Q18 Select the option that is closest to the Landé g factor for proton spin.

KEY for Q18

A	2.79	E	5.58
B	3.81	F	6.30
C	4.26	G	9.83
D	5.12	H	11.16

Q19 Select the option that is closest to the frequency of radiation emitted by protons making transitions from states in which the spin is anti-parallel to a magnetic field of magnitude 1 T to states in which the spin is parallel to the magnetic field.

KEY for Q19

A	0.26×10^8 Hz	E	0.72×10^8 Hz
B	0.34×10^8 Hz	F	0.86×10^8 Hz
C	0.39×10^8 Hz	G	1.29×10^8 Hz
D	0.43×10^8 Hz	H	1.72×10^8 Hz

Q20 and Q21 share the same key and concern the angular momentum operator $\hat{\mathrm{L}}_z$.

Q20 Select the *two* options that are *not* eigenfunctions of $\hat{\mathrm{L}}_z$.

Q21 Select the *two* options that commute with $\hat{\mathrm{L}}_z$. [Hint: In plane polar coordinates $x = r\cos\phi$ and $y = r\sin\phi$, where $r^2 = x^2 + y^2$.]

KEY for Q20 and Q21

A	x	E	$x + \mathrm{i}y$
B	xy	F	$x - \mathrm{i}y$
C	z	G	$(x + \mathrm{i}y)^2$
D	$x^2 + y^2 + z^2$	H	$(x - \mathrm{i}y)^2$

PART C (Units 9–11)

Q22 to Q25 mainly concern Unit 9.

Q22 to Q24 share the same key and concern spinors.

Q22 Select the *two* options that can represent spin states of an electron.

Q23 Select the *two* options that differ only by a phase factor of unit modulus.

Q24 Select the option that is orthogonal to $[(1+\mathrm{i}) \quad 2]^T$.

KEY for Q22 to Q24

A	$\frac{1}{2}[(1+\mathrm{i}) \quad 1]^T$	E	$\frac{1}{2}[(1-\mathrm{i}) \quad 1]^T$
B	$\frac{1}{2}[(1+\mathrm{i}) \quad \mathrm{i}]^T$	F	$\frac{1}{2}[(1-\mathrm{i}) \quad (1+\mathrm{i})]^T$
C	$\frac{1}{2}[(1+\mathrm{i}) \quad -\mathrm{i}]^T$	G	$\frac{1}{2}[(1-\mathrm{i}) \quad 2\mathrm{i}]^T$
D	$\frac{1}{2}[(1+\mathrm{i}) \quad -1]^T$	H	$\frac{1}{2}[(1+\mathrm{i}) \quad (1-\mathrm{i})]^T$

Q25 concerns a state for which it has been found that the component of electron spin, in the direction with spherical polar angles $\theta = \pi/3$ and $\phi = \pi/4$, is $\hbar/2$.

Q25 Calculate the probability that a measurement of S_y will yield the value $\hbar/2$, and select the option that is nearest to your answer.

KEY for Q25

A	0.1	E	0.5
B	0.2	F	0.6
C	0.3	G	0.7
D	0.4	H	0.8

Q26 to Q34 mainly concern Unit 10.

Q26 to Q29 share the same key and concern the complex matrices

$$\mathbf{a} = [-\mathrm{i} \quad 0 \quad 1]^T$$
$$\mathbf{b} = [-\mathrm{i} \quad 1 \quad 0]^T$$
$$\mathbf{M} = \begin{bmatrix} 0 & 1 & \mathrm{i} \\ 0 & \mathrm{i} & 1 \\ 1 & 0 & 1 \end{bmatrix}$$

Q26 Select the option giving $\mathbf{a}^\dagger\mathbf{b}$.

Q27 Select the option giving $\mathbf{b}^\dagger\mathbf{M}\mathbf{a}$.

Q28 Select the option giving $\mathbf{b}^\dagger\mathbf{M}^\dagger\mathbf{a}$.

Q29 Select the option giving $(\mathrm{i}\mathbf{b})^\dagger\mathbf{a}$.

KEY for Q26 to Q29

A	-1	E	0
B	$-\mathrm{i}$	F	1
C	-2	G	i
D	$-1+\mathrm{i}$	H	2

Q30 and Q31 share the same key and concern two quantum states represented in the general notation by $\boldsymbol{\Phi}$ and $\boldsymbol{\Psi}$. The matrix notations for these states are $\mathbf{a}$ and $\mathbf{b}$, respectively. The Schrödinger notations are $\Phi(x)$ and $\Psi(x)$, respectively.

Q30 Select the *three* options that are equal to $(\boldsymbol{\Psi}, \boldsymbol{\Phi})$.

Q31 Select the *three* options that are equal to $(\boldsymbol{\Phi}, \boldsymbol{\Psi})$.

KEY for Q30 and Q31

A	$\mathbf{a}^\dagger\mathbf{b}$	E	$\Psi^*(x)\,\Phi(x)$
B	$(\mathbf{a}^\dagger\mathbf{b})^*$	F	$\Psi(x)\,\Phi^*(x)$
C	$\mathbf{b}^\dagger\mathbf{a}$	G	$\int_{-\infty}^{\infty} \Psi^*(x)\,\Phi(x)dx$
D	$(\mathbf{b}^\dagger\mathbf{a})^*$	H	$\int_{-\infty}^{\infty} \Psi(x)\,\Phi^*(x)dx$

Q32 to Q35 mainly concern Unit 11.

Q32 to Q35 share the same key. Each concerns the spectrum of an operator. In each case, select the option that best describes the spectrum.

Q32 Select *one* option to describe the spectrum of the position operator for a free particle moving in one dimension.