SIGNATURE ______________________ NAME _________________________

Student ID # ______________________

Physics 410
Spring 2013
Prof. Anlage
FINAL Exam
14 May, 2013
CLOSED BOOK, Calculator Permitted, Single 8.5″ x 11″ Crib Sheet (2-sided) Allowed

Point totals are given for each part of the question.
If you run out of room, continue writing on the back of the same page. If you do so, make a note on the front part of the page!
Note: You must solve the problem following the instructions given in the problem. Correct answers alone will not receive full credit.

Partial Credit:

→ Show Your Work! Answers written with no explanation will not receive full credit.

→ You can receive credit for describing the method you would use to solve a problem, even if you missed an earlier part.

Problem	Credit	Max. Credit
1		20
2		25
3		20
4		15
5		20
TOTAL		100

$\vec{r}\cdot\vec{s} = rs\cos\theta$ $\vec{r}\times\vec{s} = det\begin{bmatrix}\hat{x} & \hat{y} & \hat{z}\\ r_x & r_y & r_z\\ s_x & s_y & s_z\end{bmatrix}$ $\vec{F} = m\ddot{\vec{r}}$ $Constant\ a: x(t) = x_0 + v_0 t + \frac{1}{2}at^2; v(t) = v_0 + at;\ v_f^2 - v_i^2 = 2a\Delta x$ $\vec{f} = -f(v)\hat{v}$ $f(v) = bv + cv^2$

$\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$ $m\dot{v} = -\dot{m}v_{ex} + F^{ext}$ $v - v_0 = v_{ex}\ln\frac{m_0}{m}$ $\vec{R} = \frac{1}{M}\sum_{\alpha=1}^{N} m_\alpha \vec{r}_\alpha$

$\vec{R} = \frac{1}{M}\int \vec{r}\,dm = \frac{1}{M}\int \rho\,\vec{r}\,dV$ $\vec{\ell} = \vec{r}\times\vec{p}$ $\vec{L} = \sum_{\alpha=1}^{N}\vec{r}_\alpha\times\vec{p}_\alpha$ $\dot{\vec{L}} = \vec{\Gamma}^{ext}$ $\Delta T = T_2 - T_1 = \int_1^2 \vec{F}\cdot d\vec{r} = W(1\to 2)$ $T = mv^2/2$ $U(\vec{r}) = -W(\vec{r}_0\to\vec{r}) = -\int_{\vec{r}_0}^{\vec{r}}\vec{F}(\vec{r'})\cdot d\vec{r'}$

$\vec{\nabla}\times\vec{F} = 0$ $\vec{F} = -\vec{\nabla}U$ $E = T + U_1 + \cdots + U_n$ $\Delta E = W_{nc}$ $t = \sqrt{\frac{m}{2}}\int_{x_0}^{x}\frac{dx\prime}{\sqrt{E-U(x')}}$

$\vec{F}(\vec{r}) = f(\vec{r})\hat{r}$ $U = U^{int} + U^{ext} = \sum_\alpha\sum_{\beta>\alpha}U_{\alpha\beta} + \sum_\alpha U_\alpha^{ext}$ $Net\ force\ on\ particle\ \alpha = -\nabla_\alpha U$ $T + U = constant$ $F = -kx \leftrightarrow U = \frac{1}{2}kx^2$ $\ddot{x} = -\omega^2 x \leftrightarrow x(t) = A\cos(\omega t - \delta)$

$\ddot{x} + 2\beta\dot{x} + \omega_0^2 x = 0 \leftrightarrow x(t) = Ae^{-\beta t}\cos(\omega_1 t - \delta)$ $(assuming\ \beta < \omega_0), \beta = \frac{2b}{m}, damping\ force = -bv, \omega_0 = \sqrt{\frac{k}{m}}, \omega_1 = \sqrt{\omega_0^2 - \beta^2}$ $F(t) = mf_0\cos(\omega t), x(t) = A\cos(\omega t - \delta), where\ A^2 = \frac{f_0^2}{(\omega_0^2-\omega^2)^2 + 4\beta^2\omega^2}$ $S = \int_{x_1}^{x_2} f[y(x), y'(x), x]dx$, $\frac{\partial f}{\partial y} - \frac{d}{dx}\frac{\partial f}{\partial y'} = 0$

$S = \int_{u_1}^{u_2} f[x(u), y(u), x'(u), y'(u), u]du$, $\frac{\partial f}{\partial x} = \frac{d}{du}\frac{\partial f}{\partial x'}, and\ \frac{\partial f}{\partial y} = \frac{d}{du}\frac{\partial f}{\partial y'}$ $\mathcal{L} = T - U$

$\frac{\partial\mathcal{L}}{\partial q_i} = \frac{d}{dt}\frac{\partial\mathcal{L}}{\partial\dot{q}_i}\ [i = 1, \ldots n]$ $p_i = \frac{\partial\mathcal{L}}{\partial\dot{q}_i}$ $\mathcal{H} = \sum_{i=1}^{n} p_i\dot{q}_i - \mathcal{L}$ $\vec{r} = \vec{r}_1 - \vec{r}_2$ $\mu = \frac{m_1 m_2}{m_1 + m_2}$

