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 2010 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.

- **Switch off completely** any communication device (phone, pager, PDA, etc.) you may have and leave it with your belongings at the front or back of the room.
- **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 Practical 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 filling 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 exam paper** and have the paper ready for an invigilator to pick up.

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

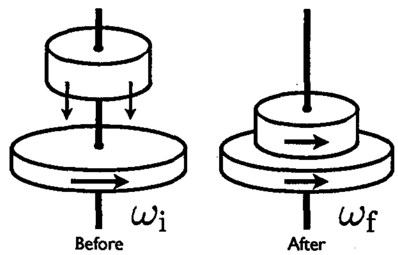
Good luck!

Long-answer marks

1	2

PART I: Multiple-Choice Questions

1. A solid disk of mass $M = 2.0\,\text{kg}$ and radius R_1 =30. cm is freely rotating on a vertical frictionless axle at angular speed $\omega_i = 300\,\text{rad/s}$. A second thicker disk with the same mass but half the radius is dropped down onto the first along the same axis. The second disk is initially not rotating, but friction between the disks spins it up so that the two disks are eventually spinning together at the same final frequency ω_f. ω_f, in rad/s, is closest to:



(A) 0.0 (B) 17. (C) 240 (D) 600 (E) 2400

2. A puck of mass $m = 180\,\text{g}$ sliding on a frictionless surface is initially moving in the $+x$ direction at $v = 40.\,\text{cm/s}$. It briefly collides with another object and a moment later is found moving in the $-y$ direction at the same speed. What are the components (J_x, J_y) of the impulse $\vec{J}$ on the puck delivered by the collision, in N·s?

(A) (0.10, 0.10) (B) (0.072, 0) (C) (0, 0.072) (D) (-0.10,0) (E) (-0.072, -0.072)

3. A professional soccer player can kick a ball at 36. m/s. A standard soccer ball has a radius of 11 cm. At this speed, which of the following statements is most correct?

(A) The air flow is fully turbulent everywhere.
(B) The air flow is laminar in front of the ball, but fully turbulent in its wake.
(C) The air flow is sometimes turbulent and sometimes laminar in the wake of the ball.
(D) There is no separation in the air flow.
(E) The air flow around the ball is laminar everywhere.

4.

19.125
21.000
22.000
23.500
21.500
22.125
20.375
18.250
21.625
23.250
21.000
22.125
23.000

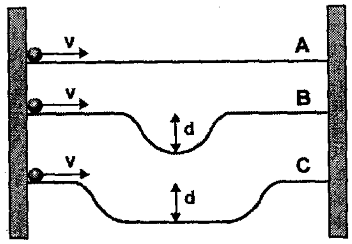
On the mid-term test you were asked about data on the height of self-fertilized *Zea Mays* (corn) plants taken by Charles Darwin in 1878. Darwin also measured the heights of cross-fertilized plants, and the data, in inches, are shown in the table on the left.
The standard deviation of the heights, as read off a calculator, is 1.53563 inches. Therefore, the best representation of the value of the first data point in the table is:

(A) 19.125 (B) 19.12500 (C) 20. (D) 19. (E) 19.13

5. A stunt driver can drive his car around a circular track with a radius of 50 m at a maximum speed of 60 km/hr before the car loses traction and begins to skid. He takes his car to a circular track with a radius of 100 m. The two tracks are both horizontal and have the same road surface. The maximum speed he can drive without skidding around the 100 m radius track is closest to:

(A) 60 km/hr (B) 120 km/hr (C) 30 km/hr (D) 85 km/hr (E) 42 km/hr

6. Three small balls **A**, **B**, and **C** are launched with equal speeds on three different tracks, as shown. Friction and air resistance are negligible. The times for the balls to reach the right side of their tracks are t_A, t_B and t_C respectively. Which answer gives the correct ranking of the three times?

