# OPEN UNIVERSITY OF SRI LANKA

## B Sc Degree Programme - Level 03 -2009/2010

## General and Thermal Physics - PYU 1160

### ASSIGNMENT

Answer ALL questions.

**Deadline:** **12th October 2009**

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1. (a) State the conditions under which the work done by a force is (i) zero (ii) positive and (iii) negative.

   (b) Consider a motion of a body on an inclined flat surface where the other forces ($\overline{F}_{\text{other}}$) like frictions acts on the body in addition to its weight. If $W_{\text{other}}$ is the additional work caused by the other forces, $\overline{F}_{\text{other}}$, obtain the relation between the change in kinetic energy, $\Delta k$, change in potential energy, $\Delta U$, and the additional work $W_{\text{other}}$.

   (c) [redacted]kg microwave oven is pushed 8.00 m up the sloping surface of a loading ramp inclined at an angle $36.9^0$ above the horizontal, by a constant force $\overline{F}$ with a magnitude 110 N and acting parallel to the ramp. The coefficient of kinetic friction between the oven and the ramp is 0.250

   (i) What is the work done on the oven by the force $\overline{F}$?

   (ii) What is the work done on the oven by the friction force?

   (iii) Compute the increase in potential energy for the oven.

   (iv) Use yours answers to part (i), (ii) and (iii) to calculate the increase in the oven's kinetics energy.

   (v) Use $\sum \overline{F} = m\bar{a}$ to calculate the acceleration of the oven.

   (vi) Assuming that the oven is initially at rest, use the acceleration obtain in (v) to calculate the oven's speed after traveling 8.00 m. From this, compute the increase in the oven's kinetic energy, and compare it to the answer you got in part (iv).

2. (a) State what is meant by *gravitational field strength* at a point in a gravitational field and state whether it is a scalar or vector quantity.

(b) (i) Show that the gravitational field strength of the Earth at height $h$ above the surface is given by $g = g_s\left(\frac{R}{R+h}\right)^2$, where $g_s$ is the gravitational field strength at the surface and $R$ is the radius of the Earth.

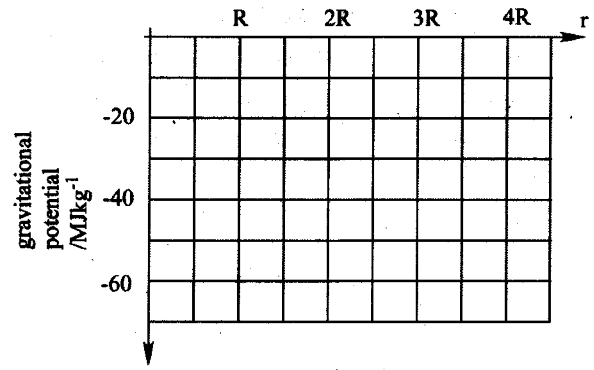
(ii) Calculate the gravitational field strength of the Earth at a height of 200 $km$ above its surface. Gravitational constant $G = 6.67 \times 10^{-11}\ Nm^{-2}kg^{-2}$, mass of the Earth $= 6.00 \times 10^{24}\ kg$ and radius of the Earth $= 6.40 \times 10^{6}\ m$.

(c) A satellite of mass $2.5 \times 10^{3}\ kg$ is to be moved from the surface of the Earth to an orbit of radius $1.6 \times 10^{7}\ m$ around the Earth.

(i) Calculate the gravitational force acting on the satellite when it orbit.

(ii) Given that the gravitational potential at the surface of the Earth (due to the Earth) is $-63\ MJkg^{-1}$, calculate the increase in the gravitational potential energy of the satellite when it placed in the orbit.

(d) Draw a graph on the axes below to show how the gravitational potential due to the Earth varies with distance, $r$, measured from the centre of the Earth, for points outside the Earth. On the horizontal axis, $R$ is the radius of the Earth.



3. ($\alpha$) Figure 1 shows a remote-control camera used in space for inspecting space stations. The camera can be moved into position and rotated by firing 'thrusters' which ejected xenon gas at high speed. The camera is spherical with a diameter of 0.34 m.

