3.10 Physics: Fields (Gravitational, Electric, Magnetic): 30-minute Pack

AQA 7408 · Calculator allowed · about 30 minutes

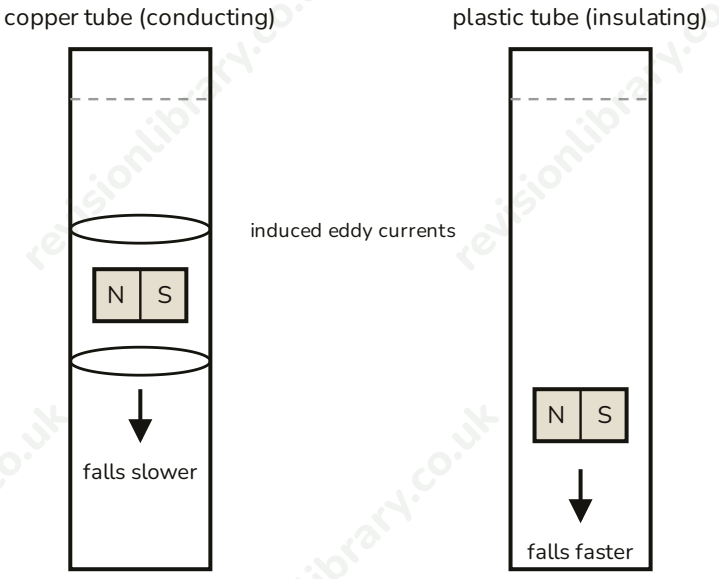
Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A student drops a strong bar magnet, from rest, down through a long vertical tube. In one trial the tube is made of a conducting metal such as copper; in a second, otherwise identical, trial the tube is made of an insulating plastic. The magnet takes noticeably longer to fall through the copper tube than through the plastic tube, even though it is dropped from the same height each time and air resistance can be ignored in both cases.

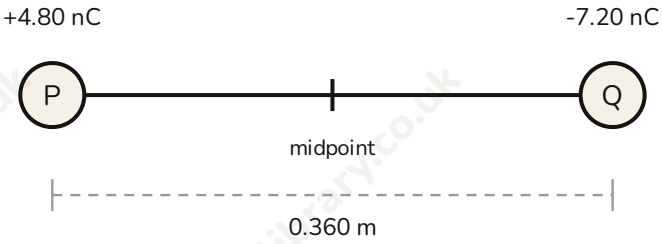
Explain, in terms of Faraday's law and Lenz's law, why the magnet falls with a smaller acceleration in the copper tube than in the plastic tube, and explain what happens to the gravitational potential energy the magnet loses as it falls through the copper tube.



(Total for Question 1 is 6 marks)

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2 Two small charged spheres, P and Q, are fixed 0.360 m apart in a vacuum. Sphere P carries a charge of +4.80 x 10^{-9} C and sphere Q carries a charge of -7.20 x 10^{-9} C. You are given $1/(4*\pi*epsilon0) = 8.99 \times 10^9$ N m^2 C^{-2}, so that the force between two point charges is $F = Q1*Q2/(4*\pi*epsilon0*r^2)$ and the electric field due to a point charge is $E = Q/(4*\pi*epsilon0*r^2)$.



(a) Calculate the magnitude of the electrostatic force between P and Q, and state whether the force is attractive or repulsive. **(3)**

(b) Calculate the electric field strength due to P alone at the location of Q. **(2)**

(c) A small test charge is placed at the midpoint between P and Q, 0.180 m from each sphere. Given that the field due to P and the field due to Q both point in the same direction at this point (from P towards Q), calculate the magnitude of the resultant electric field at the midpoint. **(4)**

(d) State the direction of the resultant electric field at the midpoint. **(1)**

(Total for Question 2 is 10 marks)

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3 A step-down transformer converts a 230 V a.c. mains supply to a 12.0 V supply for a low-voltage lighting system. The primary coil has 4600 turns. You are given the ideal transformer equation Vs/Vp = Ns/Np.

