Family Name, Given Name (please print) **Student Number** **Tutorial Leader's Name**

PHY293 – Oscillations

FALL 2014 Midterm Test

Duration: 1 hour.

Aids allowed: Only calculators from a list of approved calculators as issued by the Faculty Registrar are allowed.

Before starting, please print your name, tutorial group, and student number at the top of this page and at the top of the exam booklet. Please also put down relevant information (including your name and student number) in the multiple-choice answer sheet.

There are four questions in this mid-term, with two being standard question-and-answer (Q&A) questions and two being multiple-choice (MC) questions.

For MC questions, only the final answers will be marked by a machine.

For Q&A questions, partial credit will be given for partially correct answers. So, please show any intermediate calculations that you do and write down, in a clear fashion, any relevant assumptions you are making along the way.

POSSIBLY USEFUL EQUATIONS:

	Amplitude	Velocity	Power
Frequency	$\omega = \omega' = \omega_0\sqrt{1-1/(2Q^2)}$	$\omega = \omega_0$	$\omega = \omega_0$
Peak Value	$a_{\max} = \frac{a_0 Q}{\sqrt{1-\frac{1}{4Q^2}}}$	$v_{\max} = a_0\omega_0 Q$	$P_{\max} = \frac{1}{2}ma_0^2\omega_0^3 Q$
General	$a(\omega) = \frac{a_0\omega_0^2}{\sqrt{(\omega_0^2-\omega^2)^2+(\gamma\omega)^2}}$	$v(\omega) = \frac{a_0\omega_0^2}{\sqrt{(\omega_0^2-\omega^2)^2/\omega^2+\gamma^2}}$	$< P(\omega) >= P_{\max}\frac{\gamma^2}{(\omega_0^2-\omega^2)^2/\omega^2+\gamma^2}$
	$\tan\delta = \frac{\omega\gamma}{(\omega_0^2-\omega^2)}$		$< P >= P_{\max}\frac{\gamma^2/4}{(\omega_0-\omega)^2+\gamma^2/4} \quad Q \gg 1$

Do not separate the stapled sheets of the question paper. Hand in the question sheets together with your exam booklet at the end of the test.

Good luck!

1. (10 Marks) Consider a simple harmonic oscillator possibly with forcing and damping. Consider the following statements:
   I) If there is no forcing but there is light damping, the oscillator will always oscillate at the natural frequency $\omega_{0.}$
   II) With damping, if there is forcing with a driving frequency ω, the steady state solution of the oscillator will always oscillate at the driving frequency, ω.
   III) The quality factor, Q, is equal to $\frac{\Upsilon}{\omega_0}$ where ϒ is the damping coefficient and ω_0 is the natural frequency.

   A. Only statement I) is always true.
   B. Only statement II) is always true.
   C. Only statement III) is always true.
   D. Only statements I) and II) are always true.
   E. Only statements II) and III) are always true.

Please write down your answer to Question 1 in the **multiple-choice answer sheet** provided.

2. (10 marks) Consider an RLC circuit and the following statements:

   I) In the case of no forcing and no damping (i.e., the resistance, R, is zero), the system will exhibit a simple harmonic motion.
   II) The natural frequency is given by $\sqrt{\frac{C}{L}}$.
   III) With a driving voltage $V\ \cos(\omega t)$ at current resonance (i.e , ω=ω_0), the amplitude of the maximal current $I_{max} = \frac{V}{R}$ where V is the amplitude of the driving voltage and R is the resistance.

   A. Only statement I) is always true.
   B. Only statement III) is always true.
   C. Only statements I) and II) are always true.
   D. Only statements I) and III) are always true.
   E. Only statements I), II) and III) are always true.

Please write down your answer to Question 2 in the **multiple-choice answer sheet** provided.

3. (40 marks)
   A block of mass m is connected to a spring, the other end of which is fixed. The block is immersed in viscous damping medium. The following observations have been made of the system:

   I. If the block is pushed horizontally with a force of magnitude, mg, the spring length is reduced by h;

II. The viscous resistive force is equal to mg if the block moves with a certain speed: u.

(a) [8 marks] For this complete system (spring and mass in damping medium), in the absence of any driving force, write down the differential equation governing horizontal oscillations of the mass in terms of m, g, h and u .

Answer the following for the case $u = 4\sqrt{gh}$.

(b) [4 marks] What is the angular frequency of the damped oscillations?

(c) [8 marks] After what time, in multiples of $\sqrt{h/g}$, is the energy of the oscillator reduced by $1/e$?

(d) [8 marks] What is the quality factor, Q , of this oscillator?

(e) [12 marks] If the oscillator is driven with a force $mg\cos(\omega t)$, where $\omega = \sqrt{2g/h}$, what is the steady-state amplitude of the resulting oscillations of the mass?

4. (40 marks)

Two simple pendulums, each of length 0.300 m and mass 0.950 kg, are coupled by attaching a light horizontal spring of spring constant k = 3 N/m to the masses.

(a) [24 marks] Determine the frequencies of the two normal modes of this system of oscillators assuming small amplitudes of oscillation.

One of the pendulums is held a small distance away from its equilibrium position while the other pendulum is held at its equilibrium position. The two pendulums are then released simultaneously. As we saw in class the motion of the initially displaced pendulum eventually dies away and comes to rest (at least momentarily).

(b) [16 marks] Determine how long after the pendulums are released the initially displaced pendulum first comes to rest while hanging straight down.

The End