Family Name (Please print in BLOCK LETTERS)	Given Name(s) as on student card	Student Number	Practical Group Code (eg. F2A)

UNIVERSITY OF TORONTO — Faculty of Arts and Science
DECEMBER 2009 EXAMINATION — version 1
PHY131H1F
Duration – 2 hours

PLEASE HAND IN

PLEASE read carefully the following instructions.

Aids allowed: Non-programmable calculators without text storage are allowed. Some potentially useful formulae are on the last page right after the questions..

- **Turn off** any communication device (phone, pager, PDA, etc.) you may have and place it on the floor.
- **DO NOT separate the sheets of your question paper, except the final three pages for rough work which may be removed gently.** Work lost or unattributable because of separated question sheets will not receive any credit. Your paper should have 12 pages including the three blank sheets at the end. If this is not the case, call an invigilator.
- **Before starting, please PRINT IN BLOCK LETTERS your name, student number, and tutorial group code at the top of this page and on the answer sheet.**

Answer Sheet:

- Use a dark lead pencil.
- Locate your exam version number in the header at the top of the cover page, and **shade in** the corresponding version number on your answer sheet. No crosses, circles, or ticks!
- Mark in your student number by shading the circles.
- Indicate the most correct answer to a multiple-choice question by filling the appropriate circle on the answer sheet and also by circling the corresponding answer on the exam paper.
- If you wish to modify an answer, erase your pencil mark thoroughly. Do not use white-out.
- **Do not write anything else on the answer sheet.** Use the back of the question sheets and either side of the blank sheets at the end for rough work.

The exam has **12** equally weighted multiple-choice questions, worth **60** marks in total, plus **2** long-answer problems, each worth **20** marks for a fully correct, worked out solution.

Multiple-choice questions:

- Each correct answer is awarded 5 marks.
- Blank or incorrect answers are awarded zero marks.
- Multiple answers for a question are graded as a wrong answer.

Long-Answer Problems: Maximum credit will be awarded only to fully worked solutions to all parts of the long-answer problems. In addition to showing your work, please put your answer(s) for each part in the boxes provided. Please use the back-side of the sheets and both sides of the blank pages at the end for your rough work which will not be graded. Marks will be deducted for an incorrect number of significant figures in numerical answers.

When the invigilators declare the exam ended, stop writing immediately. Please put your answer sheet **inside your test paper** and have the paper ready for an invigilator to pick up.

Total marks = 100. This exam paper has 12 pages.

Good luck!

PART I: Multiple-Choice Questions

1. A simple pendulum is released from rest near the surface of the Earth at an angle $\theta = \theta_0$ from the vertical. Its oscillation period is measured to be T_0. The same pendulum is then released from rest at an angle $\theta = 2\theta_0$ from the vertical. The pendulum's oscillation period is

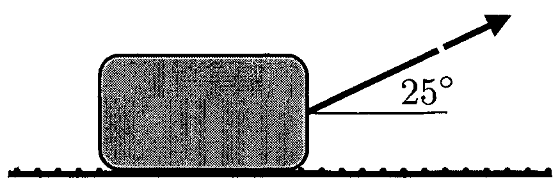
   (A) $2T_0$ for any angle $2\theta_0$.
   (B) approximately $2T_0$ if $2\theta_0$ is an angle less than about five degrees.
   (C) approximately T_0 if $2\theta_0$ is an angle less than about five degrees.
   (D) T_0 for any angle θ_0.
   (E) greater than $2T_0$ for any angle θ_0.

2. The change in angular momentum of an object during a time interval of 2.0 ± 0.1 s is 5.2 ± 0.3 kg m^2/s. The average torque, in kg m^2/s^2, on the object during this time is

   (A) 2.6 ± 0.2. (B) 2.60 ± 0.20. (C) 2.6 ± 0.1. (D) 2.60 ± 0.30. (E) 2.6 ± 0.3.

3. A box of mass 2.50 kg is pulled along a horizontal surface using a string of negligible mass. The box has an acceleration of 2.00 m/s^2. The string makes an angle of 25.0 degrees with the horizontal, as shown in the figure below. The tension in the string is 6.00 N. What is the coefficient of kinetic friction between the box and the surface? Ignore air resistance.

