Q.1–8 This question concerns the hamiltonian

$$\hat{H} = \hat{H}_1 + \hat{H}_2 + \hat{H}_3 + \hat{H}_4 + \hat{H}_5$$

that is used to predict the fine structure of the hydrogen atom. It consists of the five terms

$$\hat{H}_1 = \frac{\hat{p} \cdot \hat{p}}{2m},$$

$$\hat{H}_2 = -\frac{e^2}{4\pi\varepsilon_0 r},$$

$$\hat{H}_3 = \frac{e^2 \hat{L} \cdot \hat{S}}{8\pi\varepsilon_0 m^2 c^2 r^3},$$

$$\hat{H}_4 = -\frac{(\hat{p} \cdot \hat{p})^2}{8m^3 c^2},$$

and

$$\hat{H}_5 = \frac{e^2 \hbar^2 \delta(x)\,\delta(y)\,\delta(z)}{8\varepsilon_0 m^2 c^2},$$

where $\hat{p}$ is the momentum operator, $\hat{L}$ is the orbital angular momentum operator, $\hat{S}$ is the spin angular momentum operator and δ is the Dirac delta function.

(i) Select the **ONE** option from the key that is the operator corresponding to a perturbation to the kinetic energy of the electron which takes into account some of the effects of special relativity. ☐

(ii) Select the **ONE** option from the key that has zero expectation values for s-states ($l = 0$) of the hydrogen atom. ☐

(iii) Select the **ONE** option from the key that has zero expectation values for all except s-states of the hydrogen atom. ☐

KEY for Q.1–8 (i) to (iii)

A $\hat{H}_1$

B $\hat{H}_2$

C $\hat{H}_3$

D $\hat{H}_4$

E $\hat{H}_5$