1 **A**

2 **D** Option A: The mass of a typical car is about 1500 kg. The volume of a typical car is about 3.0m×0.7m×1.5m (lower part) + 2.0m×0.7m×1.5m (upper part) ≈ 5 m^3. So, the density of a car is about 300 kg m^{-3}.
Option B: Typical A4 paper is labelled as 80 gsm (or grams per square metre). So an A4 paper of dimension 210 mm × 297 mm has a mass of 80gm^{-2}×0.210m×0.297m = 5 g. Or, a pack of 500 sheets of A4 paper weighs about 2 kg. Hence, each sheet is about 4 g.
Option C: A safe lifting speed is about 1 m s^{-1}. So, the useful power is about $mgv \approx 10^3 \times 10 \times 1 = 10^4$ W.
Option D: Volume of a classroom is about 10×10×3=300 m^3. Room temperature is about 27 degrees = 300 K. One atmospheric pressure is about 10^5 Pascal. Hence, $n = pV/RT = (10^5 \times 300)/(8.31 \times 288) \approx 10^5$ moles.

3 **A** Only in region A does the speed change, i.e. there is acceleration.
In regions B, C and D, the velocities are constant, i.e. there is no acceleration.

4 **D** $u_y = 3.5\sin 20^\circ + 10\sin 5.0^\circ = 2.0686 \text{ m s}^{-1}$

Taking upward displacement as positive,

$$s_y = u_y t + \frac{1}{2}a_y t^2$$

$$-300 = 2.0686t - \frac{1}{2}(9.81)t^2$$

$$t = 8.03 \text{ s} \quad , \quad t = -7.61 \text{ s (N.A.)}$$

5 **B** Area under a - t graph $= \Delta v = \frac{1}{2}(1+3)(2x) - \frac{1}{2}(2)(x) = 3x$

$$\Delta p = m\Delta v$$

$$30 = (2.0)(3x)$$

$$x = 5.0$$

6 **D** By applying conservation of momentum and conservation of kinetic energy to an elastic collision, one would arrive at the conclusion that the relative speed of approach is equal to the relative speed of separation. Refer to notes for derivation.

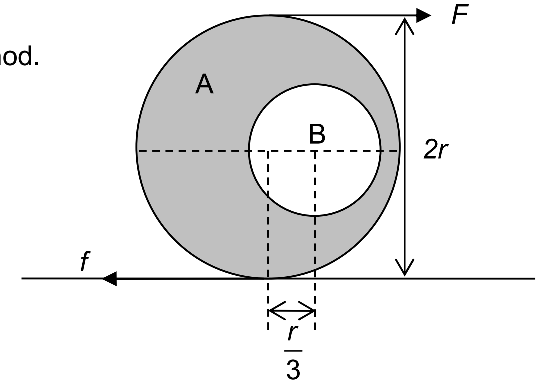
7 **A** With A intact, the system would be in equilibrium without F. With B removed, and the system requires F to be in equilibrium. Hence, the moment due to F (and the resulting friction) should be equal to that due to the weight of B.

With F in place, translational equilibrium in the horizontal direction requires a friction f equal in magnitude to F but acting in the opposite direction to F. F and f form a couple.

Weight of section removed (B) = 48 – 36 = 12 N.

Method 1: Taking centre of mass of cylinder A as pivot
Moment due to the weight of B = 12 × r/3 = 4r
Moment due to the couple of F and f = F × 2r
Equating the two moments, F = 2 N

Method 2: Taking point of contact between cylinder and ground as pivot
Friction f does not contribute a moment, since it passes through the point of contact.
Moment due to the weight of B = $4r$
Moment due to $F = F \times 2r$
It yields the same answer as the previous method.



8 **C** The scale will measure the following forces:

i. weight of beaker of water (Z)
ii. weight of object at bottom of beaker (X)
iii. force exerted by suspended object on water (Y)

Hence, the total force = X+Y+Z

9 **A**

$$K_1 = \frac{p_1^{\,2}}{2m_1},\ K_2 = \frac{p_2^{\,2}}{2m_2},\ p_2 = 2p_1$$

$$\frac{K_1}{K_2} = \frac{p_1^{\,2}}{p_2^{\,2}}\frac{m_2}{m_1} = \frac{m_2}{4m_1}$$

10 **C** At the same distance d from the sphere, the electrostatic force F experienced by both particles is the same because they carry the same charge. Since time of action t is equal, the change in momentum $\Delta p = Ft$ must also be equal for both particles.