In use, the camera develops a spin about it axis of rotation. In order to bring it to rest, the thrusters on opposite ends of a diameter are fired, as shown in the figure.

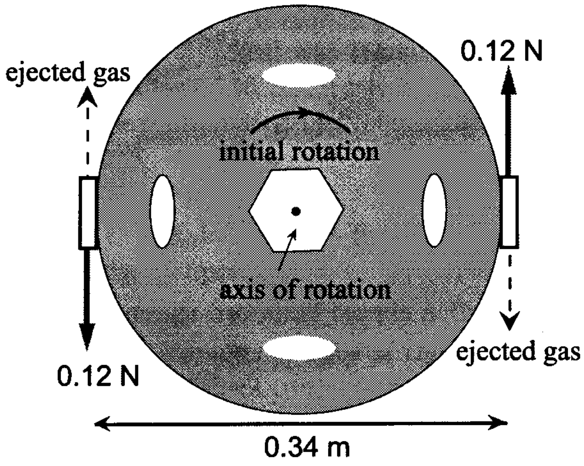



Figure 1:

(a) When fired, each thruster provides a constant force of 0.12 N.

(i) Calculate the torque on the camera provided by the thrusters.

(ii) The moment of inertia of the camera about its axis of rotation is 0.17 $\mathrm{kgm}^{-2}$. Calculate the angular deceleration of the camera whilst the thrusters are firing.

(b) The initial rotational speed of the camera is 0.92 rad $\mathrm{s}^{-1}$. Calculate

(i) the time for which the thrusters have to be fired to bring the camera to rest.

(ii) the angle turned through by the camera whilst the thrusters are firing. Express your answer in degrees.

($\beta$) A flywheel store energy very efficiently and are being considered as an alternative to battery power.

(a) A flywheel for an energy storage system has a moment of inertia of 0.60 $kgm^{-2}$ and a maximum safe angular speed of 22000 rev $min^{-1}$. Calculate

(i) the angular speed in rad $s^{-1}$.

(ii) the energy stored in the flywheel when rotating at its maximum safe speed.

(b) In a test the flywheel was taken up to maximum safe speed and then allowed to run freely until it came to rest. The average power dissipated in overcoming friction was 8.7 W.

Calculate

(i) the time taken for the flywheel to come to rest from its maximum speed.

(ii) the average frictional torque acting on the flywheel.

(c) The energy storage capacity of the flywheel can be improved by adding solid discs to the flywheel as shown in cross-section in **A** in Figure 2, or by adding a hoop or tyre to the rim of the flywheel as shown in **B** in Figure 2. The same mass of material is added in each case. State, with reasons, which arrangement stores the more energy when rotating at a given angular speed.

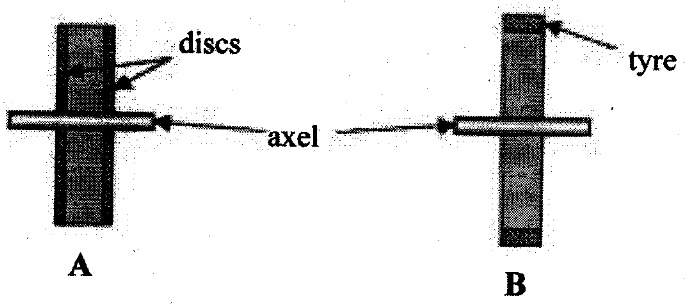



Figure 2:

4. Rockets are propelled by the ejection of the products of the combustion of fuel. Consider a rocket of total mass $m_1$ to be travelling at speed $v_1$ in region of space where gravitational forces are negligible. Suppose that the combustion products are ejected at a constant speed $v_r$ relative to the rocket. Show that a fuel 'burn' which reduces the total mass of the rocket to $m_2$ results in an increase in the speed of the rocket to $v_2$, such that

$$v_2 - v_1 = v_r \ln \frac{m_1}{m_2}.$$

A Rocket at rest in space, where there is virtually no gravitational force, has a mass of $2.55 \times 10^5$ kg, of which $1.81 \times 10^5$ kg, is fuel. The engine consumes fuel at the rate of 480 kg $s^{-1}$, and the exhaust speed is 3.27 km $s^{-1}$. The engine is fired for 250 s.

