m s^{-1})

  OR

  Time to fall to the ground = 1.3 (1.28) (s)
- $v_{avg} = \frac{v}{2}$ with their v

  OR

  $v_{avg} = \frac{s}{t}$ for their t

$\varepsilon = 2.3 \times 10^{-4}$ ✓ (V)

(b) Max 4✓✓✓✓

Fall to the left

Statement	Explanation
the direction of the emf changes	the rod cuts across the magnetic field in both directions / passes parallel point
the emf goes through a zero (when 68° to the vertical)	momentarily the rod travels parallel to the field or does not cut lines of flux / 0 change in flux
emf reduces (and then increases)	as (direction of) velocity or motion gets closer to being parallel to field / same direction as field / cuts less flux per unit time

Fall to the right

Statement	Explanation
the direction of the emf stays the same	the rod cuts across the magnetic field always in the same direction
Idea that the emf goes through a maximum (when 22° to the vertical)	the rod cuts across the magnetic field at right angles or the cutting of field line is a maximum
emf increases (and then decreases)	as (direction of) velocity or motion gets closer to perpendicular to field / cuts more flux per unit time

All marking points are to be OWTTE.

Ignore comments about different direction falling left and right.

Statement and explanation are separate marking points.

Explanation must not contradict statement to be awarded.

Condone emf increases as speed of fall increases (Blv) or smaller time $\left(N\frac{\Delta\Phi}{\Delta t}\right)$✓ ✓ *for either direction but not both.*

Allow the following statement and explanation as an alternative to ***either*** *a fall to the left or to the right but not both:*

Statement - when falling left the ***average*** *emf is less than falling to the right.*

Explanation - as the total change in flux / number of flux lines cut is less than when falling to the right.

4

[7]

Q2.

(a) (use of a ruler to) **measure** height **from bench to rod** at (minimum of two) different points $_{1}$✓

*for $_{1}$✓ points may be **anywhere** along rod;*

allow 'measure height of rod at each end' / 'at both clamps'/ 'measure height from ground'

do not allow 'find height' / 'measure on both sides of the rod / wire'

explains how the **ruler** is made vertical $_{2}$✓

*for $_{2}$✓ expect to see a set-square in **contact with** the bench AND in **contact with** the upright ruler;*

checks heights are the same $_{3}$✓ (contingent on $_{1}$✓)

*allow use of a spirit level / T-square / plumb line / **large** protractor to make ruler vertical;*

use of set-square between the ruler and the rod OR between stand and rod is neutral;

*for $_{1}$✓ and $_{2}$✓ allow annotation to **Figure 1***

OR

use of a metre ruler placed on the rod with a spirit level placed on the ruler; check no gap between ruler and rod $_{12}$✓

check bubble is at centre $_{3}$✓ (contingent on $_{12}$✓)

*allow $_{12}$✓ for use of a set-square in contact with the bench that reaches the rod (ie no ruler mentioned) as long as **measuring** is being done with it*

OR

use of metre ruler placed with no gap on top of nested set-squares so the metre ruler can be compared with rod $_{12}$✓

lower set-square in contact with the bench (no gaps) $_{3}$✓ (contingent on $_{12}$✓)

for $_{3}$✓ allow 'compare heights to check rod is parallel to bench / level'

allow 'measurements match' / 'contingent' etc

'straight' for horizontal or for vertical / 'heights are constant' is neutral

3

(b) force on **rod** is down(wards) $_1$✓

'force down' & 'current to right' & 'field out of page by left-hand rule' earns ✓✓✓ = 3/3;

*for $_1$✓ allow use of F ↓ for force on rod down; may be indicated on **Figure 2***

allow unqualified 'force';

condone force = 'motion' / rod = 'wire'

*'force **on balance / yoke** is up' is neutral*

the current (in rod) is from left / to right / rightwards $_2$✓

for $_2$✓ allow I → for current from left / to right;

*may be indicated on **Figure 2***

condone 'current clockwise';

'from positive to negative' is neutral

predicts direction of field based on their force and their current using valid (left-hand) rule or WTTE $_3$✓

$_3$✓ is contingent on seeing $_1$✓ force up or down and on seeing $_2$✓ current left or right etc;

for $_3$✓ allow use of B for field and LHR for left-hand rule;

allow B ⊙ by LHR;

for reversed F OR for reversed I allow ⊗ by LHR, eg 'force upwards' / 'current to right' / 'field into page' etc earns ✓✓ = 2/3

3

(c) MAX 2 from:

- **any** valid expression to demonstrate homogeneity of terms $_A$✓
- $B = \frac{F}{IL}$ OR $BI = \frac{F}{L}$ $_B$✓
- identifies the base units of *F* as kg m s^{-2} $_C$✓

correct units for k earns 3 marks unless evidence of incorrect working seen

for $_A$✓ and $_B$✓ allow any valid expression or statement that contains both units AND quantities

