Given name:____________________ **Family name:**____________________

Student number:__________________ **Signature:**____________________

UNIVERSITY OF TORONTO
Faculty of Arts and Science

MAT 334 Y (Complex Variables)
Instructor: Yuri Burda

AUGUST 2011 EXAMINATIONS
August 18, 2011

Duration: 3 hours

No aids allowed

This examination paper consists of **??** pages and **??** questions. Please bring any discrepancy to the attention of an invigilator. The number in brackets at the start of each question is the number of points the question is worth.

Answer all questions.

To obtain credit, you must give arguments to support your answers.

1. Evaluate the following integrals:

   (a) [10]

$$\int_{-\infty}^{\infty} \frac{\cos(2011x)}{x^2+1}\, dx$$

   (b) [10]

$$\int_{-\pi}^{\pi} \frac{d\theta}{(5-4\cos\theta)^2}$$

2. (a) [10] Give an example of a Möbius transformation that maps the upper half-plane Im$z > 0$ to the unit disc $|z| < 1$.

(b) [10] Show that every function f analytic on the complex plane and satisfying $\operatorname{Im} f(z) > 0$ for all z is constant.

3. Evaluate the following expressions:

(a) [5]

$$\int \operatorname{Re} z \, dz$$

over the straight line segment from $z = 1 + i$ to $z = 2 + 2i$

(b) [5]

$$\int e^{\pi z} \, dz$$

over the curve $z(t) = t^2 - t + it$ for $0 \le t \le 1$

(c) [5]

$$\int \tan z \, dz$$

over the circle $|z - i| = 3$

(d) [5]

$$\lim_{r \to 0} \int_{C_r} \frac{dz}{\sin z}$$

where C_r is the semicircle $z(t) = re^{it}$ for $0 \leq t \leq \pi$ (hint: you can use Laurent series expansion of $1/\sin z$ around $z = 0$)

4. (a) [5] Find the number of zeroes of the function

$$f(z) = z^6 - iz^4 - z^3 - iz^2 - i - 10$$

in the upper half-plane $\operatorname{Im} z > 0$.

(b) [5] Find the number of zeroes of the function $f(z) = z^{2011} + 4z^4 - 2$ in the disc $|z| < 1$.

(c) [5] Find the order of the zero of the function

$$f(z) = (\cos z - 1)^2 (e^{iz} - 1)^3 \left(\frac{z - \pi}{z} \right)^4$$

at $z = 2\pi$

(d) [5] Give an example of a non-constant analytic function $f(z)$ such that the equation $f(z) = 0$ doesn't have any solutions.

5. For each of the following statements determine whether it is true or false and write a short explanation supporting your answer (a guess without an explanation will not be graded).

   (a) [4] The function $u(x, y) = e^x \sin y$ is harmonic

   (b) [4] The function $v(x, y) = e^x - e^x \cos y$ is a harmonic conjugate of $u(x, y) = e^x \sin y$ (i.e. $f(x + iy) = u(x, y) + iv(x, y)$ is analytic)

   (c) [3] There exists an analytic (one-valued) function on the complex plane whose square is equal to $e^z - 1$
   (hint: what could be its order of zero at $z = 0$?)

   (d) [3] There exists an analytic (one-valued) function on the complex plane whose square is equal to $\cos^2 z - 1$

   (e) [3] All values of $(-1)^i$ are real numbers

   (f) [3] There are real numbers among the values of 2^i

Total pages: ??