

Fall 1998

Physics 131: Midterm II
Professor Frank De Lucia

2:30 Section

Name (1 pt): De Lucia

Recitation Instructor (1 pt): De Lucia

This midterm consists of four pages of problems plus this cover page. It is important that you write your name on each page and the name of your recitation instructor on the first page. Each name is worth one point. Be sure to include the proper units in your answers.

$$v = v_0 + at$$

$$x - x_0 = v_0 t + \frac{1}{2} at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t$$

$$x - x_0 = vt - \frac{1}{2} at^2$$

$$F = ma$$

$$a = \frac{v^2}{r}$$

$$F = \frac{GMm}{r^2}$$

$$K = \frac{1}{2} mv^2$$

$$U_g = mgh$$

$$U_g = -\frac{GMm}{r}$$

$$U_s = \frac{1}{2} kx^2$$

$$f_{s,\max} = \mu_s N$$

$$f_k = \mu_k N$$

$$W = \dot{F} \cdot \dot{d}$$

$$F = -kx$$

$$P = \frac{dW}{dt}$$

$$P = \dot{F} \cdot \dot{v}$$

$$F(x) = -\frac{dU(x)}{dx}$$

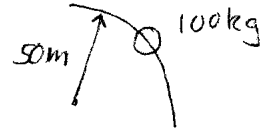
$$G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$$

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Section I – short problems

Problem I-1 (8 pts): A 100 kg student is riding in a car whose speed is 10 m/s as it goes around a curve in the road whose radius is 50 m. How much radial force must the car exert on the student so that the student does not move relative to the car?

$$F_r = -\frac{mv^2}{r} = -\frac{100\text{kg} \cdot (10\text{m/s})^2}{50\text{m}} = -200\text{N}$$



$$F = 200\text{N towards the center}$$

Problem I-2 (8 pts): A block of mass m has an initial velocity of 10 m/s on a flat horizontal surface. The coefficient of kinetic friction between the block and the surface is μ_k . If the block slides 20 m before stopping, what is the coefficient of kinetic friction?

$$F_k = \mu_k N = \mu_k mg$$

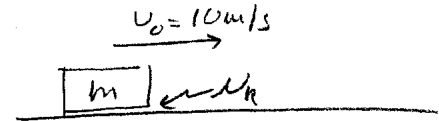
$$F_k = ma = \mu_k mg \Rightarrow a = \mu_k g$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

minus because F_k is in opposite direction of motion

$$0 = (10\text{m/s})^2 + 2(-\mu_k \cdot 9.8\text{m/s}^2)(20\text{m})$$

$$\mu_k = \frac{100}{2 \cdot 9.8 \cdot 20} = 0.255$$



Problem I-3 (9 pts): A car with a 100 hp engine (1 hp = 746 W) accelerates from a standing start. When the velocity of the car reaches 10 m/s, what is the force of friction which is accelerating the car?

$$P = Fv$$

$$F = \frac{P}{v} = \frac{(100\text{hp})(746\text{W}/\text{hp})}{10\text{m/s}} = 7460\text{N}$$

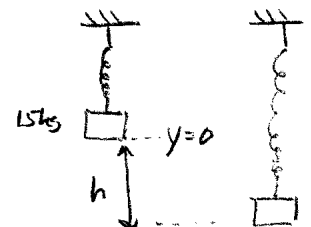
Problem I-4 (9 pts): A 15 kg mass is attached to a vertical spring of force constant 300 N/m. If the mass is released from the equilibrium position of the spring, how far does it fall before the force of the spring stops it?

$$E_i = 0$$

$$E_f = -mgh + \frac{1}{2}kh^2$$

$$E_i = E_f \Rightarrow mgh = \frac{1}{2}kh^2$$

$$h = \frac{2mg}{k} = \frac{2 \cdot 15\text{kg} \cdot 9.8\text{m/s}^2}{300\text{N/m}} = .98\text{m}$$



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Section II - Problems (20 points each)

Problem II-1: An 1000 kg elevator starts from rest, accelerates to a speed of 2 m/s (upward), travels at a constant speed for 15 seconds, and then decelerates and comes to a stop 50 m above its starting point.