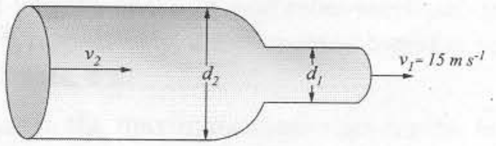
(a) Find the thrust of the rocket engine.

(b) What is the mass of the rocket after the engine burn?

(c) What is the final speed attained?

5. (a) Derive Bernoulli's theorem for an incompressible fluid explaining any assumption you make. Explain the significance of the energy terms incorporated in it.

(b) Water flows through a horizontal pipe and is delivered into the atmosphere at a speed of 15 m $s^{-1}$ as shown in the figure. The diameters of the left and right sections of the pipe are 5.0 cm and 3.0 cm, respectively.




(i) What volume of water is delivered into the atmosphere during a 10 min period?

(ii) What is the flow speed of the water in the left section of the pipe?

(iii) What is the gauge pressure in the left section of the pipe?

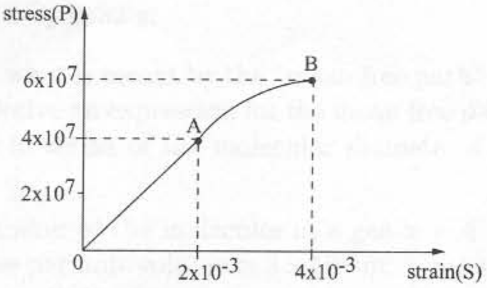
6. (a) Explain the terms stress and strain.

(b) Define the Young modulus and state its units .

(c) Describe how would you make an accurate determination of Young's modulus of a metal in the form of wire.

(d) Why are stresses and strains rather than forces and extensions generally considered when describing the deformation behaviour of solids?

(e) Figure shows the stress(P) - strain (S) curve obtained for a material for all possible stress values.




(i) Identify the points A and B on the curve.

(ii) Calculate the Young's modulus of the material. What is the energy stored per unit volume when the strain in the material is $2 \times 10^{-3}$

(f) Two uniform wires, made out of materials mentioned in part (e), of equal lengths of 0.5 m and cross-sectional are of 0.5 $cm^{-2}$ and 0.2 $cm^{-2}$, respectively, are connected together to form a compound wire of length 1 m.

(i) What is the maximum mass that can be hunged by the compound wire so that the proportional limit is not exceeded?

(ii) Calculate the total elongation of the compound wire in the above situation?

(iii) If the two wires are joined at the end so they are parallel to each other and forms a compound wire of length 0.5 m, what is the maximum mass that can be hunged by the compound wire so that the proportional limit is not exceeded?

7. (a) Distinguish between adiabatic and isothermal changes. Show for a perfect gas undergoing an adiabatic change, $PV^\gamma$ = constant. Where $P$ and $V$ have their usual meanings and $\gamma$ is the ratio of the specific heat capacities of the gas.

   (b) A monatomic gas, initially at atmospheric pressure, expands to four times its original volume (i) isothermally (ii) adiabatically. What is the final pressure of the gas in each case? $\gamma = \frac{C_P}{C_V} = \frac{5}{3}$.

   (c) 8 g of $O_2$ is taken at $27^0$C. They are adiabatically compressed to half of the original volume. Calculate the resulting temperature and the work done. $\gamma = 1.4$, $R = 8.31$J mole$^{-1}$ K$^{-1}$, Molecular weight of $O_2$ is 32 g.

8. (a) Explain what is meant by the "mean free path" of the molecules of a gas. Derive an expression for the mean free path of the molecules of a gas in terms of the molecular diameter $d$ and the Loschmid number $n$.

   (b) The diameter of the molecules in a gas is 2 $\AA$ and the number of molecules per unit volume is $3 \times 10^{25} m^{-3}$, calculate the mean free path, the collision frequency and the number of collisions per unit length. Average speed of molecules is 752 ms$^{-1}$.

Dr. J C N Rajendra
May 2009