Name of the Student:_____
Max. Marks : 24 Marks **Time : 24 Minutes**

Mark Schemes

Q1.

(a) search coil is not suitable or wtte:

no emf (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 flux

OR

search coil is not cut by changing flux

OR

flux (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 flux through search coil

OR if search coil is cut by changing flux 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 $_1$✔

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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;

$\frac{2\times0.5}{25}$ *×100 = 4% (use of 0.5°) earns $_1$✔$_2$✔$_3$✔*

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

$\frac{2\times1}{25}$ *× 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

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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 ± 0.01 at x = 0 OR $B_{(H)}$ = -0.43 ± 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

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

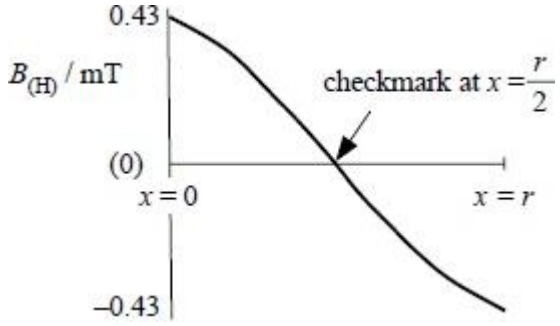
single quadrant can score $_1$✔ or $_3$✔

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]

Q2.

(a) An object that has an escape velocity greater than the speed of light.

Reject idea of 'beyond' or 'past' the event horizon if the direction is unclear.

OR

An object that has a gravitational field strength that is so great that light cannot escape. ✔

Do not accept 'mass' 'density' 'light cannot escape' 'light cannot escape its gravity' on their own.

1

(b) $R_s = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 6.5 \times 10^9 \times 1.99 \times 10^{30}}{(3 \times 10^8)^2}$ ^{1}✔

Angle subtended by region around event horizon of black hole

$= \frac{1.917 \times 10^{13} \times 2 \times 1000}{5.3 \times 10^7 \times 9.46 \times 10^{15}} = 7.64 \times 10^{-8}$ (rad) $_{2a}$✔

resolution of EHT = $(\frac{1.3 \times 10^{-3}}{1.3 \times 10^7} =)$ 1(.0) × 10^{-10} (rad)

OR

resolution of Hubble = $(\frac{410 \times 10^{-9}}{2.4} =)$ 1.71 × 10^{-7} (rad) $_3$✔

Both resolutions calculated correctly **and** conclusion drawn that EHT is better than Hubble. $_4$✔

Condone rounding errors in this question.

Award MP1 for R_s = 1.9(17) × 10^{13}(m) seen

Condone missing mass of Sun (1.99 × 10^{30}) in MP1

Condone missing '2' in MP2.

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*Award MP2 for 7.6(4) × 10^{-8} **OR** 3.8(2) × 10^{-8} seen.*

Allow POT error in MP1 and MP3

ALTERNATIVE

$R_s = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 6.5 \times 10^{9} \times 1.99 \times 10^{30}}{\left(3 \times 10^{8}\right)^2}$ ✔

One resolution calculated $_2$ ✔

Determination of the size of the object that can be resolved by a telescope at the distance of black hole

*For EHT size = 5(.0) × 10^{13} (m) **OR***

For Hubble size = 8.6 × 10^{16} (m) 3 ✔

*Both sizes calculated correctly **and** conclusion drawn that EHT is better than Hubble.* $_4$ ✔

4

(c) Evidence of difference in wavelength = 374.96 - 373.53 ✔

(= 1.43 nm)

Evidence of sum of wavelengths = 374.96 + 373.53 ✔

(= 748.49 nm)

($z = \frac{\Delta\lambda}{\lambda} = \frac{0.72}{374.25}$ = 1.9 × 10^{-3})

($v = zc$ = 1.9 × 10^{-3} × 3.00 × 10^{8} =)

5.7 × 10^{5} (m s^{-1}) ✔

MP1 can be given for determination of Δλ (= 0.72 nm)

MP2 can be given for determination of average (= 374.25 or 374.24(5) nm)

Alternative method for z:

$z = \frac{374.96 - 373.53}{374.96 + 373.53}$ = 1.9 × 10^{-3}

3

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