*for $_A$✓ idea that k B I has units of **mass***

any subject eg k ≡ kg T^{-1} A^{-1}

allow 'M OR mass OR g = k B I'

*condone words for **units**, eg 'amps' / 'tesla';*

the units for *k* are s^2 $_3$✓

accept use of dimensional analysis, M (mass), L (length) and T (time)

for $_B$✓ allow T (OR *B*) $\equiv \frac{N}{A\,m} \equiv \frac{N\,s}{C\,m}$

for $_B$✓ allow TA (OR *B I*) $\equiv \frac{N}{m}$

for $_{AB}$✓✓ allow $k \equiv kg\ \frac{(A)m}{N}(A^{-1})$

for $_{BC}$✓✓ allow T (OR *B*) $\equiv \frac{kg\,(m)\,s^{-2}}{A\,(m)} \equiv \frac{kg}{C\,s}$

for $_{BC}$✓✓ allow TA (OR *B I*) $\equiv \frac{kg\,(m)\,s^{-2}}{(m)}$

3

(d) records **two** vertical intercepts to 2 dp with at least one intercept correct to ± 0.05 (g)

OR

*M*1 and *M*2 read off to 2 dp for the same value of *I* with at least one read off correct to ± 0.05 (g) $_1$✓

M1 intercept = 134.85 ± 0.05 (g)

M2 intercept = 181.85 ± 0.05 (g)

allow either value seen in working

derives **two** valid equations using their *M*1 and *M*2 that can be solved to determine *Y*

OR

their *Y* min 1 dp, consistent with their intercepts to ± 0.1(0) (g) $_2$✓

for $_2$✓ *mark is for method OR for their Y*

*equations **[A]** and **[B]** seen:*

*134.85 = (0 +) 2Z + Y .....**[A]***

*181.85 = (0 +) 4Z + Y .....**[B]***

OR

Y = 2 × M1 intercept - M_2 intercept;

$_2$✓ not contingent on $_1$✓ so allow their Y correctly deduced using two incorrect intercepts including intercepts rounded to 1 dp

Y = 87.85 ± 0.1(0) (g) CAO $_3$✓

$_3$✓ is contingent on $_1$✓

for $_3$✓ min 1 dp;

only allow 1 dp 87.8 OR 87.9

3

(e) identifies that *B* is less $_1$✓

*for $_1$✓ allow 'field' / '(magnetic) **flux density**' for B;*
allow 'B weaker' / 'less field lines through the rod' / '(rod) not affected by field as much';
'B is not uniform' / '(rod) cuts less flux' / 'cutting less field lines' are neutral $_1$✓

states and explains why the intercept is the same $_2$✓

*for $_2$✓ allow intercept is the same **because***
*'intercept is the mass of yoke **and** magnets' / 'intercept = 2Z AND Y' / 'Z AND Y don't change' / 'there is the same initial mass'*

states and explains why the line is less steep $_3$✓

*for $_3$✓ allow 'gradient is smaller' / 'gradient is **less** negative' / 'line is flatter' **because***

allow $_{23}$✓ for **stating** that the line is less steep **AND** that the intercept is the same without a valid explanation for either statement

*'**change in** M1 / balance reading / force is less for each (**change in**) I ' OR 'force won't **change as much** with current' OR 'less force per unit current' OR gradient is kB / gradient ∝ B*

allow $_{13}$✓ for *B* = 0 or WTTE (reject 'rod not in field');

'less force for same current' is neutral

intercept same as in **Figure 4** AND gradient = 0 or WTTE;

then mark $_2$✓ as above

*take account any sketch graph that correctly compares the new graph of M1 against I with **Figure 4***

3

[15]

Q3.

(a) search coil is not suitable or wtte:

no <u>emf</u> (would be induced in a search coil) $_1$✓

$_1$✓and $_2$✓ can be earned independently but are contingent on a statement that the search coil is not suitable;

insist on suitable use of the appropriate underlined term

for $_1$✓condone 'potential difference' OR 'voltage' for emf

1

a search coil needs (to be cut by) changing <u>flux</u>

OR

search coil is not cut by changing <u>flux</u>

OR

<u>flux</u> (cutting coil) is constant or wtte $_2$✓

for $_2$✓ accept ϕ for flux;

do not insist on 'flux linkage';

do not allow 'field' for 'flux';

'current (in the coil on frame) must be ac' is neutral;

the suggestion that a search coil cannot be connected to a data logger is neutral