   (A) 0.0408 (B) 0.0199 (C) 0.129 (D) 0.000 (E) 0.0179



4. Laminar flow is characterized by

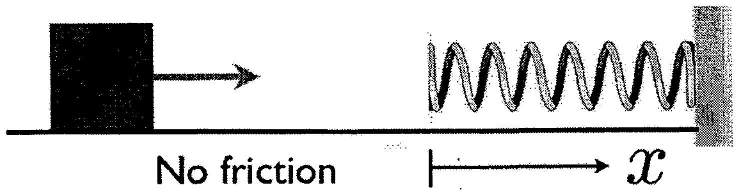
   (A) steady, two-dimensional flow patterns.
   (B) strongly time dependent flow velocities, wildly varying from place to place in the flow.
   (C) a mixture of turbulent regions and non-turbulent regions in the flow.
   (D) a flow which has negligible viscous effects.
   (E) smooth variations of the flow velocity from place to place.

5. A parked car is at rest on a flat, horizontal surface. The two front wheels are 3.00 m from the two rear wheels. The car's centre of mass is located 1.20 m behind the front wheels, and 1.80 m in front of the rear wheels. The mass of the car is 1.00×10^3 kg. The magnitude of the total normal force, in Newtons, exerted by the ground on the two front wheels is

   (A) 3.92×10^3. (B) 2.94×10^3. (C) 9.80×10^3. (D) 4.90×10^3. (E) 5.88×10^3.

6. A 200. g block slides on a frictionless horizontal surface at a speed of 0.250 m/s to the right. It runs into a horizontal massless spring with spring constant 40.0 N/m that extends outward from a fixed vertical wall, as shown in the figure below. It compresses the spring and is pushed back in the opposite direction. It rebounds off and eventually loses contact with the spring. The time, in seconds, that the block remains in contact with the spring is

(A) 0.444. (B) 0.222. (C) 0.111. (D) 0.889. (E) 0.00125.



7. Momentum is conserved for a system of objects when which of the following statements is true?

(A) The internal forces cancel out due to Newton's Third Law and forces external to the system are conservative.
(B) The sum of the momentum vectors of the individual objects equals zero, so that forces external to the system act on the centre of mass.
(C) The forces external to the system are zero and the internal forces sum to zero, due to Newton's Third Law.
(D) The impulses delivered during internal collisions between the objects cancel out, while the impulses due to forces external to the system all act in the same direction.
(E) Both the internal and external forces are conservative.

8. A U-shaped tube, open to the air on both ends, contains liquid mercury that has a density of 1.36×10^4 kg/m^3. Water is poured into the left arm of the tube until the water column is 15.0 cm deep. Water does not mix with mercury. How far upward, in cm, from its initial position does the top surface of the mercury in the right arm of the tube rise?

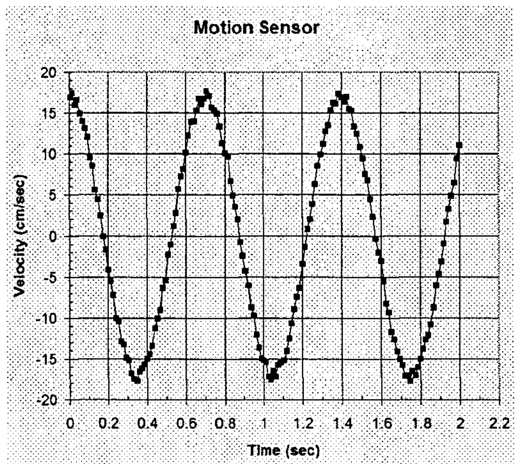
(A) 0.000 (B) 1.10 (C) 0.551 (D) 102 (E) 0.276

9. A simple pendulum near the surface of the Earth consists of an object of mass m at the end of an unstretchable string of length L. It swings from $\theta = 0$ to $\theta = \theta_{\text{max}}$, where θ is the angle with respect to the vertical. The work done on the object *by* the tension in the string is

(A) $mgL\,(1 - \cos\theta_{\text{max}})$.
(B) $mgL \cos\theta_{\text{max}}$.
(C) $-mgL \sin\theta_{\text{max}}$.
(D) $mgL\,(1 - \sin\theta_{\text{max}})$.
(E) zero.

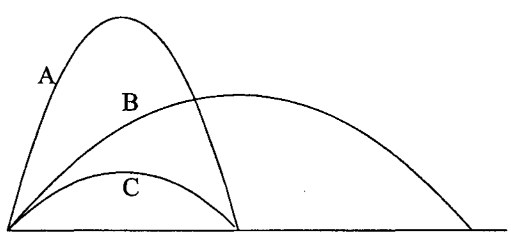
10. An object with a mass of 200. g hangs from a spring. A motion sensor is positioned under the object and points up at it. You run the motion sensor with a sampling rate of 75 Hz and analyze the position data to produce a velocity-versus-time graph, as shown in the figure below. From this graph, what is the best estimate of the maximum acceleration of the object, in cm/s^2, during the 2 seconds in which it oscillates approximately with simple harmonic motion?

