PHYS1001/PHYS1901 Mid-Semester Test SAMPLE SOLUTIONS

Question 1 **[Total: 4 marks]**

(a) Estimate dimensions of door:

- height 2 m, width $1\ \mathrm{m} \Rightarrow$ area $A =$ (2 m)(1 m) = 2 m^2.
- acceptable answers (1.5 to 3) m^2.

(2 marks)

(b)
- Amount of paint $V = (A/10)\ \mathrm{L} = (2/10)\ \mathrm{L} = 0.2\ \mathrm{L}$.
- acceptable answers (0.15 to 0.3 L)

(2 marks)

Question 2 **[Total: 4 marks]**

(a) This value has 2 significant figures. Note that it is ambiguous; if you wanted to specify $1200\ \mathrm{N}$ to four significant figures, you would need to write it as

$$W = 1.200 \times 10^3\ \mathrm{N}$$

(2 marks)

(b) Convert the dimensions to SI units: $1\ \mathrm{mm} = 10^{-3}\ \mathrm{m}$, so the area A is

$$A = 2.10 \times 10^{-1} \times 2.97 \times 10^{-1}\ \mathrm{m}^2 = 6.237 \times 10^{-2}\ \mathrm{m}^2$$

Surface density is mass per unit area:

$$\frac{m}{A} = 8.0 \times 10^1\ \mathrm{g.m}^{-2}$$

Hence

$$m = (8.0 \times 10^1)(6.237 \times 10^{-2})\ \mathrm{g} = 4.9895\ \mathrm{g}$$

which should thus be written

$$m = 5.0\ \mathrm{g}(2\ \mathrm{sf})$$

(2 marks)

Question 3 **[Total: 4 marks]**

Values:

$$W = 650 \text{ N}$$
$$\Delta W = 35 \text{ N}$$
$$A = 0.3 \text{ m}^2$$
$$\Delta A = 0.1 \text{ m}^2$$

(a) Pressure is force/area, so

$$P = \frac{W}{A} = \frac{650}{0.3} = 2166.667 \text{ Pa} \quad (\text{or N.m}^{-2})$$

(b) Uncertainty on P:

$$\frac{\Delta P}{P} = \frac{\Delta W}{W} + \frac{\Delta A}{A} = \frac{35}{650} + \frac{0.1}{0.3} = 0.054 + 0.333 = 0.387$$

so

$$\Delta P = 0.387 \times 2166.667 = 839 \text{ Pa} \approx 800 \text{ Pa}$$

(c) The pressure should be reported as

$$2200 \pm 800 \text{ Pa}$$

or (better)

$$(2.2 \pm 0.8) \times 10^3 \text{ Pa}$$

(4 marks)

Question 4 **[Total: 4 marks]**

Values: convert diameter to radius, and units to SI:

$$\begin{aligned} r &= 1.27 \times 10^{-2}\ \mathrm{m} \\ \Delta r &= 0.03 \times 10^{-2}\ \mathrm{m} \\ h &= 9.00 \times 10^{-2}\ \mathrm{m} \\ \Delta h &= 0.06 \times 10^{-2}\ \mathrm{m} \\ M &= 0.490\ \mathrm{kg} \\ \Delta M/M &= 0.01 \end{aligned}$$

(a) Density is

$$\rho = \frac{M}{V} = \frac{0.490}{\pi(1.27 \times 10^{-2})^2(9.00 \times 10^{-2}} = \frac{0.490}{4.56 \times 10^{-5}} = 1.0745 \times 10^4\ \mathrm{kg.m^{-3}}$$

(b)
- Fractional uncertainty in the mass: $\Delta M/M = 0.01$
- Fractional uncertainty in the radius: $\Delta r/r = 0.024$
- Fractional uncertainty in the height: $\Delta h/h = 0.007$
- Fractional uncertainty in the volume: $\Delta V/V = 2(\Delta r/r) + (\Delta h/h) = 0.055$
- Fractional uncertainty in the density: $\Delta\rho/\rho = (\Delta V/V) + (\Delta M/M) = 0.065$
- Uncertainty in the density: $\Delta\rho = \rho \times (\Delta\rho/\rho) = 0.065 \times 1.075 \times 10^4 = 698 \approx 700\ \mathrm{kg.m^{-3}}$

