APPLIED MECHANICS

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets.

1. TWO masses initially at rest are connected by a cable, running parallel to their respective surfaces, which is guided by a pulley as shown in Fig Q1. Mass A is 60 kg, mass B is 80 kg and the pulley is 15 kg, has a diameter of 1.6 m, a radius of gyration of 0.6 m and turns against a constant bearing friction of 20 Nm.

The coefficient of friction for mass A is 0.2 and the coefficient of friction for mass B is 0.25.

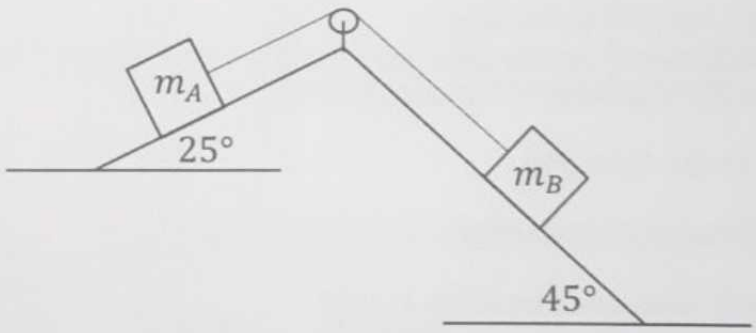

Fig Q1

Calculate the angular acceleration of the pulley. (16)

2. A windlass, supported in frictionless bearings A and B, holds a 200 N weight stationary as shown in Fig Q2.

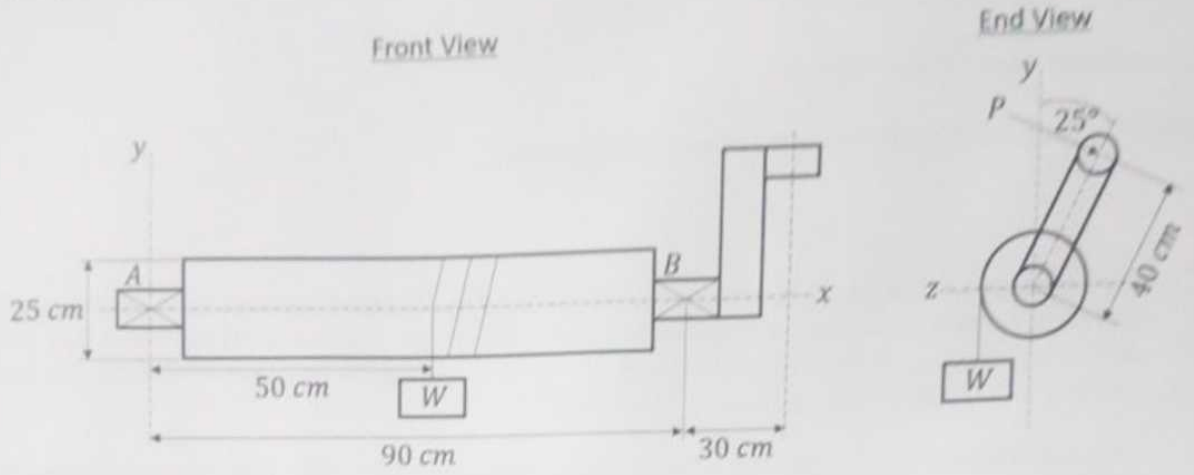

Fig Q2

Equilibrium is maintained by the force labelled P which is applied perpendicular to the crank positioned 25° clockwise of top dead centre.

Calculate EACH of the following:

(a) the vertical reaction at bearings A and B; (10)

(b) the horizontal reaction at bearings A and B. (6)

3. A projectile is fired out to sea with an initial velocity of 60 m/s at an angle of 30° above the horizontal from a cliff top 100 m above sea level.

Calculate EACH of the following:

(a) the linear displacement from launch site to impact; (14)

(b) the vertical velocity just before impact. (2)

4. The tension in a flat belt pulley system is 100 N when stationary. The drive wheel is 225 mm diameter and rotates at a constant speed of 1800 rpm whilst in operation with a 225° angle of lap. The power output is 1.8 kW.

Using the relationship:

$$\frac{F_1}{F_2} = e^{\mu\theta}$$

where: F_1 = force in the tight side of the belt.
F_2 = force in the slack side of the belt.
μ = the coefficient of friction.
θ = the angle of lap in radians.

Calculate the minimum coefficient of friction when no slipping occurs. (16)

5. A winch drum has a mass of 800 kg and a radius of gyration of 600 mm. The winch has a single brake shoe acting on a brake drum of diameter 1.2 m. The coefficient of friction between the shoe and the drum is 0.8. Friction in the winch bearings is constant at 10 Nm.

Calculate EACH of the following:

(a) the normal force to be applied to the brake shoe to slow the winch down from 320 rev/min to 100 rev/min in 30 seconds; (10)

(b) the work done by the brake during this process. (6)

6. A FOUR-stroke single cylinder engine produces 750 kW at 720 RPM with an energy fluctuation of 20% of the work done per cycle. A flywheel is to be fitted in order to stabilise the speed for power generation such that the frequency is 60 ± 0.2 Hz.

Calculate the diameter of a solid flywheel that is 350 mm thick. (16)

Note: Density of the flywheel material = 7800 kg/m³

7. Block A is connected to block B by a cable that runs on a pulley system comprised of TWO identical massless, frictionless pulleys as shown in Fig Q7.

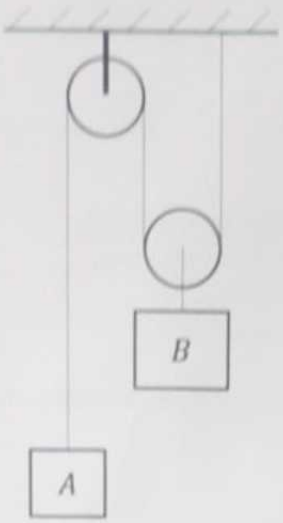

Fig Q7

Block A has a mass of 2.8 kg and is initially at rest whilst block B has a mass of 6 kg.

Calculate EACH of the following:

(a) the cable tension once the system is released; (14)

(b) the vertical displacement of block B for it to attain a velocity of 0.75 m/s. (2)

8. A winding drum is driven through 85% efficient 1:1 gearing by a solid square section shaft with a length of side x. The shaft rotates at 150 rpm whilst lifting a 20 tonne mass at a constant velocity of 0.25 m/s and the angle of twist within the shaft is 1° for its overall length of 30x.

Calculate the minimum dimension for the length of side x. (16)

Note: Modulus of Rigidity for the shaft material = 80 GN/m²
Polar 2nd moment of area for solid square cross section = $\frac{x^4}{6}$

9. A solid alloy shaft of 50mm diameter is concentrically friction welded to the end of a hollow steel shaft of the same external diameter. The shear stress in the alloy shaft and the steel shaft are limited to 50 MN/m^2 and 75 MN/m^2 respectively.

Calculate EACH of the following:

(a) the internal diameter of the steel shaft if the angle of twist per unit length is to be 75% of that of the alloy shaft; (10)

(b) the maximum torque that can be transmitted by the composite shaft. (6)

Note: Modulus of Rigidity for the steel is 2.2 times greater than that of the alloy