1. (a) A car of total mass 1200 kg is travelling at a constant speed of 20 ms^{-1} down a sloping road inclined at $10°$ to the horizontal. The engine of the car is producing a power of 112.5 kW. What is the resistive force experienced by the car (from air resistance and friction on the road) during the motion? You may assume the resistive force to be constant.

[3 marks]

1. (b) While travelling down the slope at 20 ms^{-1}, the driver suddenly sees an obstacle at a distance 40 m directly in front of the car. He immediately stops the engine of the car and then steps hard on the brake in an attempt to stop the car. Assuming that the reaction time of the driver is 0.5 s, what is the minimum force that the brake must exert on the car to avoid collision with the obstacle? Take the resistive force calculated in part 1(a) to remain constant.

[4 marks]

1. (c) Suppose the braking force on the car is only 95% of the minimum value found in part 1(b). What is the impulse experienced by the car during the impact?

[3 marks]

1. Car on a Sloping Road

(a) Resistive Force

When the car moves at a constant speed, the net force is zero. Let the direction down the slope be positive. The forces along the slope are the driving force (F_{engine}), the component of gravity ($mg\sin(\theta)$), and the resistive force ($F_{\text{resistive}}$). The equation is:

$$F_{\text{engine}} + mg\sin(\theta) - F_{\text{resistive}} = 0$$

The driving force is calculated from the power ($P = 112.5\,\text{kW}$) and speed ($v = 20\,\text{m/s}$):

$$F_{\text{engine}} = \frac{P}{v} = \frac{112500\,\text{W}}{20\,\text{m/s}} = 5625\,\text{N}$$

The gravitational component is:

$$F_g = mg\sin(10^\circ) = (1200\,\text{kg})(9.81\,\text{m/s}^2)\sin(10^\circ) \approx 2043.6\,\text{N}$$

Solving for the resistive force:

$$F_{\text{resistive}} = F_{\text{engine}} + F_g = 5625\,\text{N} + 2043.6\,\text{N} = 7668.6\,\text{N} \approx \mathbf{7670}\,\text{N}$$

(b) Minimum Braking Force

The total stopping distance is 40 m. The process has two stages:

1. **Reaction Time:** Distance covered in $t_{\text{reaction}} = 0.5\,\text{s}$ is $d_{\text{reaction}} = v \times t_{\text{reaction}} = 20 \times 0.5 = 10\,\text{m}$.
2. **Braking:** Remaining distance is $d_{\text{braking}} = 40\,\text{m} - 10\,\text{m} = 30\,\text{m}$.

The required acceleration to stop in 30 m is found using $v_f^2 = v_i^2 + 2ad$:

$$0^2 = (20)^2 + 2a(30) \implies a = -\frac{400}{60} = -\frac{20}{3} \approx -6.67\,\text{m/s}^2$$

Applying Newton's Second Law during braking (engine is off):

$$F_{\text{net}} = mg\sin(10^\circ) - F_{\text{resistive}} - F_{\text{brake}} = ma$$

$$F_{\text{brake}} = mg\sin(10^\circ) - F_{\text{resistive}} - ma$$

$$F_{\text{brake}} = 2043.6 - 7668.6 - (1200)(-\frac{20}{3}) = -5625 + 8000 = \mathbf{2375}\,\text{N}$$

(c) Impulse During Impact

The new braking force is $F'_{\text{brake}} = 0.95 \times 2375\,\text{N} = 2256.25\,\text{N}$. The new acceleration is:

$$a' = \frac{mg\sin(10^\circ) - F_{\text{resistive}} - F'_{\text{brake}}}{m} = \frac{2043.6 - 7668.6 - 2256.25}{1200} \approx -6.568\,\text{m/s}^2$$

The speed just before impact after traveling 30 m is:

$$v_{\text{impact}}^2 = v_i^2 + 2a'd = (20)^2 + 2(-6.568)(30) = 5.92 \implies v_{\text{impact}} \approx 2.43\,\text{m/s}$$

The impulse (J) is the change in momentum. Assuming the car stops after impact ($v_{\text{final}} = 0$):

$$J = \Delta p = mv_{\text{final}} - mv_{\text{impact}} = 0 - (1200\,\text{kg})(2.43\,\text{m/s}) = -2916\,\text{Ns}$$

The magnitude of the impulse is **2920** Ns.