

# Theory

## Question 2: X-ray jets from active galactic nuclei

### Marking scheme

			Available	Score
A1	Length contraction	0.1		
	Answer	0.2	0.3	
A2	Answer	0.2	0.2	
A3	Curved edge flux zero	0.1		
	End contributions	0.2		
	Mass injection term	0.2	0.5	
A4	Transform from jet to AGN frame	0.2		
	Energy flux through cross section	0.1		
	Mass injection term	0.1		
	Final answer	0.2	0.6	
A5	Express $P_j$ in terms of jet parameters	0.2		
	Comparing two points	0.1		
	Using previous relationships	0.2		
	Final answer	0.1	0.6	
A6	Expression for $\dot{M}$ , in known variables	0.2		
	Values	0.2	0.4	
A7	Average momentum per particle - rel	0.2		
	Expression for total p flux	0.2		
	Numerical value	0.1	0.5	
A8	Pressure from 3 surfaces	0.1		
	Correctly constructed integral for curved surface force	0.2		
	Final answer	0.2	0.5	
A9	Relationship	0.1		
	% difference	0.1	0.2	
B1	Integral including correct limits	0.2	0.2	
B2	Factor of two in change of momentum	0.1		
	$E = pc$	0.1		
	Number of electrons hitting wall in $\Delta t$	0.2		
	Set up of integral	0.2		
	Final answer	0.2	0.8	
B3	Identify $E/V$	0.2		
	Identify pressure	0.2		
	Equation of state	0.2	0.6	
B4	$dQ = 0$ so $dE = dW$	0.2		
	$dE$ from equation of state	0.1		
	Setting up integral	0.1		
	Final relationship	0.2	0.6	
C1	Force perpendicular to $v$ , $F = \gamma ma$	0.3		
	Magnetic force	0.1		
	$a = v\Omega$	0.1		
	Gyrofrequency	0.2	0.7	

C2	Find time between emission of front and back of pulse	0.1	0.5	
	Find relationship to apparent time	0.2		
	Final answer with ultrarelativistic approximation	0.2		
C3	Frequency from characteristic timescale	0.2	0.3	
	Final expression	0.1		
C4	Linear approximation	0.1	0.2	
	Expression	0.1		
D1	Constant flux	0.1	0.4	
	Area scaling	0.1		
	Final expression	0.2		
D2	Scaling of number density	0.1	1	
	Scaling of energy	0.2		
	Applying scaling of energy implies $p$ unchanged.	0.3		
	Integral for number density	0.2		
	Final expression	0.2		
D3	Ticking steeper (and nothing else)	0.1	0.3	
	Reasonable justification (e.g. cooling time is shorter for higher $E$ )	0.2		
D4	Cen A: adiabatic expansion, D3, consistency		0.6	
	One or both of the correct boxes are ticked in the first two rows	0.1		
	One or both of the correct part numbers are stated in the first two rows	0.1		
	Both of the first two rows are completely correct (they should be identical).	0.1		
	M87: synchrotron/other, D2, consistency			
	One or both of the correct boxes are ticked in the second two rows	0.1		
	One or both of the correct part numbers are stated in the second two rows	0.1		
	Both of the second two rows are completely correct (they should be identical).	0.1		