(A) 1400 (B) 17 (C) 24 (D) 150 (E) 8000



11. The figure below shows the trajectories of three tennis balls. Each was launched with the same initial speed. Ignoring air resistance, which ball was in the air for the longest time?

(A) Ball A
(B) Ball B
(C) Ball C
(D) Balls A and C were in the air for equal time, which was longer than that for ball B
(E) Balls A and B were in the air for equal time, which was longer than that for ball C



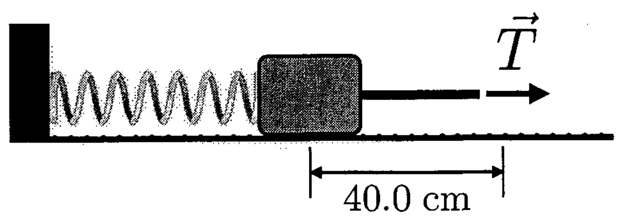
12. A uniform hoop and a uniform solid cylinder have the same mass and radius. They both roll, without slipping, on a horizontal surface. If their total kinetic energies are equal, then

(A) the hoop has a greater translational speed than the cylinder.
(B) the cylinder has a greater translational speed than the hoop.
(C) the hoop and the cylinder have the same translational speed.
(D) the hoop has a greater rotational speed than the cylinder.
(E) the translational speeds of the hoop and the cylinder cannot be compared without more information.

PART II: Long-Answer Problems

There are several parts to each of the Long-Answer Problems. Clearly show your reasoning and work as some part marks may be awarded. Write your final answers in the boxes provided.

1. A 5.50 kg box on a horizontal surface is attached to one end of a horizontal ideal spring with spring constant $k = 80.0$ N/m. The other end of the spring is connected to a fixed vertical wall. The spring is initially at its equilibrium position and the box is initially at rest. A horizontal massless rope with a constant tension of magnitude $T = 90.0$ N pulls the box away from the wall. The coefficient of kinetic friction between the box and the surface is $\mu_k = 0.300$.



PART A [5 marks] What is the work W done on the box by the tension force $\vec{T}$ while the box moves from its initial position through a displacement of 40.0 cm ?

$W =$

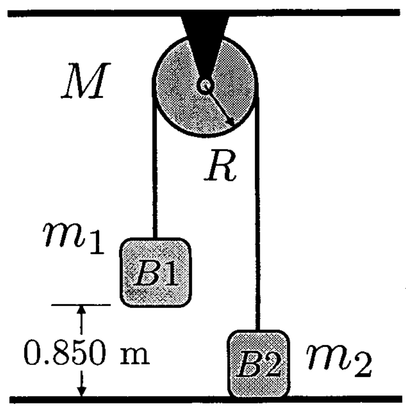
PART B [5 marks] What are the magnitude and direction of the friction force $\vec{f}$ between the box and the surface during the motion?

$\vec{f} =$

PART C [10 marks] What is the speed v of the box when it arrives at a position 40.0 cm from its initial position?

$v =$

2. Two boxes are connected by a massless, unstretchable rope that passes over a non-ideal pulley. The radius and mass of the pulley are $R = 0.100$ m and $M = 1.75$ kg. As the pulley turns, friction at the axle exerts a constant torque of magnitude of 0.480 Nm. The moment of inertia of the pulley is $\frac{1}{2}MR^2$. Box B1 has a mass $m_1 = 3.98$ kg and its initial location is 0.850 m above the floor. Box B2 has a mass of $m_2 = 2.01$ kg and its initial location is at the floor. After the boxes are released from rest, B1 descends to the floor, while B2 is lifted.



PART A [10 marks] What is the tension T_1 in the rope between B1 and the pulley as B1 descends to the floor?

$T_1 =$

PART B [5 marks] What is the acceleration a_1 of B1 as it descends to the floor?

$a_1 =$

PART C [5 marks] How long does it take B1 to reach the floor?

