Name:

IQS Module S2 Take-home Exam, 2014

Instructions:

Once you begin work on this portion of the test, you have 120 minutes to complete it. You will need to be able to run Spartan for one question, so make sure you have access to a university computer with the software (eg in C201). Write your answers on separate sheets of paper, and be sure to put your name on each sheet. As with the in-class portion of the exam, you are not allowed to use any reference materials except those that come with the exam, and you may not discuss this exam with anyone except Dr. Gilfoyle or Dr. Stevenson.

This portion of the test must be turned in by 11:20 am on Friday, March 20. Please return all sheets with your work.

I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Signature ______________________________

Name:

IQS S2 Integrative Questions (10 pts)

The $n = 0$ to $n = 1$ vibrational transition of the HI molecule occurs at a frequency $\nu_{\mathrm{HI}} = 6.69 \times 10^{13}$ Hz. The same transition for the NO molecule occurs at $\nu_{\mathrm{NO}} = 5.63 \times 10^{13}$ Hz.

1. What is the effective force constant k for each molecule?

2. What is the amplitude of vibration of each molecule around the equilibrium point?

3. Explain the differences between the results for these two molecules.

4. If the hydrogen in HI is replace by deuterium, to form DI, what would you predict would be the new vibrational frequency?

5. If an electron is removed from the NO molecule, leaving the NO^+ molecular cation, would you expect the vibrational frequency to increase or decrease? Justify your answer:

   (a) with pen and paper, using Lewis structures and (non-computational) MO theory

   (b) using Spartan to perform whatever quantum mechanical calculations you wish.

Physics Constants, Conversion Factors, and Equations

$$x(t) = \frac{1}{2}at^2 + v_0 t + y_0 \quad v = at + v_0 \quad \theta = \frac{\alpha}{2}t^2 + \omega_0 t + \theta_0 \quad \omega = \alpha t + \omega_0 \quad a_c = \frac{v^2}{r}$$

$$\theta = \frac{s}{r} \quad \omega = \frac{v_T}{r} = \frac{d\theta}{dt} \quad \alpha = \frac{a_T}{r} = \frac{d\omega}{dt} \quad I = \sum m_i r_i^2 = I_{cm} + MR^2$$

$$x(t) = A\cos(\omega t + \phi) \quad \mu = \frac{m_1 m_2}{m_1 + m_2} \quad \omega^2 = \frac{k}{m} \quad T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\Delta E = h\nu \quad E = (n + \frac{1}{2})\hbar\omega \quad \hbar = \frac{h}{2\pi}$$

$$\vec{F}_{net} = \sum_i \vec{F}_i = m\vec{a} = \frac{d\vec{p}}{dt} \quad \vec{F}_{AB} = -\vec{F}_{BA} \quad \overline{\vec{F}} = \frac{\Delta\vec{p}}{\Delta t}$$

$$|\vec{F}_f| = \mu N \quad |\vec{F}_c| = m\frac{v^2}{r} \quad \vec{F}_s(x) = -kx\hat{i} \quad \vec{F}_g(y) = -mg\hat{j}$$

$$W = \int \vec{F} \cdot d\vec{s} = \int |\vec{F}||d\vec{s}|\cos\theta = \Delta KE = -\Delta PE \quad KE = \frac{1}{2}mv^2 \quad KE = \frac{1}{2}I\omega^2$$

$$PE_g = mgh \quad PE_s = \frac{1}{2}kx^2 \quad ME_0 = ME_1 \quad \vec{p} = m\vec{v} \quad \vec{p}_0 = \vec{p}_1$$

$$|\vec{\tau}| = rF\sin\phi = I\alpha = \left|\frac{d\vec{L}}{dt}\right| \quad L = I\omega = rmv\sin\phi \quad L_0 = L_1 \quad v_{cm} = r\omega$$

$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \quad \frac{dA}{dt} = 0 \quad \frac{dt}{dt} = 1 \quad \frac{dt^2}{dt} = 2t \quad \frac{d\sin\theta}{d\theta} = \cos\theta \quad \frac{d\cos\theta}{d\theta} = -\sin\theta$$

$$\langle x \rangle = \frac{1}{N}\sum_i x_i \quad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x \rangle)^2}{N-1}} \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad A = 4\pi r^2 \quad V = Ah \quad V = \frac{4}{3}\pi r^3$$

