A-Level Physics

Forced Vibrations and Resonance

Mark Scheme

Time available: 78 minutes
Marks available: 43 marks

Mark schemes

1. (a) (mark should be at the equilibrium position) since this is where the mass moves with <u>greatest speed</u> [transit time is least] ✓

1

(b) (i) mean time for 20*T* (from sum of times ÷5) = 22.7 (s)$_1$ ✓ (minimum 3sf)

uncertainty (from half of the range) = 0.3 (s) $_2$ ✓ (accept trailing zeros here)

percentage uncertainty

$(\text{from } \frac{0.3}{22.7} \times 100)[\frac{100}{5} \times \sum \frac{0.3}{20T}] = 1.3\ (22)\%_3$ ✓

(allow full credit for conversion from 20*T* to *T*, e.g. 1.135 = $_1$✓ 0.015 =$_2$ ✓ ecf for incorrect $_1$ ✓ and / or $_2$ ✓ earns $_3$ ✓

3

(ii) natural frequency $(\text{from } \frac{20}{22.7}$ and minimum 2 sf) = 0.88 (1)Hz [accept s^{-1}] ✓

(ecf for wrong mean 20*T*; accept ≥ 4 sf)

1

(c) (i) linear scale with at least 3 evenly-spaced convenient values (i.e. not difficult multiples) marked; the intervals between 1 Hz marks must be 40 ± 2 mm (100 ± 5 mm corresponds to 2.5 Hz) ✓

(ecf for wrong natural frequency: 100 ± 5 mm corresponds to $\frac{2.5f}{0.88}$ Hz)

1

(ii) 4 mm [allow ± 0.2 mm] ✓

1

(d) (i) student decreased intervals [smaller gaps] between [increase frequency / density of] readings (around peak / where A is maximum) ✓ ✓

[student took more / many / multiple readings (around peak) ✓]
(reject bland 'repeated readings' idea; ignore ideas about using data loggers with high sample rates)

2

(ii) new curve starting within ± 1 mm of A = 4 mm, f = 0 Hz with peak to right of that in Figure 3
(expect maximum amplitude shown to be less than for 2 spring system but don't penalise if this is not the case; likewise, the degree of damping need not be the same (can be sharper or less pronounced)
Peak at $\sqrt{2}$ value given in **(b)(ii)**; expect 1.25 Hz so peak should be directly over 50 ± 5 mm but take account of wrongly-marked scale ✓

2

[11]

2. (a) *forced vibrations:*

repeated upwards and downwards movement ✓
vibrations at frequency of support rod ✓
amplitude is small at high frequency **or** large at low frequency ✓
correct reference to phase difference between displacements of driving and forced vibrations ✓

Acceptable references to phase differences:

*Forced vibrations − when frequency of driver » frequency of driven, displacements are out of phase by (almost) π radians or 180° (**or** ½ a period) **or** when frequency of driver « frequency of driven, displacements are (almost) in phase. [Accept either].*

[Condone >, < for », «].

resonance:

frequency of support rod **or** driver is equal to natural frequency of (mass-spring) system ✓
large (or maximum) amplitude vibrations of mass ✓
maximum energy transfer (rate) (from support rod to mass-spring system) ✓
correct reference to phase difference between displacements of driving and driven vibrations at resonance ✓

*Resonance − displacement of driver leads on displacement of driven by π / 2 radians or 90° **or** ¼ of a period (or driven lags on driver by π / 2 radians or 90° **or** ¼ of a period).*

[Condone phase difference is π / 2 radians or 90°].

max 4

(b) (i) cone oscillates without ring *(ticked)*

Only one box to be ticked.

1

(ii) damping is caused by air resistance ✓
area is the same whether loaded or not loaded ✓
loaded cone has more kinetic energy **or** potential energy **or** momentum (at same amplitude) ✓
smaller <u>proportion</u> (or <u>fraction</u>) of (condone less) energy removed per oscillation from loaded cone (or vice versa) ✓
inertia of loaded cone is greater ✓

Award marks for correct physics even when answer to (b)(i) is incorrect.

max 3

[8]

3. (a) forced vibrations or resonance **(1)**

1

(b) reference to natural frequency (or frequencies) of structure **(1)**
driving force is at same frequency as natural frequency of structure **(1)**
resonance **(1)**
large <u>amplitude</u> vibrations produced or large energy transfer to structure**(1)**
could cause damage to structure [or bridge to fail] **(1)**

max 4

(c) stiffen the structure (by reinforcement) **(1)**
install dampers or shock absorbers **(1)**
[or other acceptable measure e.g. redesign to change natural frequency or increase mass of bridge or restrict number of pedestrians]

2

[7]

4. (a) force / acceleration proportional to displacement / distance from mean position

B1

directed towards mean / fixed position

B1

(2)

(b) (i) 0.96 s to 0.98 s

B1

(1)

(ii) 1.02 Hz to 1.04 Hz e.c.f. 1 / (i)

B1

(1)

(iii) $T = 2\pi\sqrt{m / k}$ **or** $m = T^2 k / 4\pi^2$ in symbols or numbers, seen or used

C1

98 kg to 102 kg e.c.f. $10^6 \times (\text{i})^2$

A1

(2)

(iv) $a = (-)\omega^2 A$

C1

$1.03\ \text{m s}^{-2}$ to $1.07\ \text{m s}^{-2}$ e.c.f. $0.99(\text{ii})^2$

A1

(2)

(c) time period (of oscillation caused by road markings) = s / v or 1.2 / 7 or 0.17 s **C1**

frequency = 1 / T **or** 5.8 Hz
(use of $v = f\lambda$ loses both of the 1st two marks) **A1**

applied frequency / time period is different from natural / resonant frequency so no resonance **B1**

(3)

(d) (i) KE at **P** **B1**

PE at **Q** **B1**

at **R**, (nearly all of) energy absorbed by shock absorber / dissipated as internal energy (condone heat) in shock absorber / surroundings (allow lost in damping) **B1**

(3)

(ii) energy proportional to $(\text{amplitude})^2$ **C1**

at **P**, A = 2.5;
at t, A = 1.0 or 0.9 **C1**

5.3 / 6.3 = 0.84 of energy absorbed at t (or 0.90, consistent with value of A at t) **A1**

(3)

[17]