1(a)	The (total of the) quantity being conserved is constant		2	
	Poor answer only 1		1	[2]
1 (b)(i)	**e.g.** conservation of energy conservation of momentum conservation of charge conservation of mass 1 each maximum of 3		3	[3]
1(b)(ii)	1 for idea and 1 for explanation	3 x 2	6	[6]
e.g.	1. a falling object finding the speed of OR p.e. changes to k.e. with the sum of both constant 2. a collision finding speed after a collision OR (total) momentum before collision = momentum after collision 3. branched circuits finding currents in OR charge (current) into a junction = charge (current) out of a junction 4. in a chemical reaction mass of reactants = mass of products			
1(b)(iii)	**e.g.** in first example above the sum of the p.e. and k.e. may not be constant so the law of conservation of energy appears not to hold. This is because not all the energy is being considered because work may be done against air resistance. 1 for suitable example, 1 for direct explanation, 1 for greater detail		3	[3]
1(c)(i)	statement of chosen laws	2 x 1	2	
1(c)(ii)	explanation of the application of the law	2 x 1	2	
1(c)(iii)	statement of what is being conserved	2 x 1	2	
	how conservation takes place		2	[8]
	ignore any confusion between whether a law is described as Kirchhoff's first or second law		**Total: 22**	

2(a)	unit for moment of inertia is kg m^2		1	
	candidate correctly ignores the ½		1	[2]
2(b)	maximum kinetic energy = $2\pi^2 f^2 I = 2\pi^2 \times 200^2 \times 7.8$		1	
	= 6.16 x 10^6 J with at least two significant figures		1	[2]
2(c)	sensible values i.e. both smaller than values for bus		1	
	e.g. volume = π x $(0.10)^2$ x 0.2	= 6.3 x 10^{-3} m^3	1	
	mass = 6.3 x 10^{-3} x 7800	= 49 kg	1	
	$I = ½mr^2$ = 0.5 x 49 x 0.1^2	= 0.24(5) (kg m^2)	1	
	k.e. = $2\pi^2 f^2 I$ = $2\pi^2$ x 200^2 x 0.245	= 1.9(3) x 10^5 J	1	[5]
2(d)	k.e. = $2\pi^2 f^2 I$ = 0.5	= $2\pi^2$ x f^2 x 5.0 x 10^6	1	
	f^2 = 0.5 / $2\pi^2$ x 5.0 x 10^6		1	
	f =	71 (revolutions per second)	1	[3]

	bus flywheel	car flywheel	toy car flywheel
length l / m	0.40	**e.g. 0.20**	0.008
radius r / m	0.20	**e.g. 0.10**	0.015
volume V / m^3	0.050	**e.g. 6.3 x 10^{-3}**	5.7 x 10^{-6}
mass m / kg	390	**e.g. 49**	0.044
maximum frequency of rotation f / s^{-1}	200	200	**71**
moment of inertia I	7.8	**e.g. 0.24(5)**	5.0 x 10^{-6}
maximum kinetic energy stored /J	**6.16 x 10^6**	**e.g. 1.9(3) x 10^5**	0.50

(e)(i)	buses stop more frequently than cars	1	
	so (proportionally) lose more kinetic energy (as internal energy)		
	OR other valid point e.g. relating to cost	1	[2]
(e)(ii)	danger of breaking up (at such a high rotational speed)	1	
	reducing air resistance in a vacuum	1	[2]
2(e)(iii)	increase density of rotating mass	1	
	OR (and better) make radius larger by reducing the length	2	[2]
		Total: 18	

3(a) (i)	energy as the (stored) ability to do work OR the reverse argument	1	
3(a)(ii)	kinetic energy as the work which an object can do (when slowing down to a stop) by virtue of its speed. OR equal to the work which needs to be done on it to get it up to its existing speed. OR the energy an object has as a result of its motion	1	
3(a)(iii)	potential energy as the work which the object can do as a result of its position	1	
	(in a gravitational field).	1	[4]
3(b)	in a sound wave the molecules (of the material through which the sound is travelling) are vibrating. This movement implies that they have k.e.	1	
	At times during their vibration they are packed more closely than normal and repel one another. This implies that they have (elastic) potential energy.	1	[2]

3(c) **e.g.** heat OR internal energy - kinetic energy of the molecules; potential energy of the molecules

heat OR internal energy -	kinetic energy of the molecules
	potential energy of the molecules
light -	electrical potential energy in the waves
	magnetic potential energy in the waves
chemical -	potential energy in molecular attraction
	kinetic energy of molecular movement
electrical -	electrical potential energy
	(little) kinetic energy of moving charges

Throughout this part of the question allow 1 mark for a type of energy and one aspect of its energy as kinetic or potential and the second mark for further correct elaboration. 2 x 2 — 4 [4]

Total: 10

4(a)	electric field as force per unit charge so unit is $N\ C^{-1}$	1	
	potential gradient (from *V/d)* measured in $V\ m^{-1}$	1	
	$V\ m^{-1} = J\ C^{-1}\ m^{-1} = N\ C^{-1}$	1	[3]
4(b)(i)	field = 12 V / 3.4 m = 3.5 $V\ m^{-1}$	1	
4(b)(ii)	1. force = *Ee*	1	
	$= 3.5 \times 1.6 \times 10^{-19} = 5.6 \times 10^{-19}$ (N)	1	
	2. acceleration = force/mass	1	
	$= 5.6 \times 10^{-19} / 9.11 \times 10^{-31} = 6.2 \times 10^{11}$ ($m\ s^{-2}$)	1	[5]
4(c)	the acceleration is correct		
	electrons only travel a very short distance before <u>colliding</u> with atoms		
	so they do not acquire any large speed		
	start stop start stop …….. movement restricts speed	2	[2]
	full marks can be given for 'collision' + one other point		

Total: 10