From $E_k = \Delta p^2/2m$, the lighter positron gained much more kinetic energy than the proton.

Since the work done by force F on the particles is converted to a gain in kinetic energy of the particles, the work done on the positron is more than that on the proton.

Alternatively:
Since the positron is much lighter than the proton, the positron has a larger acceleration a than the proton. In the same duration t, the positron travels a further distance s and hence the work done on the positron is more than that on the proton.

11 **C** Since the car is travelling at a constant speed, there is no tangential acceleration. Therefore, one of the components of the frictional force of the road on the car must point to the right.

For the car to execute a uniform circular motion, another component of the frictional force of the road on the car must point towards the centre of the circle.

Hence, the net frictional force of the road on the car acts along C.

12 **B** For mass Q: $T\sin\theta = \dfrac{m_Q v^2}{r}$, and $T\cos\theta = m_Q g$

$$\Rightarrow T^2 = (m_Q g)^2 + \left(\frac{m_Q v^2}{r}\right)^2$$

For mass P: $T = m_P g$

$$\Rightarrow (m_P g)^2 = (m_Q g)^2 + \left(\frac{m_Q v^2}{r}\right)^2$$

$$\Rightarrow \left(\frac{m_P}{m_Q} g\right)^2 - (g)^2 = \left(\frac{v^2}{r}\right)^2$$

$$\Rightarrow \frac{2.3^4}{r^2} = (2g)^2 - (g)^2 = 3(9.81)^2$$

$$\Rightarrow r = 0.311\ \text{m}$$

13 **A** Above the equator, the gravitational force on the satellite allows it to move in the same direction of rotation as the Earth.

At any other latitude, the satellite would either require a constant input of energy to move in the same direction as the Earth or the satellite would be moving in an orbit which changes latitudes as it circles around the Earth.

14 **C** Since p and V are constants, from $pV = nRT$, nT is also constant.
Since n is proportional to mass m,
$\Rightarrow m_1T_1 = m_2T_2$.
$\Rightarrow 20 \times (20 + 273.15) = 15 \times (\theta + 273.15)$
$\Rightarrow \theta = 117.7 = 120\ °\text{C}$

15 **B**

At 30.0 °C: $\dfrac{1}{2} m_A c^2 = \dfrac{3}{2} k(30 + 273.15)$ – (1)

At 300 °C: $\dfrac{1}{2} m_B {c_B}^2 = \dfrac{3}{2} k(300 + 273.15)$ – (2)

$\dfrac{(2)}{(1)}$: $\dfrac{m_B {c_B}^2}{m_A c^2} = \dfrac{573.15}{303.15}$, where $\dfrac{m_B}{m_A} = 2$

$\Rightarrow$ $c_B = 0.972c$

16 **D** Energy supplied to melt the solid from 2 min to 4 min:
$Q = Pt = mL \Rightarrow (1000)(2) = (1)(L) \Rightarrow L = 2000\ \text{J kg}^{-1}$.

To compare the specific heat capacities of the solid and liquid states:
From $\dfrac{Q}{t} = mc\dfrac{\Delta T}{t}$,

$\Rightarrow 1000 = (1)c_{solid}\dfrac{4}{2}$ and $1000 = (1)c_{liquid}\dfrac{4}{4}$

$\Rightarrow c_{solid} = 500\ \text{J kg}^{-1}\ \text{K}^{-1}$ and $c_{liquid} = 1000\ \text{J kg}^{-1}\ \text{K}^{-1}$

Hence, option C is wrong.

17 **B** The **rate** of heat transfer between 2 bodies is proportional to the temperature difference between them. Since the temperatures of the boiling water and the environment remain unchanged for both experiments, the rate of heat loss from the boiling water to the environment is the same for both experiments (regardless of the power supplied by the heater or the duration of the experiment) and can therefore be eliminated in calculations.