1

alternative approach:

search coil **is** suitable or wtte:

suggests a valid method that changes the flux cutting the search coil eg rotate either coil / turn (dc) current off / move either coil relative to other coil $_1$✓

states their method changes <u>flux</u> through search coil

OR if search coil is cut by changing <u>flux</u> or wtte $_2$✓

alternative approach:

$_1$✓ and $_2$✓ can be earned independently but are contingent on a statement that the search coil is suitable

(b) use of 1 - cos 25(°) or 1 - sin 65(°) in a calculation of percentage change ₁✓

for ₁✓ expect either ≥ 3 sf rounding to 1 - 0.906 OR 1 - 0.91 seen in working

OR 100 - 90.6 or 100 - 91 seen in working;

(-) 9.4 (%) CAO ₂✓

for ₂✓ expect min 2 sf rounding to (-) 9.4;

allow (-) 9.0 if 1 - 0.91 seen in working;

do not insist on minus sign or 'decrease' on answer line

allow ₂✓ for unsupported answer of (-) 9.4;

if no other mark is awarded allow 12✓ use of 1 - sin 25(°) or 1 - cos 65(°) in a % difference calculation leading to 58%

2

(c) uncertainty (in a single reading / judgement) is ½° ₁✓

for ₁ ✓accept 0.5 seen in numerator of % calculation OR absolute uncertainty is 2×0.5;

allow a larger uncertainty up to 3° if justified with a comment about difficulty in judging the reading due to parallax, thickness of frame etc

1

(measurement of) θ is based on (difference between) <u>two</u> readings / judgements

OR

absolute uncertainty in θ (or $\Delta\theta$) = 2 × uncertainty in each reading / judgement ₂✓

for ₂ ✓accept 2×0.5 OR 2 × their uncertainty in (a single) reading seen in numerator OR evidence for use of 2 × their uncertainty in result of % calculation;

'measured twice' is ambiguous

correct percentage uncertainty calculation based on 100 × their absolute uncertainty divided by 25 $_3$✓

for $_3$ ✓ allow 1 sf result;

$\frac{2 \times 0.5}{25}$ *×100 = 4% (use of 0.5°) earns $_1$✓$_2$✓$_3$✓*

$\frac{0.5}{25}$ *×100 = 2% (missing 2×) earns $_1$✓$_2$✗$_3$✓*

$\frac{2 \times 1}{25}$ *× 100 = 8% (1° unexplained) earns $_1$✗$_2$✓$_3$✓*

$\frac{1}{25}$ *× 100 = 4% (1° unexplained) earns $_1$✗$_2$✗$_3$✓*

$_{123}$✓✓✓ for two-judgement explanation leading to 1° used in a correct % uncertainty calculation

2

(d) *r* in range 67 to 69 mm

OR

$x_{0.5}$ in range 50 to 55 mm $_1$ ✓

$\frac{x_{0.5}}{r}$ in *in range gets both marks*

for $_1$ ✓ either value can be seen in working OR on (along horizontal axis in) ***Figure 5***

$\frac{x_{0.5}}{r}$ in in range 0.73 to 0.81 $_2$ ✓

for $_2$ ✓ answer with no unit and minimum 2 sf

2

(e) **use of Figure 5:**

adds B_{H1} for experiment 1 to B_{H2} for experiment 2 at any point between x = 17 and x = 51 (mm);

resultant B_H, minimum 2 sf, in range 0.91 to 0.99 (mT) $_1$✓

resultant B_H, minimum 2 sf, in range 0.93 to 0.97 (mT) $_2$✓

ignore any sign given with result

2

(f) for more than 2 ideas mark as a list

(field lines are) parallel or wtte $_1$✓

for $_1$✓ accept 'in the same direction' / 'uniform-direction';

'horizontal' / 'directed to the right' / 'straight' / 'linear' / 'perpendicular to the coil' are neutral

evenly-spaced or wtte $_2$✓

for $_2$✓ accept 'equally-spaced' / 'equidistant' / 'uniform-spacing' / 'equal distance between lines' or wtte;

'close together' / 'do not touch' are neutral;

'uniform field' / 'field lines are uniform' / 'they are uniform' are neutral

2

(g) a vertical axis drawn (at any point between $x = 0$ and $x = r$);

continuous line (accept poorly-marked) between $x = 0$ and $x = r$ (by eye);

intersecting or meeting horizontal axis / $B_{(H)} = 0$ at $x = \frac{r}{2}$ $_1$✓

vertical axis drawn, labelled with symbol B;

negative gradient, line continuous between $x = 0$ and $x = r$; 2-quadrant graph $_2$✓

vertical axis drawn with symbol and unit eg $B_{(H)}$ / mT;

continuous line between $x = 0$ and $x = r$;