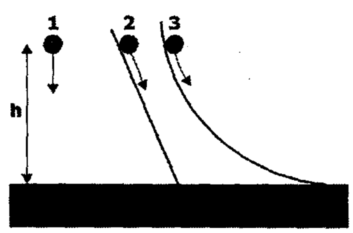


(A) $t_A = t_B = t_C$
(B) $t_A > t_B = t_C$
(C) $t_A = t_B > t_C$
(D) $t_A < t_B = t_C$
(E) $t_A > t_B > t_C$

7. A cyclist's average metabolic rate during a workout is 500 W. The cyclist wishes to expend at least 300 kcal of energy. The time, in **minutes**, that the cyclist must exercise at this rate is closest to:

(A) 0.6 (B) 3.6 (C) 36 (D) 42 (E) 2500

8. Three children, represented by circles and labelled 1, 2, and 3, are initially at rest the same height h above the ground. Child 1 falls straight down. Children 2 and 3 slide down frictionless slides shaped as shown. Air resistance is negligible. At the bottom, which child has the smallest speed?



(A) Child 1
(B) Child 2
(C) Child 3
(D) They all have the same speed at the bottom.
(E) It depends on the masses of the children.

9. Astronauts on the first trip to Mars take along a pendulum that has a period of 1.50 s when used near the surface of the Earth. They observe that its period on the surface of Mars is 2.45 s. The free-fall acceleration on Mars is closest to:

(A) 3.67 m/s^2 (B) 9.80 m/s^2 (C) 16.0 m/s^2 (D) 13.5 m/s^2 (E) 6.00 m/s^2

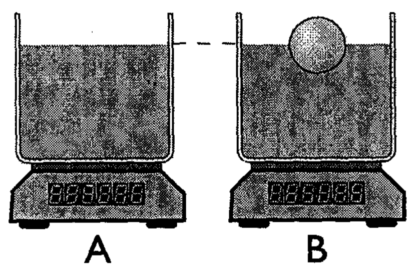
10. When a container full of water with a small hole in the side is at rest on a table, water flows out of the hole and follows an approximately parabolic arc before hitting the table. Suppose the same container is dropped down a mine shaft so that it is in free fall. Air resistance is negligible. As viewed by an observer standing at the bottom of the mine, the water flow:

(A) diminishes.
(B) stops altogether.
(C) travels in a horizontal straight line.
(D) curves upward.
(E) curves downward.

11. A solid sphere, a solid cylinder and a circular hoop, all with the same radius and the same mass are started from rest and rolled down an inclined surface. They are all started at the same time and all roll without slipping and reach the bottom at the same instant. Which of the following must be true?

(A) They were all started at the same position on the slope.
(B) They were each started from different positions, with the hoop nearest the bottom and the sphere nearest the top.
(C) They were each started from different positions, with the sphere nearest the bottom and the hoop nearest the top.
(D) They were each started from different positions, with the cylinder nearest the bottom and the hoop nearest the top.
(E) They were each started from different positions, with the sphere nearest the bottom and the cylinder nearest the top.

12. Two identical beakers are filled to the same height with water, as shown in the figure. Beaker B has a plastic ball floating on the surface. Suppose each beaker is rests on a mass scale. How do the readings on the scales compare?

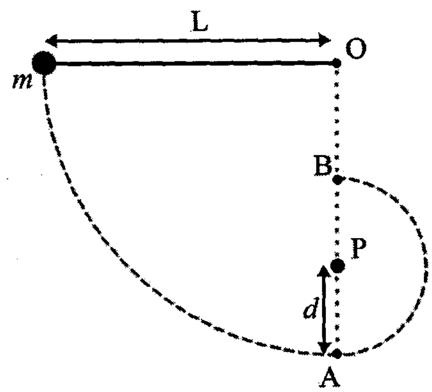


(A) Scale A displays a larger value than B
(B) Scale B displays a larger value than A
(C) Each scale shows the same value
(D) It depends on the mass of the ball
(E) It depends on the ratio of the densities of the ball and the water

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. **Each problem is worth 20 marks in total.**

1. A ball of mass m is connected to a massless string of length L that is fixed to point O. Initially the string is horizontal. The ball is released from rest and follows the dashed line circular path to point A. The length of the string remains constant. When the ball reaches point A, the string contacts a small cylinder at point P, and the ball follows the second dashed line circular path to point B. Point P is a distance d above point A. Points A, P, B, and O are aligned vertically, as shown. Air resistance is negligible.



Part A [4 marks] What is the speed of the ball at point A, v_A? Express your answer in terms of the variables given in the statement of the problem above.

$v_A =$

Part B [4 marks] What is the speed of the ball at point B, v_B? Express your answer in terms of the variables given in the statement of the problem above. Your answer should not include v_A.