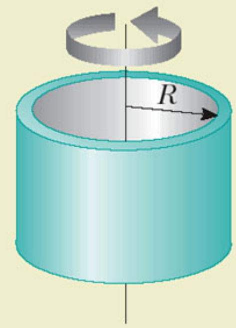
$$\frac{df(x)}{dx} = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x} \quad \int_a^b f(x)dx = \lim_{\Delta x \to 0} \sum_{n=1}^{N} f(x)\Delta x \quad \frac{dy}{dx} = \frac{dy}{du}\frac{du}{dx}$$

Speed of Light (c)	$2.9979 \times 10^8\ m/s$	proton/neutron mass	$1.67 \times 10^{-27}\ kg$
R	$8.31 J/K - mole$	g	$9.8\ m/s^2$
Earth's mass	$5.98 \times 10^{24}\ kg$	Earth's radius	$6.37 \times 10^6\ m$
Earth-Moon distance	$3.84 \times 10^8\ m$	Electron mass	$9.11 \times 10^{-31}\ kg$
h	$6.626 \times 10^{-34}\ J - s$	$1.6 \times 10^{-19}\ J/eV$	$1.66 \times 10^{-27}\ kg/u$

TABLE 10.2 Moments of Inertia of Homogeneous Rigid Objects With Different Geometries

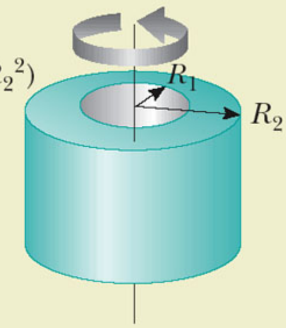
Hoop or thin cylindrical shell

$I_{CM} = MR^2$



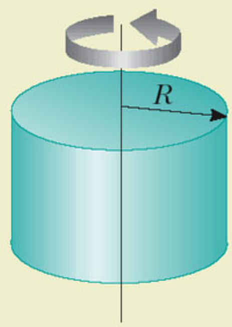
Hollow cylinder

$I_{CM} = \frac{1}{2}M(R_1{}^2 + R_2{}^2)$



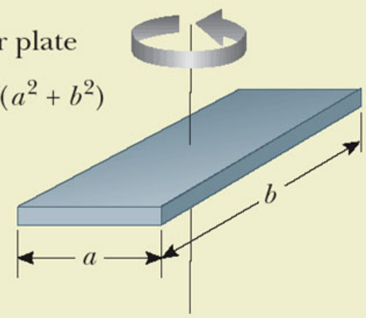
Solid cylinder or disk

$I_{CM} = \frac{1}{2}MR^2$



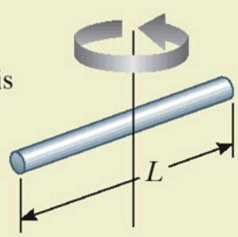
Rectangular plate

$I_{CM} = \frac{1}{12}M(a^2 + b^2)$



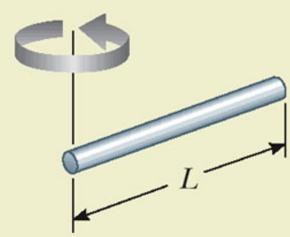
Long thin rod with rotation axis through center

$I_{CM} = \frac{1}{12}ML^2$



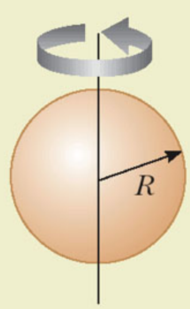
Long thin rod with rotation axis through end

$I = \frac{1}{3}ML^2$



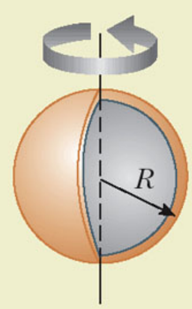
Solid sphere

$I_{CM} = \frac{2}{5}MR^2$



Thin spherical shell

$I_{CM} = \frac{2}{3}MR^2$



hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

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