Option A: To reduce random errors in the measurements of mass per unit time, the experiments should be repeated using the same power and finding the average of the readings.

Option C: To determine the average value of the latent heat of vaporisation from two sets of measurements without taking into account the heat loss to the surrounding will not produce an accurate result.

Option D: To check for reproducibility of the measurements, the experiments should be repeated using the same power and same duration.

18 **C** $PE_{\text{max}} = KE_{\text{max}}$

$$1.800 = \frac{1}{2}m(x_0\omega)^2, \text{ where period } T = \frac{0.600}{2.5} = 0.240 \text{ s}$$

$$1.800 = \frac{1}{2}m(0.050 \times \frac{2\pi}{0.240})^2$$

$$m = 2.1 \text{ kg}$$

19 **B** When the first wavefront has moved 6 squares, the dipper has only moved 3 squares. Hence, horizontal speed of dipper is ½(20) = 10 cm s^{-1}.

Wavelength = radius of 1st wave – radius of 2nd wave = ½ (12 – 8) = 2 cm.
$f = v / \lambda$ = 20 / 2 = 10 Hz.

20 **C** $I = I_0 \cos^2 30°$ – (1), where I_0 is the intensity of light incident on Q
$I' = I_0 \cos^2 120°$ – (2)

(2)/(1): $I' = I (\cos^2 120° / \cos^2 30°) = 0.33\, I$

21 **B** Pipe open at both ends: $L = \lambda / 2 \Rightarrow f = v / 2L$
Pipe open one end: $L = \lambda' / 4 \Rightarrow f' = v / 4L = f / 2$

22 **D** Add the electric field strength vector due to each charge at the respective points.

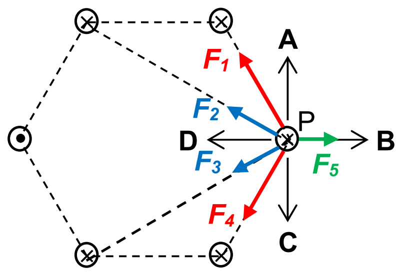
23 **C** Refer to the definition of an ohmic conductor.

24 **B** P.d. V across both cells is zero.

$$I_1 = \frac{3.0}{6.0 \times 10^3} = 0.50 \text{ mA}$$

$$I_2 = \frac{3.0}{3.0 \times 10^3} = 1.0 \text{ mA}$$

25 **D**



Four wires attract P towards the left, while the furthest wire repels P towards the right. Hence, the net force is towards the left.

26 **A** As the magnet is pushed towards the coil, an induced current is set up in the coil which produces a magnetic field around it. According to Faraday's and Lenz's laws, this increasing magnetic field will produce an induced current in the ring which will oppose its increase, and hence the ring will repel towards the left. Similarly, when the magnet is removed from the coil, the ring also experiences an increasing magnetic field (in the opposite direction to the initial case), and hence oppose it and move to the left.

27 **C** If the magnetic flux linkage is a sine function, the induced e.m.f. will be a cosine function, and vice-versa. Hence, the phase difference between them is $\pi/2$ rad.

28 **A** When diode is forward bias for 1st half of the cycle, peak power dissipated $= V_0^2 / (R/2)$
Average power = ½ of peak = V_0^2 / R

When diode is reverse bias for 2nd half of the cycle, peak power dissipated $= V_0^2 / (R)$
Average power = ½ of peak = ½ V_0^2 / R

Hence, average power for one cycle = ½ ((V_0^2 / R) + (½ V_0^2 / R)) = ¾ V_0^2 / R

29 **D** Reduced wavelength means energy hf of photons is higher
$\Rightarrow$ KE_{max} ($= hf - \Phi$) is higher.

Reduced intensity means fewer photons per unit time
$\Rightarrow$ rate of emission of photoelectrons is lower.

30 **B** $C = C_0 e^{-\lambda t}$
$\Rightarrow \ln C = -\lambda t + \ln C_0$.

Before time T: graph is linear with a constant gradient λ.

After time T: Initially, the gradient is steeper than λ due to the newly added fast-decaying gas (a larger decay constant). For larger time t, the gradient is approximately the same as that before T, since the population of the fast-decaying gas has decreased significantly.