$B_{(H)} = 0.43 \pm 0.01$ at $x = 0$ OR $B_{(H)} = -0.43 \pm 0.01$ at $x = r$ $_3$✓

2-quadrant graph, continuous line between $x = 0$ and $x = r$; approximately correct shape: see below;

their y-value at $x = 0$ equal and **opposite** to their y-value at $x = r$ (by eye) $_4$✓

for $_1$✓use checkmark on axis for guidance;

for $_2$✓allow 'magnetic flux density' in words; condone any flat section ≤ r/4 (judge by eye);

allow (always) positive gradient

for $_1$✓and $_2$✓allow a straight line;

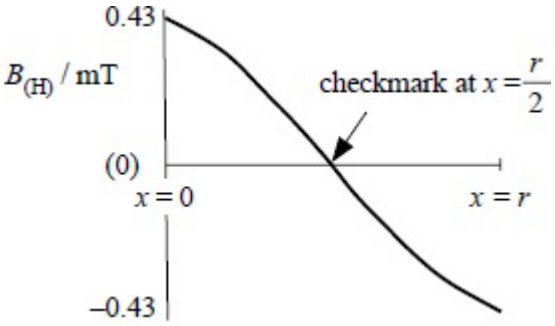
single quadrant can score $_1$✓or $_3$✓

for $_3$✓apply usual symbol-separator-unit convention / allow $B_{(H)}$ = 4.3 × 10^{-4} etc;

adjust criteria for positive gradient graph

for $_4$✓if no values are marked on the axis, assume $B_{(H)}$ = 0 is aligned horizontally with the x-axis (judge by eye);

condone missing vertical axis



Max 3

[16]

Q4.

(a) Core – idea that it provides greater linkage/increases linkage of magnetic flux/field (from the primary coil to the secondary coil compared to an air core) ✓$_1$ OWTTE

✓$_1$ *This can be expressed using terms such as "channels/directs/concentrates/focuses/funnels".*

In MP1 the reference to an air core can be inferred.

Condone " links all/most flux".

Secondary coil – (a conductor) has a varying/alternating/changing magnetic flux/field passing through/linking with it ✓$_2$ OWTTE

✓$_2$ *'varying' is important for this mark.*

✓$_3$ *errors may cancel this mark eg 'this increases the power output', will not gain this mark.*

Producing an induced emf / <u>induces an emf</u> that is determined by the number of turns in (the primary and) the secondary coils ✓3 OWTTE

Do not allow reference to "induced voltage" or "induced current" in MP3.

When no other mark awarded, MAX 1 for "this is a step-up transformer/the voltage is less on the primary than on the secondary because there are more secondary turns than primary turns"

3

(b) MAX 3

Design feature 1 ✓1a

Link to efficiency ✓1b

Design feature 2 ✓2a

Link to efficiency ✓2b

Award ✓a only once for "thin sheets/ laminations of iron are used".

For each example ✓b is contingent on ✓a

Example A

*✓a The (sheets) of material **M** / laminations are made from insulator/high resistivity material*

✓b reduces/limits (eddy) currents or charge flowing in the core.

Example B:

✓a thin sheets/ laminations of iron are used

✓b so smaller emf's are induced in the core

Example C:

✓a thin sheets/ laminations of iron are used

✓b so resistance is high causing lower (eddy) currents

If no other marks awarded, give 1 MAX for

✓Iron is used which magnetises and demagnetises easily

OR

✓Eddy currents produce a magnetic field that opposes the magnetic field supplied to the core

3 Max

(c) If the voltage is lower/33 kV then power is transmitted at high current. So energy/power is wasted/lost in the cable by (I^2R) heating. ✓1 OWTTE

These two points can be expressed the other way round. They could state why the voltage needs to be high and then why it should not be low.

Do not accept 'changes affect the resistance (of the cable)'.

If the voltage is made too high this will create major insulation/isolation difficulties. ✓2 OWTTE

In ✓2 accept "taller pylons", "transformers that have better insulation against spark/flash over", "more expensive equipment"

2

(d) Use of efficiency $\eta = \frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}}$ once ✓1

Correct use of $I = P/V$ with their values once at any point ✓2

✓1 examples could be:

power at 132 kV = 72 / 0.98 = 73.5 MW

OR

at transmission line start = 73.5 / 0.94 = 78.2 MW

OR

at 25 kV = 78.2 / 0.98 = 79.8 MW

OR

in single stage

Power at 25 kV = 72 / (0.94 × 0.98²) = 79.8 MW)

✓2 eg at consumers I = 72 × 10⁶ / 11 × 10³ = 6545 A

✓1 examples could be:

I = 3200 (A) (correct answer only, no ecf) ✓3

(Calculator value: 3190.16 A)

3

[11]