Unit 14 · Electricity and Magnetism

HARDER PRACTICE QUESTIONS

Full marks 56

Write your answers on separate paper. Show your working. Take $k = 9 \times 10^9$ N m^2/C^2 and $g = 10$ m/s^2.

1 Spot the error [3]

Find the mistake in the working and correct it.

Two small balls with charges of +2 μC and +3 μC are 10 cm apart in air. Tashi wrote: "$F = kq_1q_2/r^2 = 9 \times 10^9 \times 2 \times 10^{-6} \times 3 \times 10^{-6} \div 10^2 = \mathbf{5.4 \times 10^{-4}\ N}$."

2 Three charges in a line [5]

Charges of +4 μC and +9 μC are fixed 30 cm apart.

i. A charge of +1 μC is placed between them, 10 cm from the +4 μC charge. Find the size and direction of the resultant force on it.

ii. Explain why there must be one point between the two charges where a test charge feels no force.

iii. Find how far that point is from the +4 μC charge.

3 Is the charge possible? [4]

In an experiment like Millikan's, an oil drop of mass 9.6×10^{-15} kg hangs still in an electric field of 3×10^5 N/C pointing **downward**. One electron carries 1.6×10^{-19} C.

i. Is the drop's charge positive or negative? Give a reason.

ii. Find its charge.

iii. How many extra electrons does it carry?

iv. Another student reports a charge of 2.4×10^{-19} C on a drop. Why can't this be right?

4 Estimate it [3]

Compare the electric push with the gravitational pull between two protons. Each carries 1.6×10^{-19} C and has a mass of about 1.66×10^{-27} kg; $G = 6.67 \times 10^{-11}$ N m^2/kg^2. Show that the distance between them makes no difference to your answer. Why, then, does gravity rule the sky?

5 Check the readings [4]

Sabina charged a capacitor marked "500 μF 10 V" at several voltages and worked out the charge from a meter.

V (volts)	3	6	9	12
Q (mC)	1.5	3.0	4.5	7.4

She wrote: "Its capacitance goes up as the voltage goes up."

i. Copy the table and add a row for Q/V in μF.

ii. Which reading stands out, and what would it be if the capacitance held?

iii. Is her claim right for a capacitor working properly?

iv. What is the danger in that last reading?

6 A defibrillator [4]

A defibrillator has a capacitor of 32 μF charged to 2,000 V. (These are made-up values.)

i. Find the charge it stores.
ii. It empties in 5 ms. Find the average current.
iii. A battery charges it with an average current of 8 mA. How long does that take?
iv. What if a capacitor of 64 μF had to store the same charge? What voltage would it need?

7 Closer plates [4]

Write your prediction first, then explain it.

The plates of a capacitor are pushed closer together. Predict what happens to its charge and to its voltage **(a)** if it is still connected to a battery, and **(b)** if it was charged and then disconnected.

8 Where does the compass point? [3]

A bar magnet like the one in Practical 26 lies on a table with its N pole pointing north. Its neutral points are 12.5 cm east and west of its center. Which way does a compass point when it is east of the center at **(a)** 5 cm, **(b)** 12.5 cm and **(c)** 40 cm? Give a reason for each.

9 How far off? [4]

At a place the true dip is 45° (tan 45° = 1).

i. A dip circle there is turned 60° from the magnetic meridian. What does it read? (tan 63.4° = 2)
ii. Another student reads 70°. Through what angle is her circle turned from the meridian? (tan 70° = 2.75; cos 68.7° = 0.364)
iii. At what angle from the meridian would the circle read 90°, and why?

10 Two parts of the field [3]

This uses Unit 11.

In Kathmandu the Earth's field is about 49 μT with a dip of about 44° (sin 44° = 0.695, cos 44° = 0.719). Find its horizontal and vertical parts. Show that they add up to 49 μT by the rule for vectors at right angles, and that V/H gives the tangent of the dip.

11 Does it matter? [3]

Bibek walks 10 km on a straight compass bearing in Kathmandu, taking it for true north. The declination is 0.4° E (tan 0.4° = 0.0070). About how far east of true north does he end up? Would the same mistake matter more or less at a place near the magnetic poles? Why?

12 Design a fair test [4]

Radhika thinks that the more times a balloon is rubbed on a woolen sweater, the more it bends a thin stream of water. Plan a fair test.

i. What will she change, and what will she measure?
ii. Name three things to keep the same.
iii. How can she make her results more reliable?
iv. What result would support her idea, and what could spoil the test on a wet day?

13 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

Rajan wrote: "The pole of the Earth's magnet in the far north is a north pole, since it is called the North Magnetic Pole. Magnetic lines of force stop when they reach a pole. A charged capacitor has a total charge of +Q on it, because it is storing charge."

14 Which explanation fits the evidence? [3]

Two students try to explain why the N end of a dip needle dips down in Nepal.
Salim: "Its weight pulls the N end down, because the N end is heavier."
Bhawana: "It lines up with the Earth's field, which slopes down into the ground in the northern half of the world."
Which explanation fits both these facts? In Australia, the **S** end of the same needle dips down. At the magnetic equator, it rests level.

15 Make your own [2]

Choose two charges and a distance so that the force between them is exactly 0.9 N and an attraction. Show that your choice works.

16 Think [4]

A small ball of mass 3 g with a charge of +1 μC hangs in the air, held only by the push of a fixed +2 μC charge straight below it.

i. Find the distance between them.
ii. If the ball is pushed a little closer, what happens to the force, and what does the ball do?
iii. If its charge were negative, could it hang there? Explain.