

MATH 265001

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Examination for the Module MATH 2650

(January 2013)

Calculus of Variations

Time allowed: 2 hours

Answer no more than four questions.
All questions carry equal marks.

1. (a) State and prove the Fundamental Lemma of the Calculus of Variations.

(b) The Euler-Lagrange equation for the integral

$$I = \int_{x_1}^{x_2} F(x, y(x), y'(x)) dx$$

takes the form

$$\frac{\partial F}{\partial y} - \frac{d}{dx} \left(\frac{\partial F}{\partial y'} \right) = 0.$$

Write down a first integral of the Euler-Lagrange equation when $F = F(x, y')$.
Derive the first integral (the Beltrami identity)

$$y' \frac{\partial F}{\partial y'} - F = C$$

(where C is an arbitrary constant) of the Euler-Lagrange equation in the case when $F = F(y, y')$.

(c) Find the functions $y(x)$ that are extrema of the following integrals, subject to the given end conditions:

(i) $I = \int_1^2 (x^2 y'^2 + 2y^2) dx$, $y(1) = 2$, $y(2) = 5$;

(ii) $I = \int_1^3 \left(y'^2 + \frac{y'}{x^2} \right) dx$, $y(1) = 1$, $y(3) = 4$;

(iii) $I = \int_0^2 (y'^2 + y^2) dx$, $y(0) = 0$, $y(1) = \sinh(1)$.

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