(c) Hence the density should be reported as

$$\rho = (1.07 \pm 0.07) \times 10^4\ \mathrm{kg.m^{-3}}$$

or

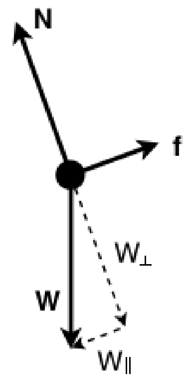
$$\rho = (10.7 \pm 0.7) \times 10^3\ \mathrm{kg.m^{-3}}$$

(d) This value is consistent with the density of silver and the density of lead.

(4 marks)

Question 5 **[Total: 5 marks]**

(a) Free-body diagram for the egg:



(dotted lines show resolved components of the weight force for part (b))

(b) Resolve the weight force into components:

$$\text{perpendicular to pan}: \quad W_\perp = W\cos\theta$$
$$\text{parallel to pan}: \quad W_\parallel = W\sin\theta$$

When the egg is just about to slip, there is no force in either direction, so

$$\text{perpendicular to pan}: \quad N - W_\perp = 0$$
$$\text{parallel to pan}: \quad f = W_\parallel = 0$$

From the perpendicular equation,

$$N - W\cos\theta = 0 \qquad \text{so} \qquad \cos\theta = \frac{N}{W}$$

From the parallel equation,

$$\mu_s N - W\sin\theta = 0 \qquad \text{so} \qquad \sin\theta = \frac{\mu_s N}{W}$$

Now

$$\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{\mu_s N}{W} \times \frac{W}{N} = \mu_s = 0.04$$

Hence

$$\theta = \tan^{-1}(0.04) = 2.3^\circ$$

(5 marks)

Question 6 **[Total: 5 marks]**

(a) The puck which has the greater acceleration will have the higher average velocity and hence reach the finish line first. Since the pucks are subjected to the same force but have different masses, the less massive puck will have the greatest acceleration and will finish first.

(b) By Newton's second law, change in momentum equals the impulse acting. Impulse is force $\times$ time. Since the larger mass takes a longer time to reach the finish line and the force is the same for both, then the impulse is greater for the larger mass and so the momentum gained by the larger mass is greater.

As equal forces have moved through equal distances, the same amount of work has been done and the same amount of kinetic energy gained (Work-energy theorem):

$$(KE)_{4m} = (KE)_m$$

(5 marks)

Question 7 **[Total: 10 marks]**

(a) The stuntman (mass m_1) converts his potential energy $PE = m_1gh$ into kinetic energy $KE = \frac{1}{2}m_1v^2$. By conservation of energy these must be equal. Thus his velocity at collision is given by:

$$v = \sqrt{2gh} = \sqrt{(2)(9.8)(5.0)} = 9.90 \text{ m.s}^{-1}$$

In the collision with the villain (mass m_2), momentum must be conserved, they stick together and their final velocity is given by:

$$m_1v = (m_1 + m_2)v_f$$

This gives

$$v_f = \frac{m_1\sqrt{2gh}}{m_1 + m_2} = \frac{80\sqrt{(2)(9.8)(5.0)}}{70 + 80} = 5.28 \text{ m.s}^{-1}$$

(b) After they collide and stick together their weight exert a normal force on the floor of $F_N = (m_1 + m_2)g$ and there is an equal contact force to balance.

The frictional force will then be

$$F_f = \mu_k F_N = \mu_k(m_1 + m_2)g$$

acting to oppose the motion. This produces an acceleration of

$$a = -\mu_k g$$

to bring the motion to a stop.

We can use the usual equation relating the velocity of an object with constant acceleration and the distance travelled:

$$v_2^2 = v_1^2 + 2as$$

Taking $v_1 = v_f$ and $v_2 = 0$ we get

$$s = \frac{v_f^2}{2\mu_k g} = \frac{(5.28)^2}{(2)(0.205)(9.80)} = 6.94 \text{ m}$$

(10 marks)