University of Nottingham
UK | CHINA | MALAYSIA

School of Physics and Astronomy

A Level 3 Module, Spring 2024-2025

Force and Function at the Nanoscale

Instructions:

Time allowed: TWO Hours

Answer all THREE questions

Candidates may complete the front cover of their answer book and sign their desk card. **DO NOT turn the examination paper over until instructed to do so.**

Only a calculator from approved list A may be used in this examination.

Basic Models	**Scientific Calculators**	
Aurora HC133	Aurora AX-582	Casio FX82 family
Casio HS-5D	Casio FX83 family	Casio FX85 family
Deli – DL1654	Casio FX350 family	Casio FX570 family
Sharp EL-233	Casio FX991 family	Sharp EL-531 family
	Texas Instruments TI-30 family	Texas BA II+ family

Permitted resources:
Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination.

Prohibited resources:
All other dictionaries, including subject specific translation dictionaries and electronic dictionaries. Electronic devices capable of storing and retrieving text.

Appended material: None

Additional material: None

Information for invigilators: None

Exam papers must not be removed from the examination venue.

Standard Table of Physical Constants

Speed of light in free space	c	3.00×10^{8} m s^{-1}
Gravitational Constant	G	6.67×10^{-11} N m^2 kg^{-2}
Planck's Constant	h	6.63×10^{-34} J s
	$\hbar$	1.055×10^{-34} J s
Elementary charge	e	1.60×10^{-19} C
Mass of the electron	m_e	9.11×10^{-31} kg
Mass of the proton	m_p	1.6726×10^{-27} kg
Mass of the neutron	m_n	1.6749×10^{-27} kg
Boltzmann's constant	k_{B}	1.38×10^{-23} J K^{-1}
Gas constant	R	8.31 J K^{-1} mol^{-1}
Permittivity of free space	ε_0	8.85×10^{-12} F m^{-1}
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Bohr magneton	μ_{B}	9.27×10^{-24} J T^{-1}
Stefan-Boltzmann constant	σ	5.67×10^{-8} W m^{-2} K^{-4}
Avogadro's number	N_{A}	6.02×10^{23} mol^{-1}

Information you may find useful

$< x^2 > \approx 6Dt$ where $D = \frac{k_B T}{6\pi\mu a}$

$P \propto \exp(-\Delta U / k_B T)$

$F(x) = -\frac{dU}{dx}$

$U_{dipole} = -\mathbf{p}.\mathbf{E}$ where $\mathbf{p} = qd\hat{\mathbf{r}}$

$\mathbf{p} = \alpha \mathbf{E_{ext}}$ where $\alpha = 4\pi\epsilon\epsilon_r d^3$

$U(x) = -\frac{\pi n_1 C}{6x^3}$

$A_{12} = n_1 n_2 \pi^2 C$

$W_{adhesion} = \gamma_{13} + \gamma_{23} - \gamma_{12}$

$\Delta P = \gamma \left[\frac{1}{R_1} + \frac{1}{R_2} \right]$

$h = \frac{2\gamma \cos(\theta)}{\rho g R}$

$k = \frac{k_B T}{<z^2>} = \frac{3EI}{L^3}$

$< I >= \frac{c\epsilon\epsilon_0 n}{2} \langle E^2 \rangle$

$\Pi = (n_+ + n_- - 2n_0) k_B T$

$\frac{-d^2 V}{dx^2} = \frac{\rho}{\epsilon\epsilon_0}$

$P_{tot} = 4n_0 \frac{z^2 e^2 V_0^2}{k_B T} \exp(-\kappa D) - \frac{A}{6\pi D^3}$

$s = k_B \ln W$

$\Delta U = \Delta H - T\Delta S$

$\Delta U = P_{osm} \Delta V_{excl}$

$$\mu = \frac{dU}{dN}$$

$$P_{tot} = \left[\frac{(k_B T)^2}{\kappa\pi^2} - \frac{A}{6\pi}\right]\frac{1}{D^3}$$

$$H = \frac{\nu}{l_c a_0}$$

where the symbols take their usual meanings as used throughout this course.