**3** **(a)** Two horizontal metal plates are separated by a distance of 1.8 cm in a vacuum.
A potential difference of 270 V is maintained between the plates, as shown in Fig. 3.1.

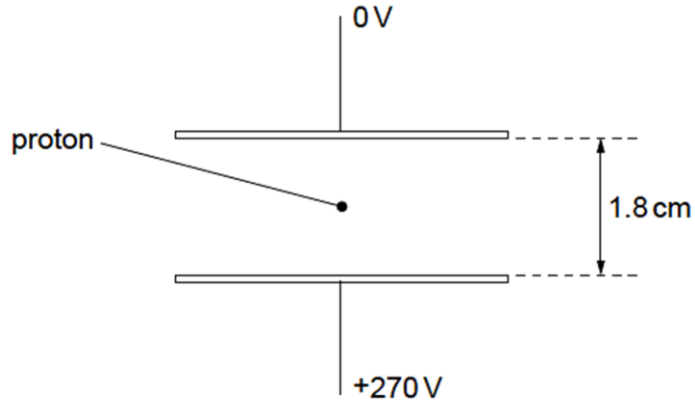



**Fig. 3.1**

A proton is in the space between the plates.

Explain **quantitatively** why, when predicting the motion of the proton between the plates, the gravitational field is not taken into consideration.

[3]

**(b)** Two point charges A and B are separated by a distance of 20 nm in a vacuum, as illustrated in Fig. 3.2.

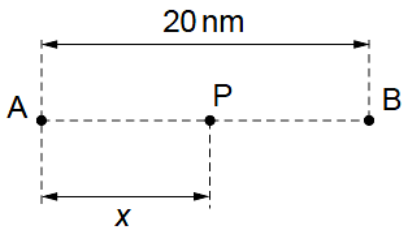



**Fig. 3.2**

A point P is a distance *x* from A along the line AB.

The variation with distance *x* of the electric potential $V_A$ due to charge A alone is shown in Fig. 3.3.

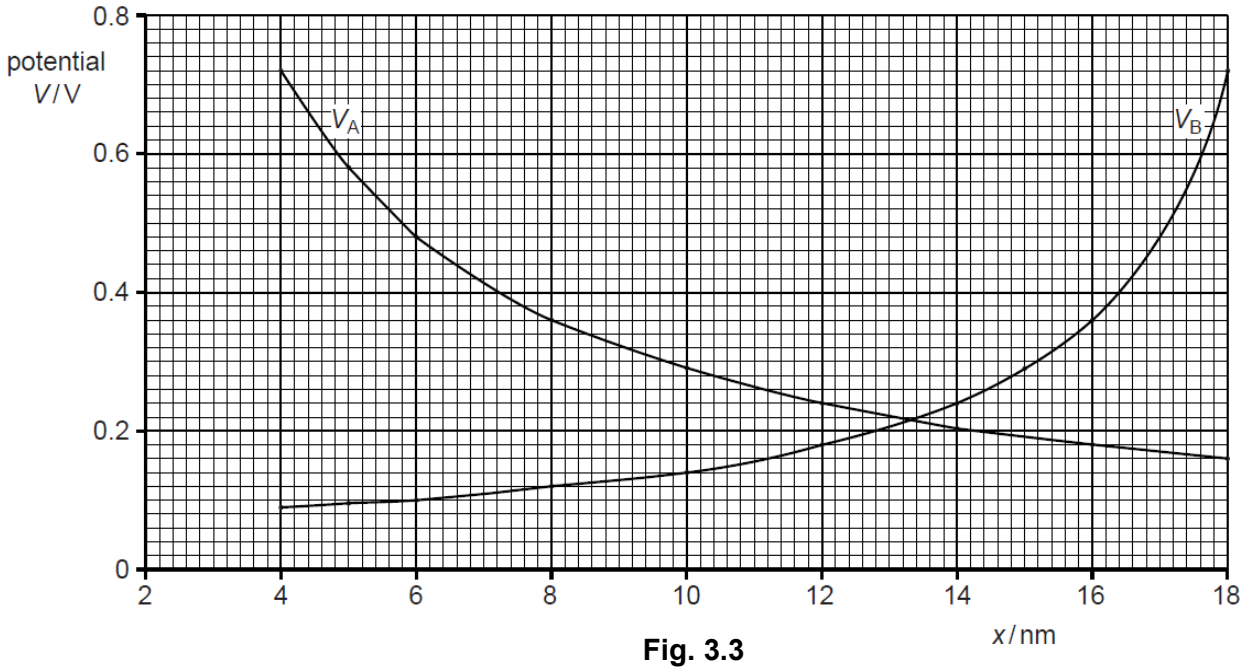



**Fig. 3.3**

The variation with distance *x* of the electric potential $V_B$ due to charge B alone is also shown in Fig. 3.3.

**(i)** State and explain whether the charges A and B are of the same, or opposite sign.

.....

.....

..... [2]

**(ii)** Without any calculation, use Fig. 3.3 to estimate the distance $x$ at which the combined electric potential of the two charges is a minimum.

$x$ = ..... nm [1]

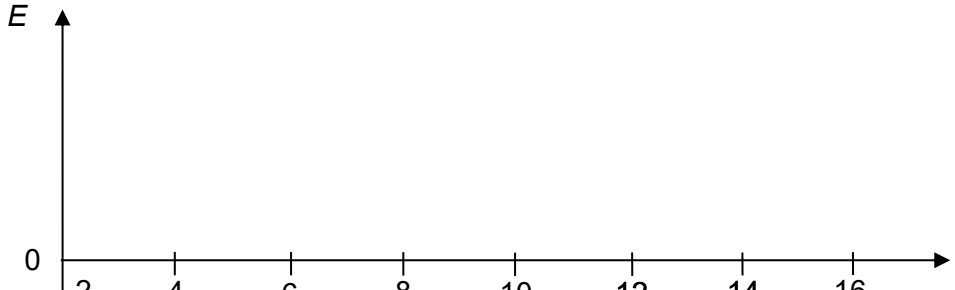
**(iii)** Use Fig. 3.3 to determine the charge on A.

charge = ..... C [2]

**(iv)** The point P is a distance $x$ = 10 nm from A. A proton has kinetic energy $E_K$ when at infinity. Use Fig. 3.3 to determine the minimum value of $E_K$ such that the proton may travel from infinity to point P.

minimum value of $E_K$ = ..... J [2]

**(v)** On Fig.3.4, sketch the variation with $x$ of the combined electric field strength $E$ due to the two point charges A and B for values of $x$ from 6 nm to 14 nm.



[2]