# ENGAA 2017
# Section 2

## Model Solutions

# 1

## 1a

We can rule out A and C as acceleration is not constant or zero. We cannot use SUVAT as acceleration is not a constant.

$$\begin{aligned} a &= 0.4t \\ v &= \int 0.4t dt \\ &= 0.2t^2 \\ \therefore v &= \frac{1}{5}t^2 \end{aligned}$$

$$\begin{aligned} \text{When } t = 1, v = 0.2 \\ \text{When } t = 0.5, v = 0.05 \end{aligned}$$

$$\therefore \text{Graph B}$$

## 1b

Let T be the time taken to first hit the floor:

$$\begin{aligned} d &= \int v dt \\ &= \int_0^T \frac{1}{5}t^2 dt \\ &= \frac{T^3}{15} \\ T &= (15d)^{\frac{1}{3}} \end{aligned}$$

## 1c

Only Graph P is possible because acceleration downwards increases with time meaning the decelerating force on the ball after each bounce is greater than the accelerating force before the bounce, so the maximum height reached after each bounce must decrease.

## 1d

$$\begin{aligned} F &= ma \\ N &= kg \cdot ms^{-2} \end{aligned}$$

## 1e

$$\begin{aligned} \text{base units for } \rho = \frac{kg}{m^3} &= kgm^{-3} \\ \text{base units for } v^2 = (ms^{-1})^2 &= m^2s^{-2} \\ kgms^{-2} &= X \cdot kgm^{-3} \cdot m^2s^{-2} \cdot m^2 \\ &= X \cdot kgms^{-2} \\ \therefore X = 1 \text{ (i.e. no units)} \end{aligned}$$

## 2

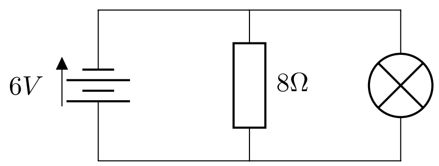
### 2a

Fixed resistors follow Ohm's Law: $V \propto I$. The resistor is therefore device Y as it is the only device whose I-V graph is a straight line through the origin.

### 2b

As power dissipation (current $\times$ p.d.) increases, the resistance of a filament lamp increases, due to higher temperature in the filament. The gradient of the I-V graph for device X is decreasing, showing that the resistance is increasing. Therefore device X is the filament lamp.

### 2c




Lamp:

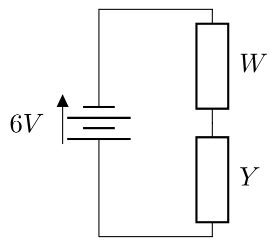
$$P = IV$$
$$9 = 6I$$
$$I = \frac{3}{2}A$$

Resistor:

$$V = IR$$
$$6 = I \times 8$$
$$I = \frac{3}{4}A$$

Total Current for parallel circuit $= 2.25A$. We could also use the graph to find the currents through devices $X$ and $Y$ at $6V$ to verify this result.

### 2d




a) P = IV; as the potential difference across each component is different (due to the differing resistances at 6V), the power dissipated is not equal

b) Potential difference is shared in the ratio of the resistances; as the resistances of W and Y are different the p.d. is not equal

c) True for components in series

d) $P = \frac{V^2}{R}$ : If device W or device Y were connected alone, the circuit resistance would be lower and therefore the power supply would deliver more power

e) If device W and device Y were connected in parallel, the combined resistance would be lower and therefore the power supply would deliver more power

## 2e

In this series circuit equal current flows through W and Y. On the I-V graph we need a value of current through W and Y for which the sum of $V_W + V_Y = 6V$. At I = 0.5A;

$$\begin{aligned} V_Y + V_W &= 4 + 2 = 6V \\ \therefore P_W &= IV = 0.5 \times 2 \\ &= 1.0W \end{aligned}$$

# 3

## 3a

Hooke's Law is that $F \propto x$. Obeying Hooke's Law is shown by a straight line through the origin on a Force-Extension graph. Clearly, Hooke's Law is obeyed up to P. Fracture occurs at a strain of:

$$\frac{0.05m}{0.5m} = 0.1$$

## 3b

$$\begin{aligned} \text{Area } &\approx \frac{1}{2} \cdot 0.03 \cdot 10 + \frac{1}{2}(10 + 40) \cdot 0.02 \\ &= 0.15 + 0.5 \\ &= 0.65 \approx 0.6 \end{aligned}$$

## 3c

When you halve the original length of the cord, the elastic potential energy which can be stored before the cord snaps, will also halve.

$$\begin{aligned} \text{Maximum EPE stored: } &= \frac{U}{2} = \frac{1}{2}mV_{max}^2 \\ \frac{U}{m} &= V_{max}^2 \\ V_{max} &= \sqrt{\frac{U}{m}} \end{aligned}$$

## 3d

Total EPE stored doubles from $\frac{U}{2}$ to U.

$$\begin{aligned} \text{Maximum EPE stored} = U &= \frac{1}{2}mV^2 \\ V &= \sqrt{\frac{2U}{m}} \\ &= \sqrt{2}\sqrt{\frac{U}{m}} \\ &= \sqrt{2}V_{max} \end{aligned}$$

# 4

## 4a

1) True, as constructive interference will occur at points on the screen where path difference is n$\lambda$
2) False; for this path difference destructive interference occurs to produce regions of minimum brightness
3) True, for the aforementioned reason
4) True; the two wave sources must have a constant phase difference
5) False; due to the inverse-square law maxima further away from the source will be less bright

## 4b

$$\begin{aligned}
\text{Time period} = \frac{\lambda}{v} &= \frac{600 \times 10^{-9}}{3 \times 10^{8}} = T \\
\text{Time to traverse 300nm in vacuum:} \quad &= \frac{300 \times 10^{-9}}{3 \times 10^{8}} = \frac{1}{2}T \\
\text{Time to traverse 300nm in material:} \quad &= \frac{300 \times 10^{-9}}{1.5 \times 10^{8}} = T
\end{aligned}$$

Therefore, after passing through the material, the light passing through one slits will be half a cycle out of phase with the other:

a) False; since the phase difference has changed the diffraction pattern changes
b) False; they still have a constant phase difference
c) False; the pattern does not disappear - it changes. The sources still have a constant phase difference
d) True; the light waves coming through the slit in front of the material will be now half a cycle out of phase with the light from the other slit. This means that maxima will occur where $r_1$ and $r_2$ differ by $(n + \frac{1}{2})\lambda$. Therefore the diffraction pattern will be shifted in the y-direction
e) False; the number of maxima does not change, nor does the wavelength of the light

## 4c

Diffraction occurs noticeably when the gap between two sources is close to the wavelength. In this case:

$$\begin{aligned}
\lambda = \frac{c}{f} &= \frac{3 \times 10^{8}}{600 \times 10^{6}} \\
&= 0.5m
\end{aligned}$$

$$\begin{aligned}
\text{Distance between maxima} &= \frac{\lambda D}{a} \\
&= 500m
\end{aligned}$$

a) False; both antennae emit radio waves so diffraction can occur
b) False; it is the relative magnitudes of the wavelength (not frequency) and gaps which affect the amount of diffraction
c) False; $\lambda = 0.5m$ so a gap of 1m is sufficiently close for diffraction
d) False; distance between maxima is 500m which means there is a significant distance between maximum and minimum intensity signals
e) True, for the aforementioned reasons