InkPhysics

ANSWER BOOK

# Comparing electric and gravitational fields

Electric fields · Year 13

AQA 3.7.1, 3.7.3.1 · OCR A 6.2.2(c)

17 questions · 48 marks

NAVY EDITION

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## SECTION A · Warm-up

**A1** Gravitational: $F = GMm/r^2$, depending on the product of the masses (1). Electrostatic: $F = kQ_1Q_2/r^2$, depending on the product of the charges; both are inverse-square laws (1). [2]

**A2** Gravitational: $g = GM/r^2$ (1). Electric: $E = kQ/r^2$ (1). [2]

**A3** The gravitational force is only ever attractive, as there is one type of mass (1); the electrostatic force can be attractive or repulsive, as charge exists in two types (1). [2]

**A4** Gravitational field strength: N $kg^{-1}$ (1). Electric field strength: N $C^{-1}$, equivalently V $m^{-1}$ (1). [2]

**A5** Both forces follow an inverse-square law, so the $r^2$ factors cancel in the ratio (1). [1]

## SECTION B · Standard

**B1** Gravitational: $V = -GM/r$ (1). Electric: $V = kQ/r$ (1). Gravitational potential is always negative, whereas electric potential is positive near a positive charge and negative near a negative charge (1). [3]

**B2** The separation cancels: ratio = $ke^2/(Gm_pm_e)$ (1)
$= (8.99 \times 10^9 \times (1.60 \times 10^{-19})^2)/(6.67 \times 10^{-11} \times 1.67 \times 10^{-27} \times 9.11 \times 10^{-31})$ (1)
ratio = $2.27 \times 10^{39}$ (1) [3]

**B3** Astronomical bodies are almost exactly electrically neutral (1); their positive and negative charges cancel, leaving almost no net electrostatic force (1). Mass cannot cancel, so with very large masses the gravitational attraction dominates (1). [3]

**B4** Any two of the following, one mark each (2): both obey inverse-square force laws; both are radial around a point source; field strength is defined as force per unit mass or per unit charge; potential in both has its zero at infinity. [2]

**B5** Weight = mg = $9.11 \times 10^{-31} \times 9.81 = 8.9 \times 10^{-30}$ N (1)
For balance EQ = mg, so $E = mg/e = 5.6 \times 10^{-11}$ V $m^{-1}$ (1)
An extremely small field balances gravity, which shows how weak gravity is on a subatomic particle: in laboratory fields the electron's weight is negligible (1) [3]

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**B6** $g = Gm_p/r^2 = (6.67 \times 10^{-11} \times 1.67 \times 10^{-27})/(5.3 \times 10^{-11})^2$ (1) [4]
$g = 4.0 \times 10^{-17}$ N kg$^{-1}$ (1)
$E = ke/r^2 = (8.99 \times 10^9 \times 1.60 \times 10^{-19})/(5.3 \times 10^{-11})^2$ (1)
$E = 5.1 \times 10^{11}$ N C$^{-1}$ (1)

**B7** Gravity is attractive, so the field itself does the work of bringing a mass in from infinity: the work done per unit mass by an external agent is negative (1). A positive test charge is repelled by a proton, so external work must be done on it to bring it in from infinity, making the potential positive (1). [2]

## SECTION C · Stretch

**C1** $F_{elec} = ke^2/r^2 = (8.99 \times 10^9 \times (1.60 \times 10^{-19})^2)/(1.0 \times 10^{-15})^2$ (1) [4]
$F_{elec} = 230$ N (repulsive) (1)
$F_{grav} = Gm_p^2/r^2$ (1)
$F_{grav} = 1.86 \times 10^{-34}$ N (attractive) (1)

**C2** Source: mass, compared with charge (1). Force law: $F = GMm/r^2$ compared with $F = kQ_1Q_2/r^2$, both inverse-square (1). Gravity gives attraction only; the electric force gives attraction or repulsion (1). Potential: $V = -GM/r$ is always negative; $V = kQ/r$ takes either sign (1). [4]

**C3** Everyday objects are electrically neutral overall (1); their positive and negative charges cancel, so they exert almost no net electric force on each other (1). Mass does not cancel, so the gravitational pull of the very large mass of the Earth is easily noticed (1). [3]

**C4** (a) $F = Gm^2/r^2 = 6.67 \times 10^{-11}$ N (1) [5]
(b) For balance, $kQ^2/r^2 = Gm^2/r^2$ (1)
$Q = m\sqrt{(G/k)}$ (1)
$Q = 8.6 \times 10^{-11}$ C (1)
A charge below a tenth of a nanocoulomb, about $5.4 \times 10^8$ electrons' worth, cancels the entire gravitational attraction: the electrostatic force is enormously the stronger (1)

**C5** Shielding requires a second field that cancels the first (1). Charge comes in two signs, so the induced charges on the case set up a field that cancels the external electric field inside (1). Mass comes in one sign only, and there is no negative mass, so no arrangement of matter can produce a cancelling gravitational field (1). [3]

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