(a) Calculate the number of turns needed on the secondary coil, assuming the transformer is ideal. **(2)**

(b) In practice this transformer is only 92.0% efficient. When the secondary current is 8.00 A, calculate the primary current, assuming Vp and Vs are unchanged. **(4)**

(Total for Question 3 is 6 marks)

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Mark scheme · 3.10 Physics: Fields (Gravitational, Electric, Magnetic): 30-minute Pack

Question 1

Level 1 Makes only basic, largely isolated statements, for example simply asserting that a current is induced or that energy is 'lost' as heat, with little or no correct use of Faraday's law or Lenz's law and no clear chain of reasoning linking cause to effect. **1-2**

Level 2 Correctly identifies that the moving magnet causes a changing magnetic flux which induces eddy currents in the copper tube (Faraday), and that Lenz's law means these currents oppose the motion, producing a retarding force. The explanation of the energy transfer to heat is present but the reasoning chain (flux change, induced EMF, induced current, retarding force, reduced acceleration, energy dissipation) has gaps, is not fully sequenced, or contains minor errors. May not fully explain the plastic-tube case. **3-4**

Level 3 Gives a complete, correctly sequenced explanation: the falling magnet causes a changing flux linkage through the copper tube's wall, which by Faraday's law induces an EMF and hence eddy currents in the conducting tube; by Lenz's law these induced currents create a magnetic field that opposes the change producing them, so they exert an upward (retarding) force on the magnet, reducing its acceleration below g. Correctly explains that the magnet's lost gravitational potential energy is transferred, via the induced current, into heat (resistive/Joule heating) dissipated in the resistance of the tube. Correctly contrasts this with the plastic tube, where no closed conducting path exists, so no eddy currents (and hence no retarding force) are induced and the magnet falls with acceleration g. Uses correct scientific terminology throughout. **5-6**

Indicative content:

- As the magnet falls, the magnetic flux linking any circular path within the wall of the copper tube changes with time.
- By Faraday's law, a changing flux linkage induces an EMF in the conducting tube.
- Because the copper tube forms continuous closed conducting loops, this induced EMF drives circulating (eddy) currents in the tube wall.
- By Lenz's law, the induced current acts in the direction that opposes the change that produced it, i.e. it opposes the relative motion between the magnet and the tube.
- This opposition means the eddy currents' magnetic field exerts a retarding (upward) force on the falling magnet.
- The net downward force on the magnet is therefore less than its weight, so its acceleration is less than g (and, given enough tube length, it approaches a constant terminal velocity).
- In the plastic tube there is no continuous conducting path, so no eddy currents (and therefore no retarding force) can be induced, and the magnet falls freely with acceleration g.
- By conservation of energy, the gravitational potential energy the magnet loses in the copper tube is transferred into electrical energy by the induced current, which is then dissipated as heat due to the resistance of the tube wall (rather than being converted entirely into kinetic energy, as in the plastic tube).

Question 2

(a) correctly substitutes into $F = Q1*Q2/(4*\pi*epsilon0*r^2)$ **M1**

(a) $F = 2.40 \times 10^{-6}$ N (awrt 3 sf) **A1**

(a) states the force is attractive, since P and Q carry opposite-sign charges **B1**

(a) Answer: $F = 2.40 \times 10^{-6}$ N, attractive

(b) correctly substitutes into $E = Q(P)/(4*\pi*epsilon0*r^2)$ **M1**

(b) $E = 333$ N C^{-1} (awrt 3 sf), allow 3.33×10^2 N/C **A1**

(b) Answer: $E = 333$ N C^{-1}

(c) calculates the field due to P at the midpoint: $E_P = 1.33 \times 10^3$ N/C **M1**

(c) calculates the field due to Q at the midpoint: $E_Q = 2.00 \times 10^3$ N/C **M1**

(c) both individual values correct to 3 sf (allow ecf on method) **A1**

(c) adds the two fields (since they act in the same direction) to give $E_{total} = 3.33 \times 10^3$ N/C (awrt) **A1**

(c) Answer: $E_{total} = 3.33 \times 10^3$ N C^{-1}

(d) states the field points from P towards Q **B1**

(d) Answer: From P towards Q

Question 3

(a) uses $Ns = Np*(Vs/Vp)$ **M1**

(a) Ns = 240 turns **A1**

(a) Answer: Ns = 240 turns

(b) calculates output power: $P(out) = Vs*Is = 96.0$ W **M1**

(b) uses efficiency = P(out)/P(in) to find P(in) = P(out)/0.920 **M1**

(b) P(in) = 104 W (awrt) **A1**

(b) Ip = P(in)/Vp = 0.454 A (awrt), allow ecf **A1**

(b) Answer: Ip = 0.454 A

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