- (a) How much work is done on the elevator by the tension in the cable during the entire process?
(b) How much work is done on the elevator by the tension in the cable during the 15 seconds of motion at constant velocity?

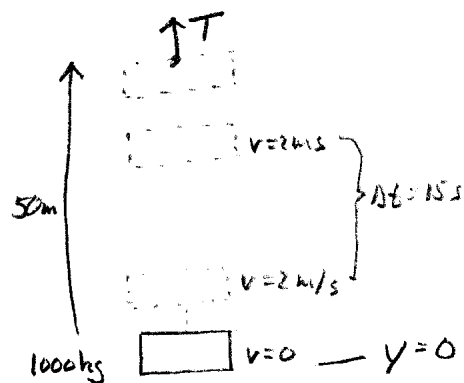
$$a) E_i = K_i + U_{g,i} = 0 + 0 = 0$$

$$E_f = K_f + U_{g,f} = 0 + mgh \quad (h=50m)$$

$$E_f = E_i + W$$

$$\Downarrow$$
$$mgh = W = 1000 \text{ kg} \cdot 9.8 \cdot 50 \text{ m}$$

$$\boxed{W = 490000 \text{ J}}$$



b) during 15 sec, elevator has a constant speed of 2 m/s

\Rightarrow it goes 30 m

\Rightarrow the kinetic energy does not change

$$E_i = K_i + U_i = K_i + 0$$

$$E_f = K_f + U_f = K_f + mgh \quad (h=30m)$$

$$E_f = E_i + W$$

\Downarrow

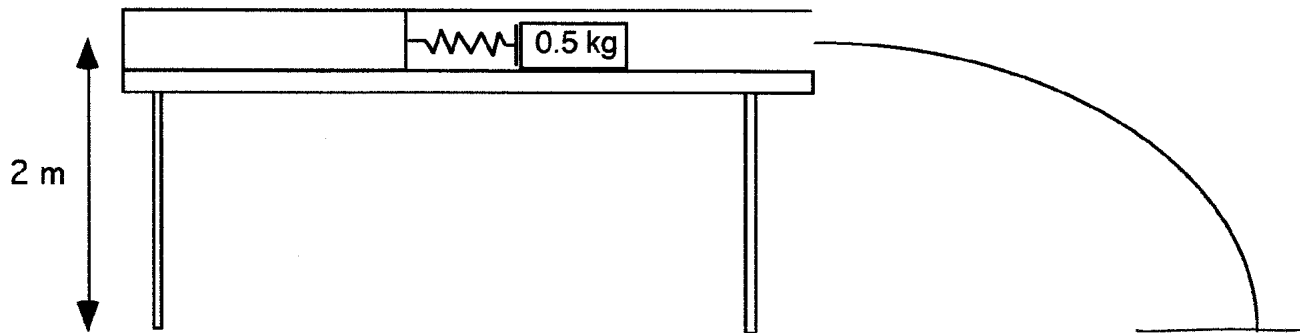
$$\cancel{K_f} + mgh = \cancel{K_i} + W$$

$$W = (1000 \text{ kg})(9.8 \text{ m/s}^2)(30 \text{ m})$$

$$\boxed{W = 294000 \text{ J}}$$

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Problem II-2: A frictionless spring-loaded gun sits atop a table as shown in the figure. If the force constant of the spring is 1500 N/m, the spring is compressed 0.1 m, the mass of the bullet is 0.5 kg, and the table is 2 m high, what is the speed of the mass when it hits the floor?



$$E_i = K_i + U_{si} + U_{gi}$$
$$= 0 + \frac{1}{2} kx^2 + mgh$$

$$E_f = K_f + U_{sf} + U_{gf}$$
$$= \frac{1}{2} mv^2 + 0 + 0$$

$$E_i = E_f \Rightarrow \frac{1}{2} kx^2 + mgh = \frac{1}{2} mv^2$$

$$\left(\frac{1}{2}\right)(1500 \text{ N/m})(0.1 \text{ m})^2 + (0.5 \text{ kg})(9.8 \text{ m/s}^2)(2 \text{ m}) = \frac{1}{2}(0.5 \text{ kg})$$