$t_1 =$

Equations and Constants

Constants $g = 9.80\ \text{m/s}^2$ $\rho_{\text{water}} = 1.00 \times 10^3\ \text{kg/m}^3$ $\eta_{\text{water}} = 1.00 \times 10^{-3}\ \text{Pa}\cdot\text{s}$

Linear motion, kinematics

$$v_s = ds/dt \qquad a_s = dv_s/dt \qquad s_f = s_i + \int v_s dt \qquad v_f = v_i + \int a_s dt$$

$$v_{\text{fs}} = v_{\text{is}} + a_s \Delta t \qquad s_{\text{f}} = s_{\text{i}} + v_{\text{is}}\Delta t + \frac{1}{2} a_s (\Delta t)^2 \qquad v_{\text{fs}}^2 = v_{\text{is}}^2 + 2 a_s \Delta s$$

Circular motion

$$\omega = d\theta/dt \qquad \alpha = d\omega/dt \qquad v_{\text{t}} = \omega r \qquad a_{\text{r}} = v^2/r = \omega^2 r$$

$$a_{\text{t}} = \alpha r \qquad \omega_{\text{f}} = \omega_{\text{i}} + \alpha \Delta t \qquad \theta_{\text{f}} = \theta_{\text{i}} + \omega_{\text{i}} \Delta t + \frac{1}{2}\alpha(\Delta t)^2$$

$$(F_{\text{net}})_{\text{r}} = mv^2/r \qquad (F_{\text{net}})_{\text{t}} = ma_{\text{t}}$$

Friction, spring forces, gravitation

$$f_{\text{s}} \le \mu_{\text{s}} n \qquad f_{\text{k}} = \mu_{\text{k}} n \qquad (F_{\text{sp}})_s = -k\Delta s \qquad F_{\text{G}} = \frac{GMm}{r^2} \qquad T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$$

Vector dynamics, impulse, momentum

$$\vec{F}_{\text{net}} = m\vec{a} \qquad \vec{v} = d\vec{r}/dt \qquad \vec{a} = d\vec{v}/dt$$

$$\vec{p} = m\vec{v} \qquad \vec{F} = d\vec{p}/dt \qquad \vec{J} = \int \vec{F} dt = \Delta \vec{p}$$

Work, energy, power

$$K = \frac{1}{2} mv^2 \qquad U_{\text{g}} = mgy \qquad U_s = \frac{1}{2} k (\Delta s)^2 \qquad W = \int F_s ds \qquad P = dE_{\text{sys}}/dt$$

$$\Delta K = W_{\text{c}} + W_{\text{ext}} + W_{\text{diss}} \qquad \Delta U = -W_{\text{c}} \qquad F_s = -dU/ds \qquad \Delta E_{\text{th}} = f_{\text{k}} \Delta s$$

Rotational dynamics, angular momentum

$$I = \sum_i m_i r_i^2 \qquad x_{\text{cm}} = \frac{1}{M} \sum_i m_i x_i \qquad \tau_{\text{net}} = I\alpha$$

$$\vec{\tau} = \vec{r} \times \vec{F} \qquad \vec{L} = \vec{r} \times \vec{p} \qquad \vec{L} = I\vec{\omega} \qquad \vec{\tau}_{\text{net}} = d\vec{L}/dt$$

Rolling $v_{\text{cm}} = \omega R$ $a_{\text{cm}} = \alpha R$

Oscillations $\omega = 2\pi f = 2\pi/T$ $x(t) = \cos(\omega t + \phi_0)$

$$x(t) = A\,\mathrm{e}^{-bt/2m} \cos(\omega t + \phi_0) \qquad T_{\text{sp}} = 2\pi\sqrt{m/k} \qquad T_{\text{pend}} = 2\pi\sqrt{L/g}$$

Fluid mechanics $p = p_0 + \rho g d$ $v_1 A_1 = v_2 A_2$ $p + \frac{1}{2}\rho v^2 + \rho g y = B$

$$\text{Re} = \frac{\rho U d}{\eta} \qquad D = 6\pi\eta R U \qquad D = C_D(\text{Re})\rho R^2 U^2$$

$$u(r) = -(\Delta p/\Delta L)(R^2 - r^2)/(4\eta) \qquad \text{St} = fd/U \qquad Q = \bar{v} A$$

Products of vectors $\vec{A} \cdot \vec{B} = AB\cos\alpha$ $|\vec{A} \times \vec{B}| = AB\sin\phi$

Error analysis

$$N(x) = A\,\mathrm{e}^{-(x-\bar{x})^2/2\sigma^2} \qquad \bar{x}_{\text{est}} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad \sigma_{\text{est}} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x}_{\text{est}})^2} \qquad \Delta\bar{x}_{\text{est}} = \frac{\Delta x}{\sqrt{N}}$$

$$\Delta z = \sqrt{(\Delta x)^2 + (\Delta y)^2} \qquad \frac{\Delta z}{z} = \sqrt{\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2} \qquad \frac{\Delta z}{z} = n\frac{\Delta x}{x}$$

Rough Work (not marked)

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