Q11 <u>The correct responses are B and F</u>

A is false; from the uncertainty principle, precisely specified momentum $(\Delta p_x = 0)$ means infinite uncertainty in position ($\Delta x \gtrsim \dfrac{\hbar}{\Delta p_x} = \infty$), so the particle is described by an infinitely long wave, rather than a wavepacket.

B is correct; a narrow wavepacket requires a broad range of wavelengths (i.e. a broad range of wave numbers, see Fig 11, Unit 14).

C is wrong; from $\Delta x \gtrsim \dfrac{\hbar}{\Delta p_x}$, $\Delta p_x \gtrsim \dfrac{\hbar}{\Delta x} \approx \dfrac{10^{-34}\text{ J s}}{10^{-9}\text{ m}} = 10^{-25}\text{ kg m s}^{-1}$. Thus it is not possible, even in principle, to know the momentum of the particle to a greater precision (i.e. smaller Δp_x) than $10^{-25}\text{ kg m s}^{-1}$. So $\Delta p_x \sim 10^{-26}\text{ kg m s}^{-1}$ is not simultaneously achievable.

D is wrong; an uncertainty Δy in the position implies a minimum uncertainty of $\dfrac{\hbar}{\Delta y}$ in the y–component of the particle's momentum, but does not relate to the particle's total energy.

E is wrong; $\Delta E \gtrsim \dfrac{\hbar}{\Delta t} \approx \left(\dfrac{10^{-34}\text{ J s}}{10^{-10}\text{ s}}\right) = 10^{-24}\text{ J}$. So the *minimum* energy uncertainty is 10^{-24} J, but it can be larger than this.

F is correct; uncertainties in the x–component only place restrictions on the precision of p_x, the x–component of the particle's momentum.

Q12 <u>The correct response is D</u>

The transition is from (1,2,2) [or 2,2,1 or 2,1,2] to the (1,1,1) level. The change in E_{tot} is therefore

$$(9-3)\,\frac{h^2}{8m_eD^2} = \frac{3h^2}{4m_eD^2}.$$

Using $\Delta E_{tot} = hf$, the frequency of the emitted photon is $\dfrac{3h}{4m_eD^2}$.

Q13 <u>The correct responses are D and G</u>

A is correct; the gravitational and electrostatic forces are both inverse square in nature and it is quite possible to analyze the orbit of a satellite using Schrödinger's equation. Because of the large masses and energies involved the quantum numbers are very large and (as would be expected from the correspondence principle), the results are equivalent to the analysis of classical mechanics.

B is correct; the allowed levels are given by $E_{tot} = \dfrac{n^2h^2}{8mD^2}$, with $n = 1,2,3$ ... so there are an infinite number of levels.

C is correct; (see Section 5 of Unit 14).

D is wrong; only n, l and m_l are required in the Schrödinger theory. m_s is an additional quantum number arising out of the experimental observations of the Stern and Gerlach experiment; it was not predicted by the Schrödinger theory.

E is correct; the energies of the levels vary as $1/n^2$.

F is correct; the seven different m_l values for f-states (–3,–2,–1,0,1,2,3) have different energies in a magnetic field.

G is wrong; when a hydrogen atom is subject to a magnetic field, the energy of the electron also depends on the value of the m_l quantum number, so n does *not* determine the electron's energy under *all* circumstances.

Q14 <u>The correct responses are B and C</u>

A is wrong; the number of protons is equal to the atomic number Z, which is 22 for *all* titanium isotopes.

B is correct; (see Figure 22 in Unit 15).

C is correct; the full shell structure for titanium which has 22 electrons is $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^2$. (See Table 8 in Unit 15). According to Figure 20 (Unit 15) the 4s shell fills before the 3d shell, so the three outer shells are populated as $3p^6\,4s^2\,3d^2$.

D is wrong; see answer to C.