$U_{eff} = U(r) + U_{cf}(r) = U(r) + \frac{\ell^2}{2\mu r^2}$ $u''(\varphi) = -u(\varphi) - \frac{\mu}{\ell^2 u(\varphi)^2}F$

$r(\varphi) = \frac{c}{1+\epsilon\cos\varphi}\ for\ F = -\frac{\gamma}{r^2}, with\ c = \frac{\ell^2}{\gamma\mu}$ $E = \frac{\gamma^2\mu}{2\ell^2}(\epsilon^2 - 1)$

$\vec{F}_{inertial} = -m\vec{A}$ $\vec{\omega} = \omega\hat{u}$ $\vec{v} = \vec{\omega}\times\vec{r}$ $\left(\frac{d\vec{Q}}{dt}\right)_{S_0} = \left(\frac{d\vec{Q}}{dt}\right)_S + \vec{\Omega}\times\vec{Q}$

$m\ddot{\vec{r}} = \vec{F} + \vec{F}_{cor} + \vec{F}_{cf}, with\ \vec{F}_{cor} = 2m\dot{\vec{r}}\times\vec{\Omega}, and\ \vec{F}_{cf} = m(\vec{\Omega}\times\vec{r})\times\vec{\Omega}$

$\vec{g} = \vec{g}_0 + (\vec{\Omega}\times\vec{R})\times\vec{\Omega}$ $\vec{L} = \vec{L}(motion\ of\ CM) + \vec{L}(motion\ relative\ to\ CM)$
$T = T(motion\ of\ CM) + T(motion\ relative\ to\ CM)$ $\vec{L} = \bar{\bar{I}}\vec{\omega}$

$\bar{\bar{I}} = \begin{bmatrix}I_{xx} & I_{xy} & I_{xz}\\ I_{yx} & I_{yy} & I_{yz}\\ I_{zx} & I_{zy} & I_{zz}\end{bmatrix}$ $I_{xx} = \sum_\alpha m_\alpha(y_\alpha^2 + z_\alpha^2), etc.$ $I_{xy} = -\sum_\alpha m_\alpha x_\alpha y_\alpha, etc.$ $\vec{L} = \lambda\vec{\omega}$

$\bar{\bar{I}}' = \begin{bmatrix}\lambda_1 & 0 & 0\\ 0 & \lambda_2 & 0\\ 0 & 0 & \lambda_3\end{bmatrix}$ $\dot{\vec{L}} + \vec{\omega}\times\vec{L} = \vec{\Gamma}$ $\bar{\bar{M}}\ddot{\vec{q}} = -\bar{\bar{K}}\vec{q}$ $T = \frac{1}{2}\sum_{j,k} M_{jk}\,\dot{q}_j\dot{q}_k$ $U = \frac{1}{2}\sum_{j,k} K_{jk}\,q_j q_k$ $\vec{q}(t) = Re(\vec{a}\,e^{i\omega t})$ $(\bar{\bar{K}} - \omega^2\bar{\bar{M}})\vec{a} = 0$ $\ddot{\phi} + 2\beta\dot{\phi} + \omega_0^2\sin\phi = \gamma\omega_0^2\cos(\omega t), with\ \gamma = \frac{F_0}{mg}, and\ F(t) = F_0\cos(\omega t)$ $|\Delta\phi(t)| \sim Ke^{\lambda t}$ $\dot{q}_i = \partial\mathcal{H}/\partial p_i$ and $\dot{p}_i = -\frac{\partial\mathcal{H}}{\partial q_i}\ [i = 1, \ldots n]$

$N_{oc} = N_{inc}n_{tar}\sigma_{oc}$ $N_{sc}(into\ d\Omega) = N_{inc}n_{tar}\frac{d\sigma}{d\Omega}(\theta,\phi)d\Omega$ $\frac{d\sigma}{d\Omega} = \frac{b}{\sin\theta}\left|\frac{db}{d\theta}\right|$
$\frac{d\sigma}{d\Omega} = \left(\frac{kqQ}{4E\sin^2(\theta/2)}\right)^2$ $\Delta t = \gamma\Delta t_0$ $\gamma = 1/\sqrt{1-\beta^2},$ $\beta = V/c$ $\ell = \ell_0/\gamma$ $x' =$

$\gamma(x - Vt),\ \ y' = y,\ \ z' = z,\ \ t' = \gamma(t - Vx/c^2)$ $v_x' = \frac{v_x - V}{1 - v_x V/c^2},\ v_y' = \frac{v_y}{\gamma(1 - v_x V/c^2)},\ v_z' = \frac{v_z}{\gamma(1 - v_x V/c^2)}$ ${q^{(4)}}' = \Lambda q^{(4)}$ $x^{(4)} \cdot y^{(4)} = x_1 y_1 + x_2 y_2 + x_3 y_3 - x_4 y_4$ $u^{(4)} = \frac{dx^{(4)}}{dt_0} = \gamma(\vec{v}, c)$ $p^{(4)} = mu^{(4)} = (\gamma m\vec{v}, \gamma mc) = (\vec{p}, E/c)$ $\vec{\beta} = \vec{p}c/E$ $p^{(4)} \cdot p^{(4)} = -(mc)^2$
$E^2 = (mc^2)^2 + (\vec{p}c)^2$