$v_B =$

Part C [4 marks] From when the ball is released to when it reaches point B, what is the total work done on the ball by gravity? Express your answer in terms of the variables given in the statement of the problem above. Your answer should not include v_A or v_B.

$W =$

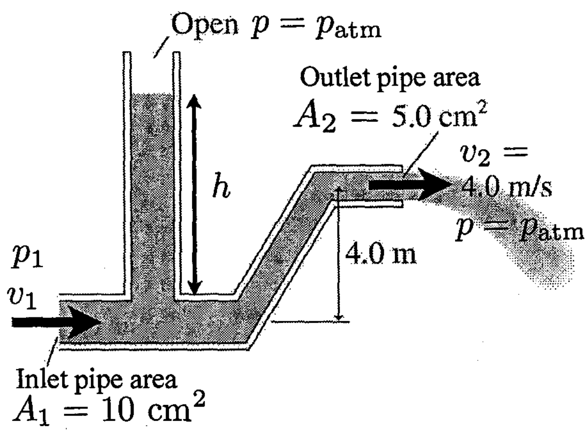
Part D [4 marks] What is the maximum value of d for which the ball will reach point B? Express your answer in terms of the variables given in the statement of the problem above. Your answer should not include v_A or v_B.

$d =$

Part E [4 marks] If air resistance were not negligible, would your answer to Part D be larger or smaller than what you answered? *Briefly* explain your reasoning.

2. Water flows from the righthand open end of the circular pipe system shown in the figure at $v_2 = 4.0\,\text{m/s}$. The right-hand open end has cross sectional area $A_2 = 5.0\,\text{cm}^2$. Meanwhile, the water in the vertical section whose top end is open does *not* flow, but simply maintains its level h. Water is entering the inlet, which has cross sectional area $A_1 = 10.\,\text{cm}^2$, at speed v_1. The pressures at the open ends are that of the atmosphere, p_{atm}, while the inlet pressure is p_1.

For parts A, B and C, assume the water is ideal, *i.e.* that it has no viscosity and contains no turbulence.



Part A [5 marks] Calculate the speed of the water entering the inlet v_1.

$v_1 =$

Part B [5 marks] Calculate the inlet pressure in excess of atmospheric $p_1 - p_{\text{atm}}$ necessary to maintain this flow.

$p_1 - p_{\text{atm}} =$

Part C [5 marks] Find the height h of the standing column of water. You may assume that the entire vertical column is hydrostatic.

$h =$

Part D [5 marks] Now suppose that the water, instead of being ideal, has viscosity η_{water} and all the usual properties of real water. Estimate the largest Reynolds number likely to be encountered in this flow and give a *very brief* qualitative description of the flow pattern in that region of the pipe.

Equations and Constants

Constants $g = 9.80\ \text{m/s}^2$ $\rho_{\text{air}} = 1.28\,\text{kg/m}^3$ $\eta_{\text{air}} = 2.00 \times 10^{-5}\ \text{Pa}\cdot\text{s}$
$\rho_{\text{water}} = 1.00 \times 10^3\,\text{kg/m}^3$ $\eta_{\text{water}} = 1.00 \times 10^{-3}\ \text{Pa}\cdot\text{s}$ 1 year = 365 days 1 kcal = 4186 J

Linear motion, kinematics

$$v_s = ds/dt \qquad a_s = dv_s/dt \qquad s_{\text{f}} = s_{\text{i}} + \int v_s dt \qquad v_{\text{f}} = v_{\text{i}} + \int a_s dt$$

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

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

$$\vec{\tau}_{\text{net}} = I\vec{\alpha} \qquad I_{\text{hoop}} = MR^2 \qquad I_{\text{disk}} = \frac{1}{2}MR^2 \qquad I_{\text{sphere}} = \frac{2}{5}MR^2$$

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

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

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

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

Fluid mechanics $p = p_0 + \rho g h$ $v_1 A_1 = v_2 A_2$ $p + \frac{1}{2}\rho v^2 + \rho g y = \text{const.}$

$$\text{Re}_{\text{pipe}} = \rho U d/\eta \qquad \text{Re}_{\text{sphere}} = \rho U R/\eta \qquad D_{\text{Stokes}} = 6\pi\eta R U \qquad D = C_D(\text{Re})\rho R^2 U^2$$

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

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

Error analysis

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

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

Rough Work (not marked)

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