$$7.5 \text{ J} + 9.8 \text{ J} = .25 \text{ kg } v^2$$

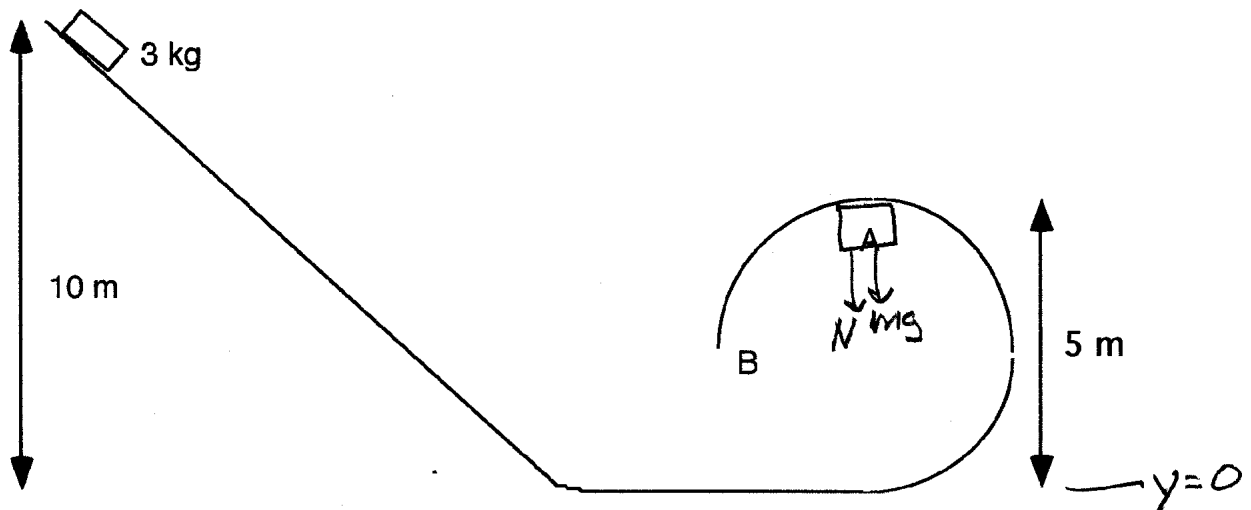
$$17.3 \text{ J} = .25 \text{ kg } v^2$$

$$v^2 = 69.2 \text{ m}^2/\text{s}^2$$

$$v = 8.3 \text{ m/s}$$

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Problem II-3: A block of mass 3 kg starts at the top of an inclined track which is 10 m high and slides without friction down the incline and around the inside of the 3/4 circle track shown in the figure.



- (a) With what speed does the block leave the track (point B)?
 (b) What force is exerted on the block at the top of the circle (point A) by the track?

$$a) E_i = K_i + U_{g_i} = 0 + mgh = 3 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot 10 \text{ m} = 294 \text{ J}$$

$$E_f = K_f + U_{g_f} = \frac{1}{2}mv^2 + mgh = \frac{1}{2}mv^2 + 3 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot 2.5 \text{ m} \\ = \frac{1}{2}mv^2 + 73.5 \text{ J}$$

$$E_i = E_f \Rightarrow 294 \text{ J} = 73.5 \text{ J} + \frac{1}{2} \cdot 3 \text{ kg} v^2$$

$$\frac{220.5 \text{ J}}{1.5 \text{ kg}} = v^2 \Rightarrow \boxed{v_B = 12.1 \text{ m/s}}$$

Point B is
2.5 m above
y=0

b) Likewise conserve energy to get velocity at "A"

$$294 \text{ J} = 147 \text{ J} + \frac{1}{2} \cdot 3 \text{ kg} v^2 \Rightarrow \boxed{v_A = 9.9 \text{ m/s}}$$

$$N + mg = \frac{mv^2}{r}$$

$$N = \frac{mv^2}{r} - mg = \frac{3 \text{ kg} \cdot 9.8 \text{ m/s}^2}{2.5 \text{ m}} - 3 \text{ kg} \cdot 9.8 \text{ m/s}^2 = 117.6 \text{ N} - 29.$$

$$\boxed{N = 88.2 \text{ N}}$$